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TITLE: TRITIUM HANDLING EXPERIENCE IN VACUUM SYSTEMS AT TSTA

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# Tritium Handling Experience in Vacuum Systems at TSTA

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## Abstract

Compound cryopumps have been added to the Tritium Systems Test Assembly (TSTA) integrated fusion fuel loop. Operations have been performed which closely simulate an actual fusion reactor pumping scenario. In addition, performance data have been taken that support the concept of using coconut charcoal as a sorbent at 4K for pumping helium . Later tests, reported in detail in reference (1), show that coconut charcoal may be used to co-pump D,T and He mixtures on a single 4K panel. Rotary spiral pumps have been used successfully in several applications at TSTA and have acquired more than 9000 hours of maintenance-free operation. Metal bellows pumps have been used to back the spiral pumps and have been relatively trouble free in loop operations. Bellows pumps also have more than 9000 hours of maintenance-free operation.

## Introduction

The Tritium Systems Test Assembly, TSTA, was started in 1977 with the goal of providing a full-scale test of a tritium-deuterium (T-D) fuel loop capable of supporting a fusion reactor. Functions include transfer pumping, impurity removal, HDT isotope separation and high vacuum pumping as well as waste treatment, clearup and computer control systems. Tritium operations were begun in 1984 and functions have been added, and improvements and refinements to the basic design have been continuous since that date. In 1987 a five-year collaboration with the Japan Atomic Energy Research Institute (JAERI) was begun. The purpose of this collaboration is the joint funding and joint operation of the facility and the joint design and testing of new devices which have application in the fusion fuel loop. As part of the first year of the collaboration, a goal of incorporating a prototypical high vacuum system, suitable for torus evacuation, into the TSTA main loop was identified. In June of 1988 pumping of DT mixtures and subsequent regeneration were performed concurrently with

full loop operation. Two compound cryopumps pumping on a mock torus were used in these operations. Additional tritium testing of one of these pumps was performed in May 1989.

## Description of the TSTA Vacuum (VAC) System and Its Operation

Early in the TSTA development three cryopumps were procured for inclusion into the fuel loop. It was believed that mechanical pumps would not be practical for a power producing reactor because of the high pumping speeds anticipated. Further, it was felt that a compound or staged cryopump was necessary because the cryosorber, used to pump helium, would soon be ineffective because of DT frost formed on the surface as the hydrogen isotopes condensed. The three pumps procured for TSTA were compound pumps with 40-cm inlet diameters and had, in turn, molecular sieve 5A, coconut charcoal and argon cryotrapping at 4K as the means for pumping helium. Based on tests with deuterium and helium, charcoal was the sorbent of choice (2); the argon cryotrapping pump was later reworked to replace the argon spray with an improved charcoal/binder combination (3), and the charcoal for the other cryopump was upgraded with the improved combination. The pump using molecular sieve 5A was removed from further consideration.

In 1987, as part of the TSTA - JAERI collaboration, it was decided to integrate a prototype torus pumping system into the TSTA main loop. Many of the necessary components were already available at TSTA; by the spring of 1988 the system had been assembled, and was ready for tritium testing.

The TSTA Vacuum facility (VAC) comprises two compound cryopumps with 40cm inlets, a mock torus of approximately 1-m3 volume and connecting 40-cm ducting fitted with 40-cm gate valves. Regeneration pumping is through 15-cm ducts and valves to a 500 l/s turbopump. All of these components are secondarily contained within an aluminum enclosure. Forepumping on the turbopump is by a rotary spiral pump located in an adjacent glovebox. Metal bellows pumps provide the final compression to approximately local ambient pressure which is the operating pressure of the fuel loop.

The cryopumps installed in VAC were supplied by Brookhaven National Laboratory (BNL) and Lawrence Livermore National Laboratory (LLNL) and original designs and performance are described in references (4) and (5). Both pumps have since had their sorbent surfaces changed to a charcoal/binder configuration described in reference (3). The basic arrangements and approximate dimensions of the pumps are shown in Figure 1.

(FIGURE 1 Cryopump Comparison)

Figure 2 shows the pump placement within the secondary containment. Forty-cm diameter gate valves are at the inlets of both pumps; 15-cm right angle valves are in the exhaust or regeneration piping. Gas feed is within a secondarily contained 6-mm copper line which runs from the adjacent transfer pump glovebox (TP1); regeneration gas is to the same glovebox in a 4-cm secondarily contained line. A 500 l/s turbopump is located within the enclosure and exhausts to a 9 l/m rotary spiral pump in the adjacent transfer pump glovebox. Within the enclosure are oxygen and tritium sensors. Should tritium be detected, the facility emergency air detritiation system (ETC) will start, purging the enclosure with room air and processing the contaminated air removing tritium by catalytic oxidation to form HTO and collecting the water on drier beds.

Figure 3 shows the relationship of the VAC flow to the main loop flow. Feed gas is extracted after being mixed and after impurity addition. After reaching capacity, or the tritium inventory safety limit of 45 standard liters DT, the pump is regenerated, using the turbopump and the transfer pumps, back into the stream going to the TSTA fuel cleanup system (FCU). It is possible to maintain a steady feed with the two cryopumps, as pumping can be cycled from pump to pump during regeneration periods. Regeneration flow back to the loop is presently done with a higher flow rate over a shorter time interval than the feed flow. Regenerated gas could be metered back at a constant rate with the addition of a holding volume but this is not necessary at TSTA because the VAC flow is only a small percentage of the total loop flow.

Integrated Flow Runs June, 1988

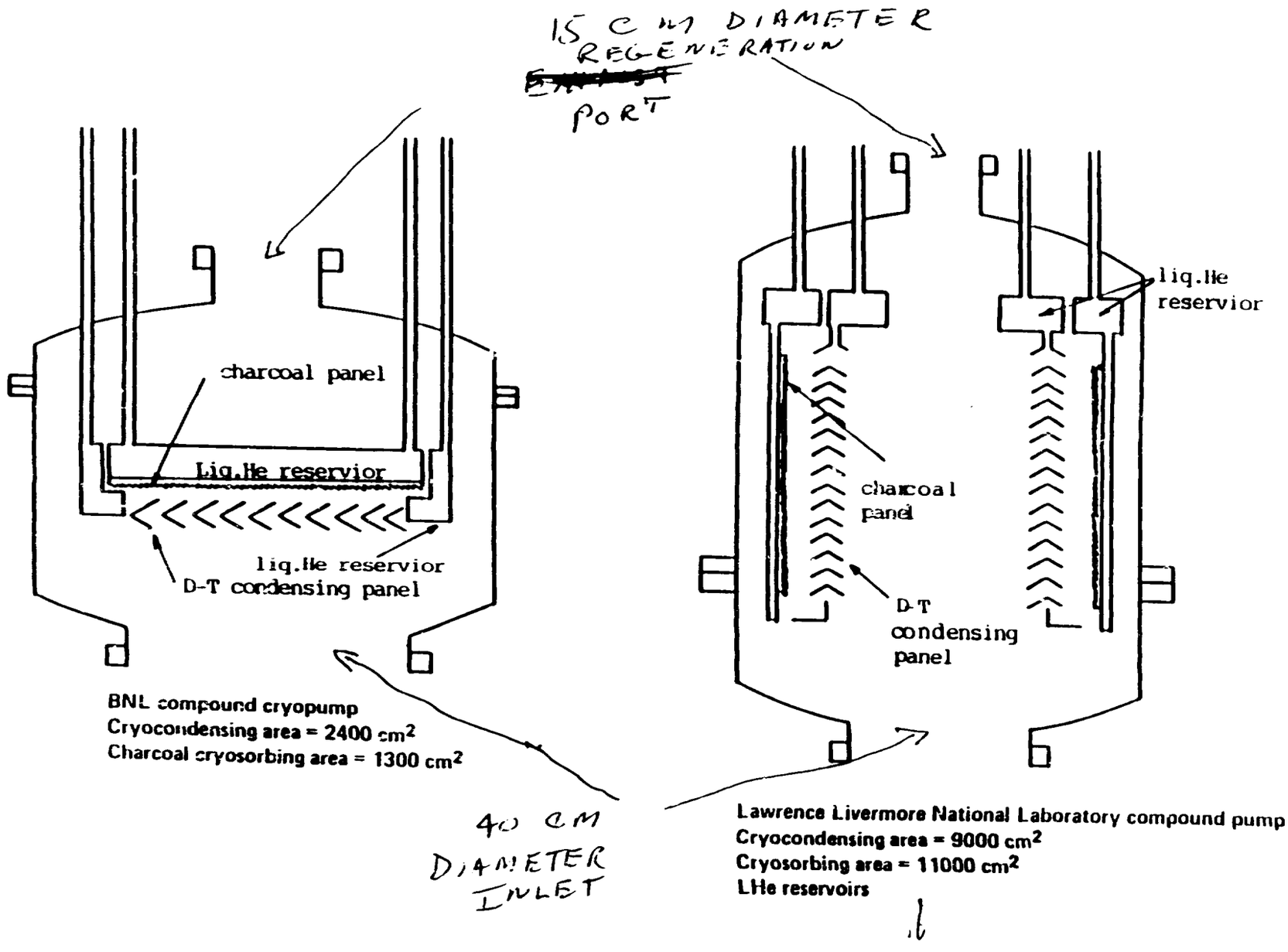
Table 1 gives the gases and flow rates for operations performed during the first integrated run in June, 1988.

TABLE 1

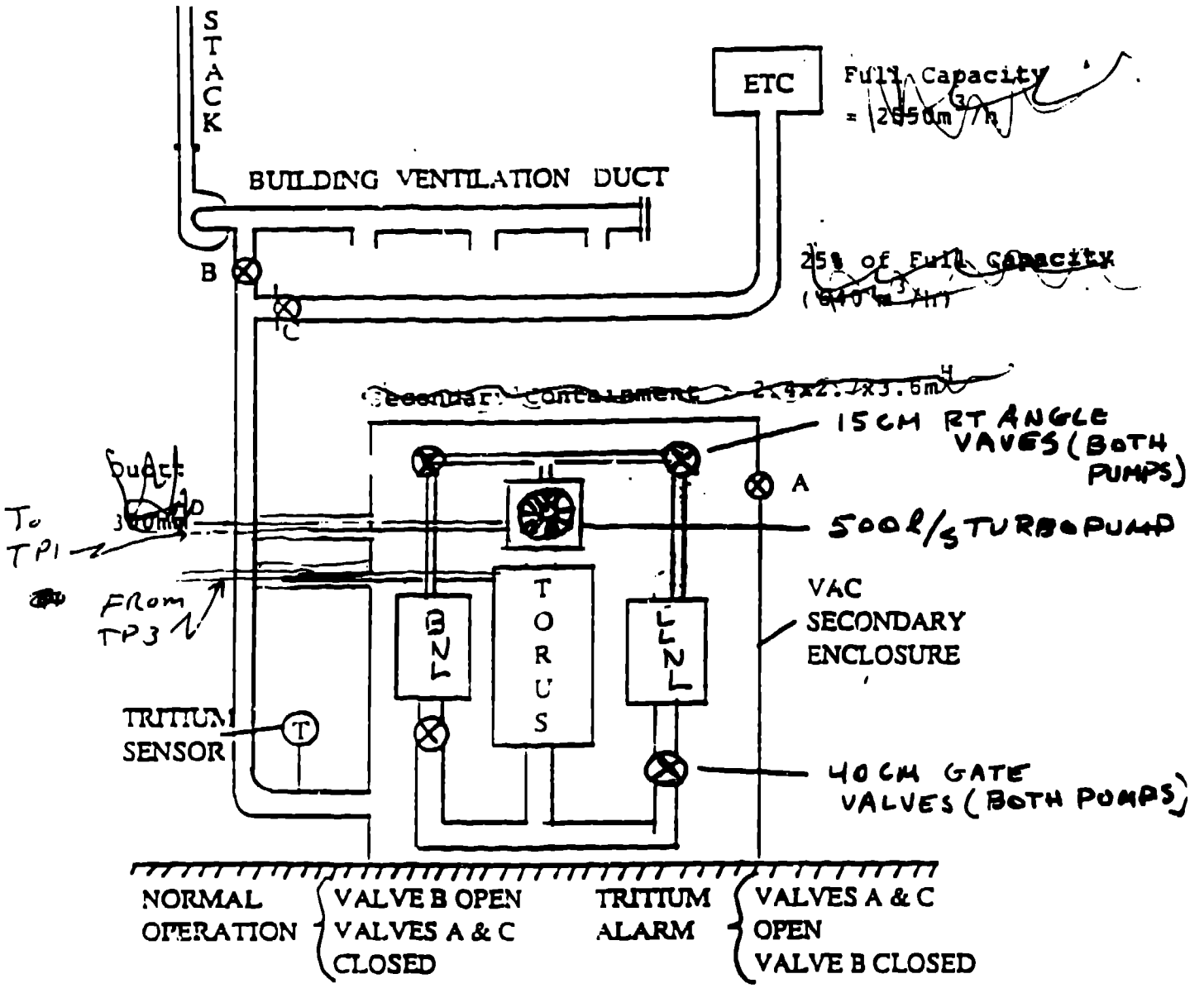
| Date | Pump | Gases | T l/s x min, Throughput and Duration | Regen. |
|---|---|---|---|---|
| 2 June | BNL | D-T | 1 x 10 min | |
| | | DT + 1% N2 | 1 x 10 min | |
| | | | 3 x 10 min | To FCU |
| | | | 5 x 30 min | |
| | | | 3 x 10 min | |
| | | | 1 x 10 min | |
| 3 June | BNL | D-T | 1 x 10 min | |
| | | | 3 x 10 min | |

| | | | | |
|---|---|---|---|---|
| | | | 5 x 30 min | To FCU |
| | | | 3 x 10 min | |
| | | | 1 x 10 min | |
| 3 June | BNL | D-T + 2% He | 5 x 10 min | |
| | | D-T + 5% He | 5 x 10 min | |
| | | D-T + 10% He | 5 x 10 min | To FCU |
| | | D-T + 20% He | 5 x 10 min | |
| | | D-T + 30% He | 5 x 10 min | |
| 4 June | BNL | D-T + 10% He | 1 x 10 min | Controlled Pressure ≤ 10-3 torr to LLNL pump, then to collection container for analysis |
| | | D-T + 10% He | 3 x 10 min | |
| | | D-T + 10% He | 5 x 60 min | |
| | | D-T + 10% He | 3 x 10 min | |
| | | D-T + 10% He | 1 x 10 min | |
| 5 June | BNL | D-T + 10% He | 1.5 x 120 min | Controlled separation of DT and He |
| 23 June | BNL | D-T | 1 x 17 min | |
| | | D-T | 3 x 8 min | |
| | | D-T | 4 x 6 min | Combined and pumped to a sample container |
| | | D-T + 10% He | 1 x 7 min | |
| | | D-T + 10% He | 3 x 7 min | |
| | | D-T + 10% He | 4 x 5 min | |
| | | D-T + 10% He | 3 x 5 min | |
| | | D-T + 10% He | 1 x 3 min | |
| | | D-T | 1 x 5 min | |
| 29 June. | LLNL | D-T | 1 x 5 min | Combined and pumped to a sample container |
| | | D-T + 10 He | 1 x 4 min | |
| | | He | 0.1 x 4 min | |
| 30 June | LLNL | He | 0.1 x 1.5 min | |
| | | D2 | 1 x 10 min | |
| | | He | 0.1 x 1.5 min | |

The pump operations listed from 2 - 5 June were performed concurrently with operation of the entire TSTA fuel loop; the tests of 23, 29 and 30 June were on the pumps alone. During combined operation, basic performance of the pumps was measured. Using the recorded pressure in the torus and

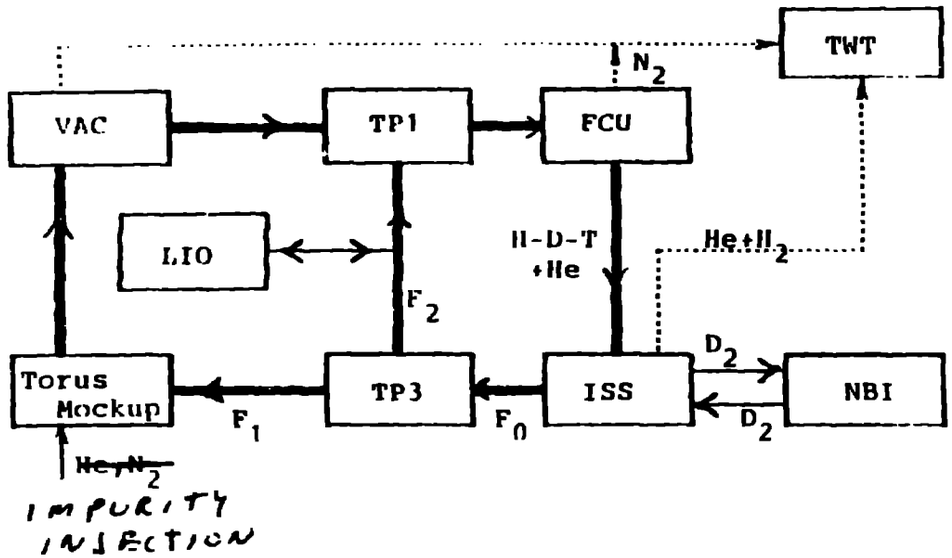



COMPOUND CRYOPUMP COMPARISON




TSTA VACUUM FACILITY (VAC)

Fig. 2. VAC




Main flow rate : $F_0$ = 15-19 g-mol DT/h

VAC flow rate : $F_1$ = 2-10% $F_0$

Circulating flow rate : $F_2$ = 90-98% $F_0$

TSTA ~~NAKED~~ INTEGRATED LOOP FLOW DIAGRAM

## LEGEND

VAC = VACUUM FACILITY

TP1 = TRANSFER PUMP UNIT 1

FCU = FUEL CLEANUP SYSTEM

ISS = ISOTOPE SEPARATION SYSTEM

TP3 = TRANSFER PUMP UNIT 3

LIO = TRITIUM LOAD-IN LOAD-OUT FACILI

TWT = TRITIUM WASTE TREATMENT SYSTE

NBI = NEUTRAL BEAM INJECTOR INTERFA

Fig 3

the feed rate, pumping speed at the torus was determined. A calculation of the conductance of the pumps manifold was then used to estimate the speed at the pump.

Nude Bayard-Alpert gauges were used for pressure measurement and thermal conductivity mass flow meters were used for feed rate control and measurement. For this paper we have used the gauge sensitivities provided by the manufacturer:

| | |
|---|---|
| Helium | ~0.15 |
| deuterium | ~0.4 |
| nitrogen | ~1.0 |

These numbers will be verified at a later date when a new nude Bayard-Alpert gauge will be calibrated by the conventional methods. This gauge will then be installed in the mock torus and used as a secondary standard to calibrate the gauges used in this experiment. This new gauge has been ordered, and delivery is expected soon. We must use this calibration technique because once tritiated it is not possible to remove these contaminated gauges to the calibration facility at the Los Alamos National Laboratory.

Pump speeds for DT and DT/helium mixtures were estimated as described above. Several attempts at separate regeneration of the sorbing and condensing panels were attempted. Separate regeneration involved warming the sorbing panel while keeping the condensing panel cold (at 4K). To be successful, the regenerated helium must be pumped away at a rate which keeps pressure lower than 10-4 torr in order to avoid thermal conductance heating of the condensing panel. This was successfully done several times by using the second cryopump as a regeneration pump for helium. The turbopump could have been used, but the speed (500 l/s) is much lower than the cryopumps; hence the heating rate would have to be much slower and more precisely controlled.

Using methods described above, the quality of separation achieved during DT/helium pumping was measured. Once the helium was pumped away to the second cryopump, that pump was valved closed at the inlet and the turbopump, backed by spiral and metal bellows pumps, was used to transfer the helium to a container in the TSTA Load-In-Out, LIO, glovebox. Because the helium sorbed on the second pump was physically separated from the frozen condensate on the first pump, the charcoal panel was warmed quickly with no restrictions on the rate of de-sorbtion or the pressure rise in the second cryopump. A sample container was connected to the transfer line near the container used to store the pumped helium. A sample of desorbed helium was taken approximately mid-way during regeneration of the second pump to assure that lines and pump volumes had been swept clean of any residual gases. The sample container was then removed to a mass spectrometer for analysis.

The rotary spiral pump mentioned above was used for pumping

during bakeout, for evacuation prior to cryogen chilling and for regeneration pumping of the cryopumps. This pump is also used during shutdown of the main loop and during inventory operations as a means of evacuating component and line volumes and transferring the gases to uranium beds for storage. The pump has been operated for approximately 10,000 hours without incident or maintenance. Other pumps by the same manufacturer (Normatex SA, Pont-Audemer, France) have been used at TSTA in operations dissociated from the main fuel loop, and have seized after short operation. The failure appeared to be related to small quantities of solid particulate being present in the feed gas. Particulate control appears to be very critical for these pumps. The pump performs well in pumping clean gases as demonstrated in the TSTA fuel loop.

Follow-up testing on the LLNL Pump, May 1989

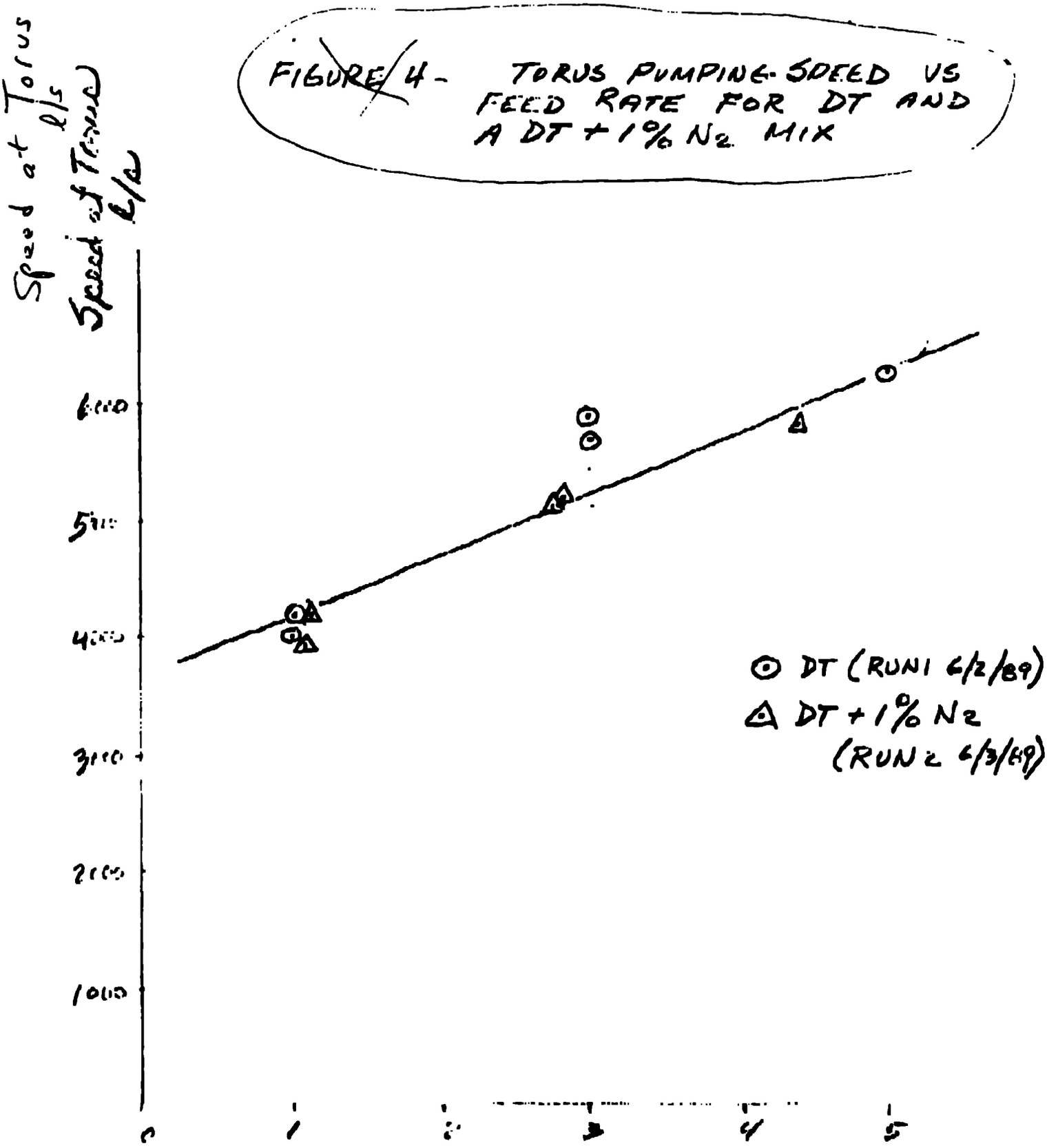
A question unanswered after the integrated tests described above was whether a compound cryopump was truly necessary for torus pumping or would a single panel coated with sorbent suffice? The LLNL pump was tested as a single panel pump in follow-up testing conducted May 15-19, 1989. In these tests, the chevron panel was chilled to approximately 70K and maintained near this level while measuring the pumping speed of the charcoal cryosorber. Deuterium and helium were fed to the torus through separate controllers which were occasionally cycled to measure the flow rate of each gas.

Results

Figure 4 shows pumping speed as a function of feed rate for the first test run on the BNL pump, June 2, 1988. The first data were taken with an approximate 50/50 D/T mix. Impurity addition of 1% N2 was begun in the main loop and a portion of this gas was diverted to, and pumped by, the BNL pumps. As expected, this had no noticeable effect on pumping speed. Speed, as measured at the torus, increased from approximately 4000 to 6000 l/s as the feed rate was increased from 1 to 5 T l/s. This increase is believed due to transition flow in the vacuum manifold which became more pronounced as pressure was increased. Based on a calculated duct conductance of 8000 l/s, the pump speed is approximately 8000 l/s at an apparent 4000 l/s torus speed.

The relationship at the torus for DT + 10% He mixtures pumped on separate panels as a function of feed rate is shown in Figure 5. Again, the effect of transition flow is evident in the increased pumping speed/pressure relationship. It can be seen that the speed for DT is unaffected by the helium addition and that the observed pressure is the sum of the DT and helium contributions.

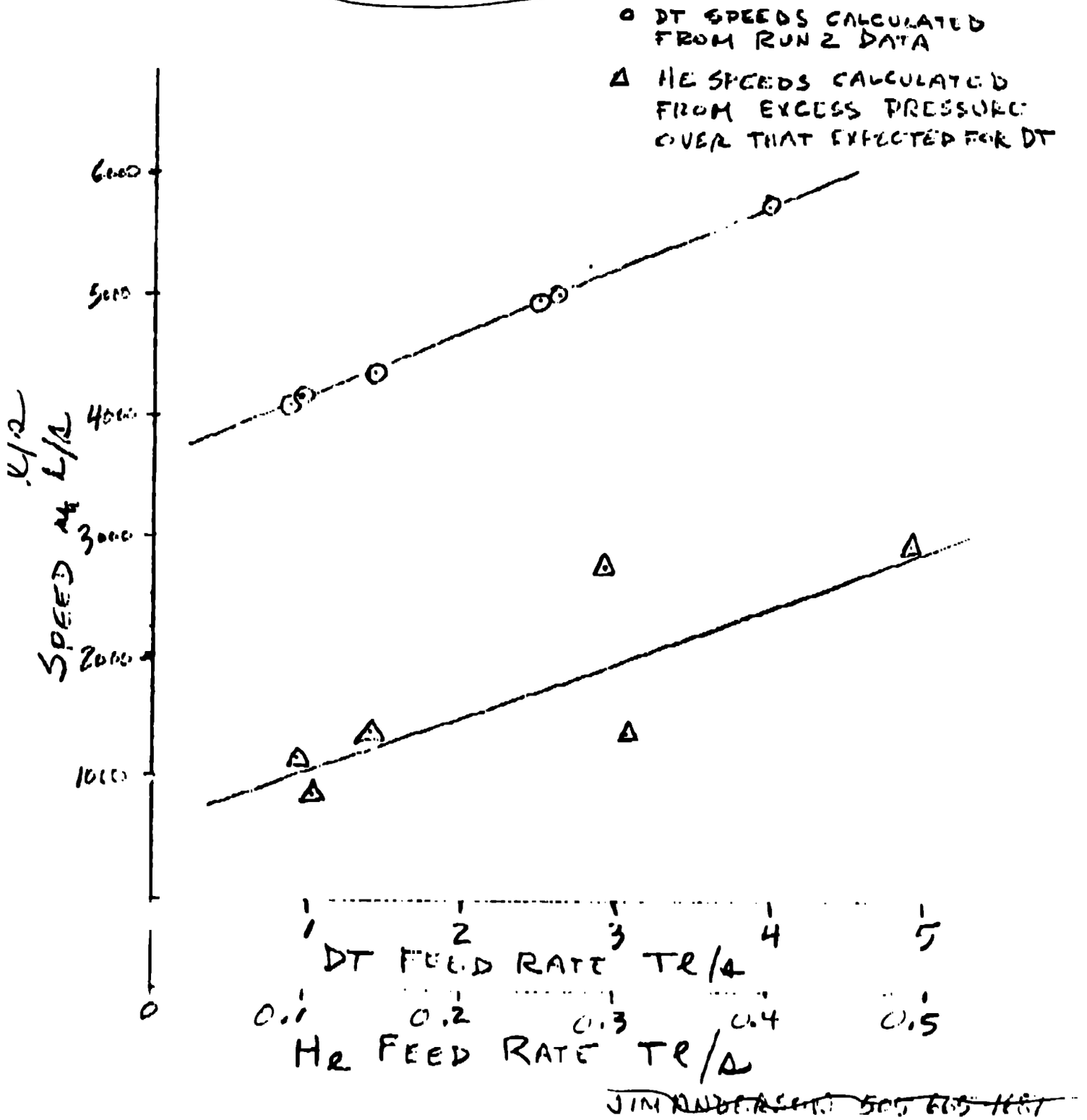
FIGURE 4 - TORUS PUMPING SPEED VS FEED RATE FOR DT AND A DT + 1% $N_2$ MIX






JIM ANDERSON
MST-3 MS C-3KB

# SPEED VS FEED RATE FOR DT ~ HE MIXTURES




~~JIM UNDERSCORE SEE FIG HERE~~

In run 3, (6/3/88), the feed rate of DT was maintained relatively constant as the percentage helium was increased from 0 to 25%. Figure 6 shows the expected increase in torus pressure with increasing helium addition and this is expressed as pumping speed for each of the gases in Figure 7.

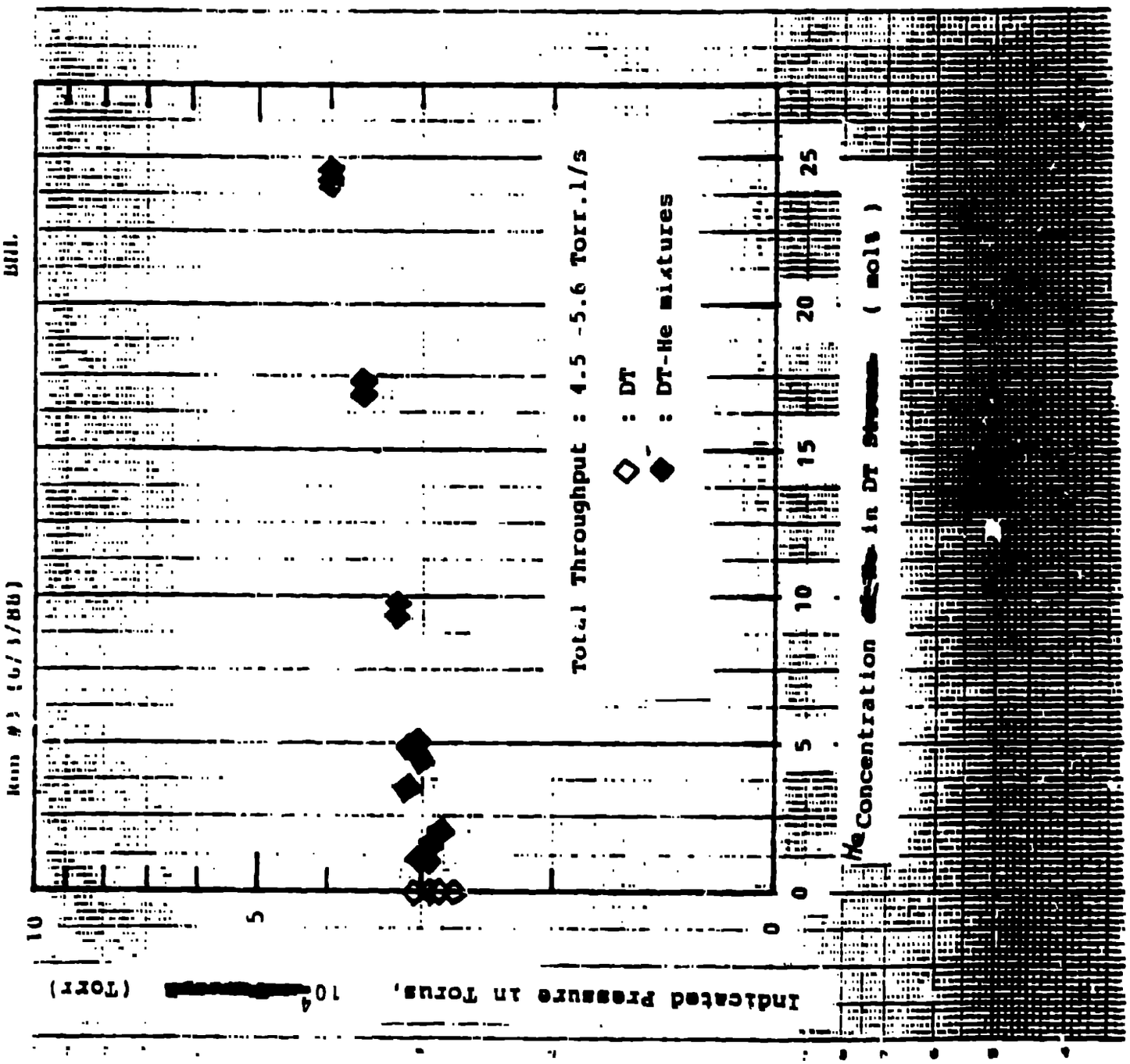
A Very slight decrease in helium pumping speed as a function of total gas sorbed was detected. Total helium sorbed during this test is approximately 900 T l or about 0.7 T l per cm2 of sorbent surface. Charcoal sorbent has demonstrated capacities as high as 5 T l/cm2 in previous tests; in co-absorption tests described in reference (1) the charcoal became saturated at a helium loading of 0.4 T l/cm2.

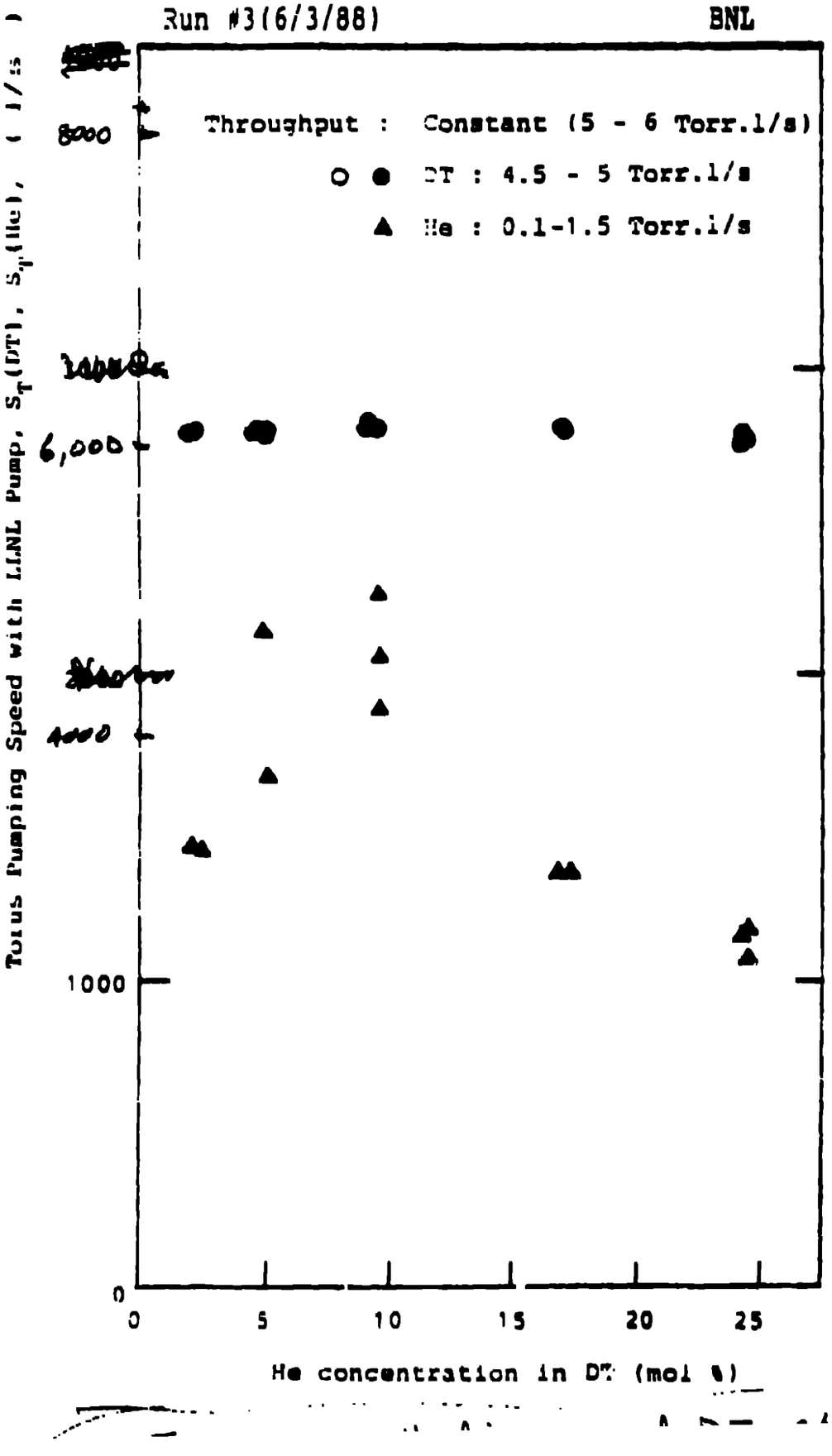
Upon completion of the DT-helium runs of 6/4 and 6/5 the helium was separately de-sorbed as described in the preceding section. Analysis of a helium sample taken during transfer to a holding tank unexpectedly showed DT contents of 10 and 25 percent for the two consecutive runs. Considerable attention was given to pumping out and flushing the transfer lines prior to transferring the helium so it is believed that the DT was able to pass through the optically tight, 4K chevrons and be pumped on the charcoal. The chevrons were conductively cooled from the periphery and a warming of the chevrons near the center of the panel may explain the presence of DT in the desorbed helium. This can be corrected by more attention to pump design.

As mentioned earlier, subsequent tests run on the LLNL pump, and described in reference 1, measured the ability of the charcoal sorbent to pump mixtures of deuterium and helium. Two tests, on consecutive days, measured pumping speed at approximately 2 T l/s deuterium flow but with 10% and 5% helium addition in the first and second tests. In both tests, pumping continued without noticeable degradation until the charcoal neared a helium loading of 0.4 T l/cm2. Helium pressure then quickly rose until pump operation was halted by high thermal loads.

## Conclusions

A prototypical vacuum system, having all the features anticipated on a fusion reactor, has been incorporated into the TSTA fuel loop. Operations have been performed which are believed to be realistic simulations of future pumping scenarios. The compound cryopumps used at TSTA appear well suited to pumping DT - helium mixtures. The ability of the pumps to perfectly separate the helium and DT is in doubt: greater attention to chevron baffle design will be needed. Data on the long term effect of tritium on the charcoal sorbent is needed and testing of this aspect will begin in the fall, 1989. Further testing at TSTA has shown it is possible to co-pump helium and DT mixtures on a single





charcoal surface with no effect on speed and an acceptable decrease in helium capacity.

References

(1) Batzer, Sedgley, Walthers - Co Pumping of DT and HE on charcoal

(2) J.L. Anderson, D.O.Coffin, and C.R. Walthers,"Vacuum Applications for the Tritium Systems Test Assembly," J. Vac. Sci. Technol.,A1 #2, 849(1983).

(3) Sedgley and Tobin - Charcoal as a Cryosorber

(4) HC Hseuh and H.A. Worwetz - "Performance of BNL-TSTA Compound Cryopump," J. VAC Sci Technol., 18#3, 1131(1981).

(5) T.H. Batzer, R.E. Patrick, W.R. Call - "A TSTA Compound Cryopump," J. VAC, Sci. Technol., 18#3, 1125(1981).