CONF-881002--4

HISTRAP VACUUM TEST STAND FOR PRESSURES OF 10^{-12} TORR

J. W. Johnson, W. H. Atkins, D. T. Dowling, J. W. McConnell,

W. T. Milner, and D. K. Olsen

ABSTRACT

HISTRAP, Heavy Ion Storage Ring for Atomic Physics, is a proposed synchrotron/cooler/storage ring accelerator optimized for advanced atomic physics research. The ring has a circumference of 46.8 m, a bore diameter of about 15 cm, and requires a vacuum of 10^{-12} Torr in order to decelerate highly-charged very-heavy ions down to low energies. To be able to test components and procedures to achieve this pressure, a test stand approximately modeling one-sixteenth of the ring vacuum chamber has been built. The 3.5-m-long test stand has been fabricated from 10-cm-diameter components, with 316LN stainless steel flanges. Prior to assembly, these components were vacuum fired at 950°C at a pressure of 10^{-4} Torr. The test stand is bakeable in situ at 300°C. Pumping is achieved with two 750-L/s titanium sublimator pumps and one 60-L/s ion pump. Pressure is measured with two extractor ion gauges and a 10^{-14} PP RGA. The roughing for the test stand consists of cyrosorbtion pumps followed by a cryopump. A pressure of 4 X 10^{-12} Torr has been achieved.

CONF-881002--4

DE88 016781

* Research sponsored by the U.S. Department of Energy under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

DISCLAIMER

I. INTRODUCTION

HISTRAP is a proposed synchrotron/cooler/storage ring optimized to accelerate, decelerate, and store beams of highly-charged very-heavy ions at energies appropriate for advanced atomic physics research.[1] The ring is designed to allow studies of electron-ion, photon-ion, ion-atom, and ion-ion interactions. An electron cooling system will provide ion beams with small angular divergence and energy spread for precision spectroscopic studies and also will allow the deceleration of heavy ions to low energies. Figure 1 shows the proposed layout. The ring has a four-fold symmetry, with each quadrant consisting of a 4-m-long straight section and a 90° acromatic bending section. The ring vacuum system will be divided with eight gate valves so that each straight section can be separated from the adjoining bending sections. The ring has a total circumference of 46.8 m. The aperture requires 15-cm diameter vacuum pipes in the straight sections and similar chamber areas in the bending sections, giving a total vacuum chamber surface area in the order of 20 m^2. HISTRAP will be injected with ions from either the existing Holifield Heavy Ion Research Facility 25-MV tandem accelerator[2] or from a dedicated ECR source and 250-keV/nucleon RFQ linac. The ring will have a maximum bending power of 2.0 T·m, a minimum bending power of 0.1 T·m, and heavy ions will be stored with energies between 50 MeV per nucleon and 20 KeV per nucleon.

The vacuum requirement to store highly-charged, low-energy, very-heavy ions is severe. Heavy ions passing through residual gas can either capture electrons from gas molecules or lose electrons by colliding with gas molecules. Estimates of beam lifetimes in HISTRAP from charge-changing collisions were made using the electron capture cross sections of Schlachter[3] and electron loss cross sections of Alonso and Gould.[4] The vacuum requirements resulting from these calculations for a tandem-injected Au^{40+} beam, one of the worst possible vacuum cases, is summarized in Fig. 2, which shows the beam survival fraction as a function of HISTRAP chamber pressure for various operating modes in a residual gas of 90% H_2 and 10% N_2. The upper panels are for acceleration from 1.9 MeV/amµ to 7.9 MeV/amµ and for deceleration from 1.9 MeV/amµ to 0.10 MeV/amµ. The remaining panels are for one-second coasts (one-second storage times) at beam energies of 7.9, 1.9, 0.10, and 0.02 MeV/amµ. With a vacuum pressure of 1×10^{-12} Torr, about 50% of a coasting 20 keV/A Au^{40+} beam would be lost by electron capture in one second. Clearly, after deceleration of highly-charged very- heavy ions down to low energies, HISTRAP storage times will be severely vacuum limited. For acceleration and storage at high energies, pressures in the order of 5×10^{-11} Torr are acceptable.

An average pressure of 2×10^{-12} Torr can be achieved in a 10-cm-diameter beam pipe with 1000 L/s pumps periodically spaced every 1.75 m, if the vacuum chamber material has a specific outgassing rate of less than 1×10^{-13} Torr L cm^{-2} s^{-1}. In order to test components and procedures to achieve pressures in the order of 10^{-12} Torr, a vacuum test stand following this goal has been built and operated.

II. VACUUM TEST STAND

A. Design

Figure 3 is a sketch of the 3.5-m-long vacuum test stand which approximately models one-sixteenth of the HISTRAP vacuum chamber and is constructed from 10-cm-diameter beam pipe. The two titanium sublimation pumps (TSP) are hung from tees which are separated by 1.75 m. The two end flanges are separated from the TSPs by one-half of the separation between pumps. A Varian 60-L/s Starcell sputter ion pump (SIP) is used to pump noble and heavy gases. Two Leybold-Heraus extractor ion gauges are used for low pressure measurements. One extractor gauge on the end flange is meant to approximate the maximum expected pressure midway between the pumping tees in a periodic system, whereas the other extractor gauge is meant to give a minimum pressure at a pumping tee. In addition, the other end flange holds a VG DX200 residual gas analyzer (RGA) to determine the composition of the residual gas and the roughing tee contains a nude BA gauge for high-pressure measurements. The system is roughed through a VAT all-metal right-angle 10-cm valve, and all components are bakeable to at least 250°C.

B. Materials, Processing, and Assembly

The vacuum system components were fabricated from 316L stainless steel tubing and 316LN "ConFlat" flanges following procedures used at CERN and BNL.[5,6,7] All welds were TIG without filler rod and were either inside welds or full penetration welds. Parts were then leak checked with a mass spectrometer leak detector having a sensitivity of $< 1 \times 10^{-10}$ scc/s of He. The vacuum chambers were initially cleaned by vapor degreasing with perchlorenthylene, water rinsed, dipped in Metex alkaline solution, and rinsed in deionized water.

Following the above cleaning, the components were baked in a clean vacuum furnace for two hours at 950°C at a pressure of less than 1×10^{-4} Torr. The cooling rate was carefully controlled to prevent grain boundary precipitations. After cooling, the parts were capped with blank flanges and copper gaskets for transportation and storage.

The assembly of the components was done under controlled clean conditions. Parts were handled only with gloves, white nylon over latex, and the people handling any internal surfaces such as gaskets, gauges etc., were not allowed to handle tools or bolts. The copper gaskets were silver-plated to reduce oxidation and sticking during baking. The complete assembly was leak checked using the RGA and helium. The chamber was covered with fourteen Briskheat heating blankets for in-situ baking up to 300°C. The temperature was read with 27 type E (Chromel-Constantan) thermocouples attached to the chambers and flanges.

C. Control Hardware and Software

Figure 4 shows a block diagram of the control system hardware configuration, which is a subset of that proposed for the full HISTRAP. Control is by DEC MicroVAX II/GPX computer and all control input/output functions are provided by VMEbus interfaced by a Performance Technologies, Inc. Model PT-VME903A QBUS–VMEbus adapter. The analog input consists of an Analogic Corp. Model ITG1300 analog input and master control module and two Model ITG1301 expansion modules. Inputs are the 27 thermocouples and two chart recorder outputs of extractor gauge controllers. The system does cold junction compensation and linearization of the thermocouple inputs and provides temperatures with a resolution of ~ 0.3°C. A Force Computers, Inc. Model ISIO-2 intelligent serial I/O module provides readout and control for an ion gauge controller, an ion pump controller and the RGA. The digital input/output is an

Acromag, Inc. Model 9480 module, which controls a contactor supplying all heater blanket power and 14 solid state relays for the individual heater blankets.

The MicroVAX runs the MicroVMS operating system. The software in FORTRAN is divided into four classes of processes: (1) monitor/operator interface, (2) data logging, (3) hardware interface driver, and (4) heater control. The monitor/operator interface provides real-time plots of pressure and average temperature versus time over any 100-hour period and also a real-time plot of temperature versus thermocouple. In addition, numeric displays of current time, current pressure and average temperature are given. The data-logging process records all temperatures, pressures and heater power every 10 minutes. The hardware interface processes transfer data between the VME modules and the shared data commons. These processes perform any translations required by the hardware devices and are the only processes which do direct I/O to the VME modules. At least one process is associated with each physical VME module. The heater control processes implement a standard PID controller function. There are separate temperature setpoint and controller parameters for each heater blanket. Required heater power is calculated every 30 seconds. During bakeout, a process monitors the control temperature for each heater and the system pressure. About 2 kW of power is needed to bake the system at 250°C.

D. Roughing System

To eliminate all sources for oil contamination, the roughing system consists of three stages of liquid-nitrogen-cooled sorption pumping, followed by an Air Products 20-cm-diameter closed-cycle gaseous helium cryopump. The cryopump is isolated from the sorption pumps and the UHV system by all-metal valves. The sorption pumps rough the system and the cryopump to 3 x 10^{-3} Torr. The cryopump pumps the system from 3 x 10^{-3} Torr down and during baking and cooling.

III. RESULTS AND DISCUSSION

Figure 5 shows pressure and temperature profiles as a function of time for a system bakeout cycle. The pressure shown is that measured at the tee containing the roughing valve. The starting point for the cycle was open-to-air after venting to dry nitrogen. After roughing to a pressure of 3 x 10^{-8} Torr, the chamber temperature was increased to 100°C at a rate of 30°C per hour. The temperature hold at 100°C during heat-up was to check the heating control system and would not be typical of a bakeout cycle. With only the cryopump pumping on the system, the temperature was raised to 250°C and held for 48 hours. During the 250°C bake, the pressure decreased to 3 x 10^{-8} Torr. Some components which did not have a 250°C upper temperature limit were heated to 300°C.

During cool-down, the temperature was held fixed at 120°C while the Ti sublimators, ion gauges, and RGA were degassed and the SIP was turned on. Cooling down then continued to ambient room temperature and a pressure of 2 x 10^{-11} Torr was obtained. The titanium sublimators were each flashed for four minutes at 47 amps and after the pressure recovered to 2 x 10^{-11} Torr, the all-metal valve to the cryopump was closed. The remainder of the pump-down was with the TSP and SIP and after one week an ultimate pressure of 4 x 10^{-12} Torr was achieved. The calculated outgassing rate of the stainless steel for this pressure is 4 x 10^{-13} Torr L

cm^{-2} s^{-1} and an average pressure of 3 x 10^{-12} Torr is calculated for the equivalent periodic system.

The vacuum firing of the stainless steel at 950°C and the in situ 300°C bakeout produce residual outgassing rates which allow for the use of reasonable pump sizes and pump spacing for obtaining pressures on the 10^{-12} scale for conductance limited type vacuum systems. The use of a cryopump for roughing during bakeout and cool-down provides a contamination-free method, with high pumping speed, of producing very low pressures (2 x 10^{-11} Torr) before the final pumping with the titanium sublimation pumps and sputter ion pumps. This should markedly extend life of the titanium filaments and reduce the time required to reach operating pressure.

REFERENCES

1. "The HISTRAP Proposal: Heavy-Ion Storage Ring for Atomic Physics," D. K. Olsen, G. D. Alton, S. Datz, P. F. Dittner, D. T. Dowling, D. L. Haynes, E. D. Hudson, J. W. Johnson, I. Y. Lee, R. S. Lord, C. A. Ludemann, J. A. Martin, J. B. McGrory, F. W. Meyer, P. D. Miller, W. T. Milner, S. W. Mosko, P. L. Pepmiller, and G. R. Young, Nucl. Instr. and Meth. B24/25 (1987) 26.

2. J. B. Ball, IEEE Trans. Nucl. Sci. NS-30, 1363 (1983); "The Holifield Heavy Ion Research Facility," C. M. Jones, G. D. Alton, J. B. Ball, J. A. Biggerstaff, D. T. Dowling, K. A. Erb, D. L. Haynes, D. E. Hoglund, E. D. Hudson, R. C. Juras, S.N. Lane, C. A. Ludemann, J. A. Martin, S. W. Mosko, D. K. Olsen, E. G. Richardson, P. H. Stelson, and N. F. Ziegler, Nucl. Instr. and Meth. A244 (1985) 7.

3. A. S. Schlachter, Tenth Internationa' Conference on Cyclotrons and Their Applications, MSU, April 23-May 3, 1984, ed F. Marti, IEEE Catalog No. 84 CHI996-3, pp. 563.

4. J. Alonso and H. Gould, Phys. Rev. A 26, 1134 (1982).

5. A. Poncet in "Mini-Symposium on UHV-Systems in Connection with Particle Accelerators," Stockholm, Oct. 9-11, 1984 (Eds: T. Lindblad, L. Bagge, and L. Westerberg) .

6. A. Poncet, CERN (private communication).

7. R. Skeltan, BNL (private communication).

FIGURE CAPTIONS

1. Proposed HISTRAP facility. The ring has a circumference of 46.8 m and will be injected with either the HHIRF tandem accelerator or a dedicated ECR source and RFQ linac. The ring vacuum chamber will have a surface area of about 20 m^2.

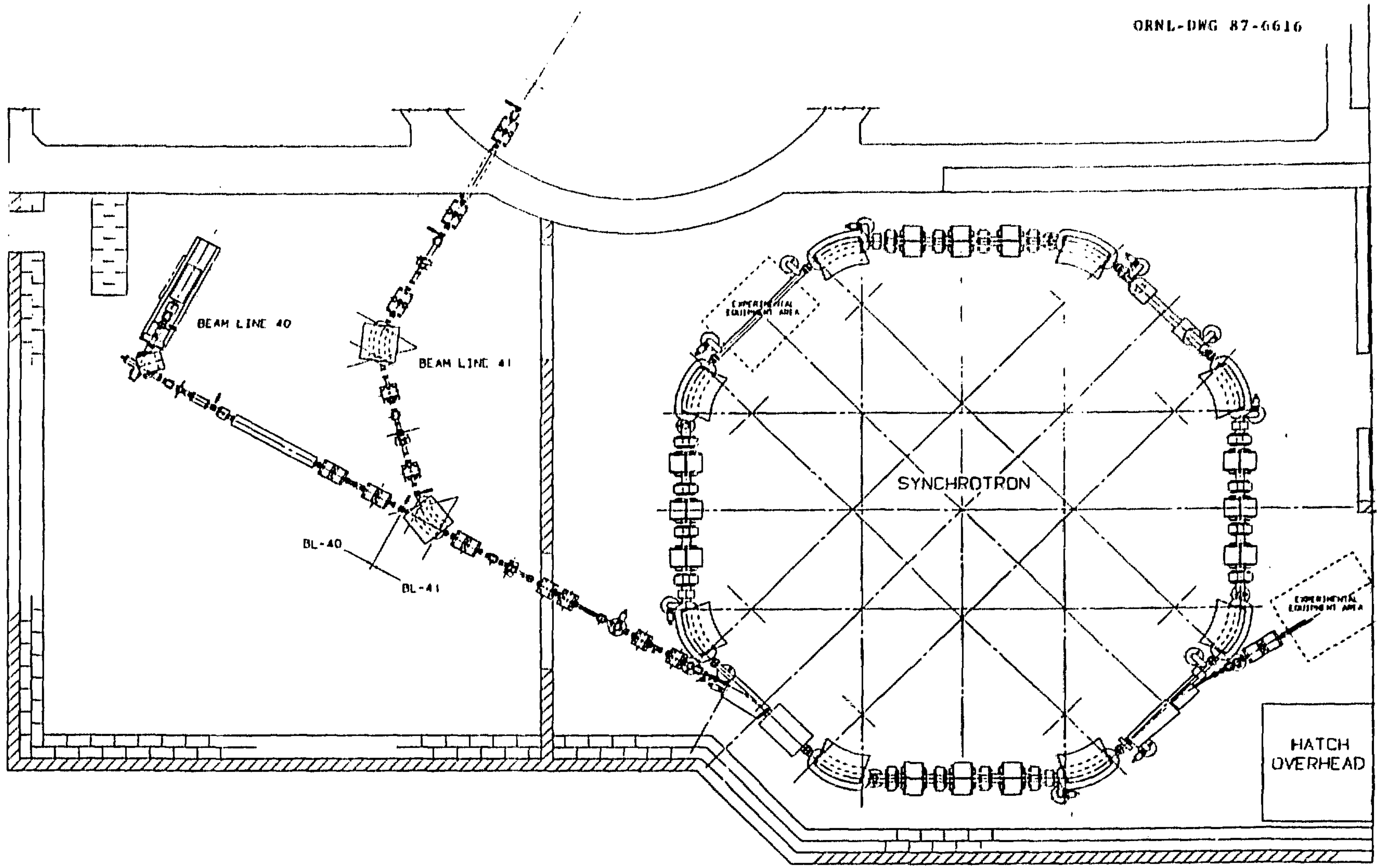
2. The surviving fraction for tandem-injected Au beams in a 40+ charge state as a function of vacuum pressure for various HISTRAP operating modes. The residual gas was assumed to be 90% H_2 and 10% N_2. E_I and E_F are the initial and final kinetic energies per nucleon, respectively. At a pressure of 1×10^{-12} Torr, 50% of a 20-keV/A Au 40+ beam would be lost by electron capture in one second.

3. UHV vacuum test stand which models one-sixteenth of the HISTRAP vacuum system. The stainless steel chambers were initially vacuum baked at 950°C and are covered with heater blankets for in situ bakes at 300°C. The system is roughed with a crysorbtion pump followed by a crypump.

4. Block diagram of the control system hardware.

5. Pressure and temperature profile as a function of time for a bakeout cycle of the vacuum test stand. After a pumpdown cycle of one week, a pressure of 4×10^{-12} Torr was obtained.

ORNL-DWG 87-6616



ORNL-DWG 85-18504

TANDEM INJECTION

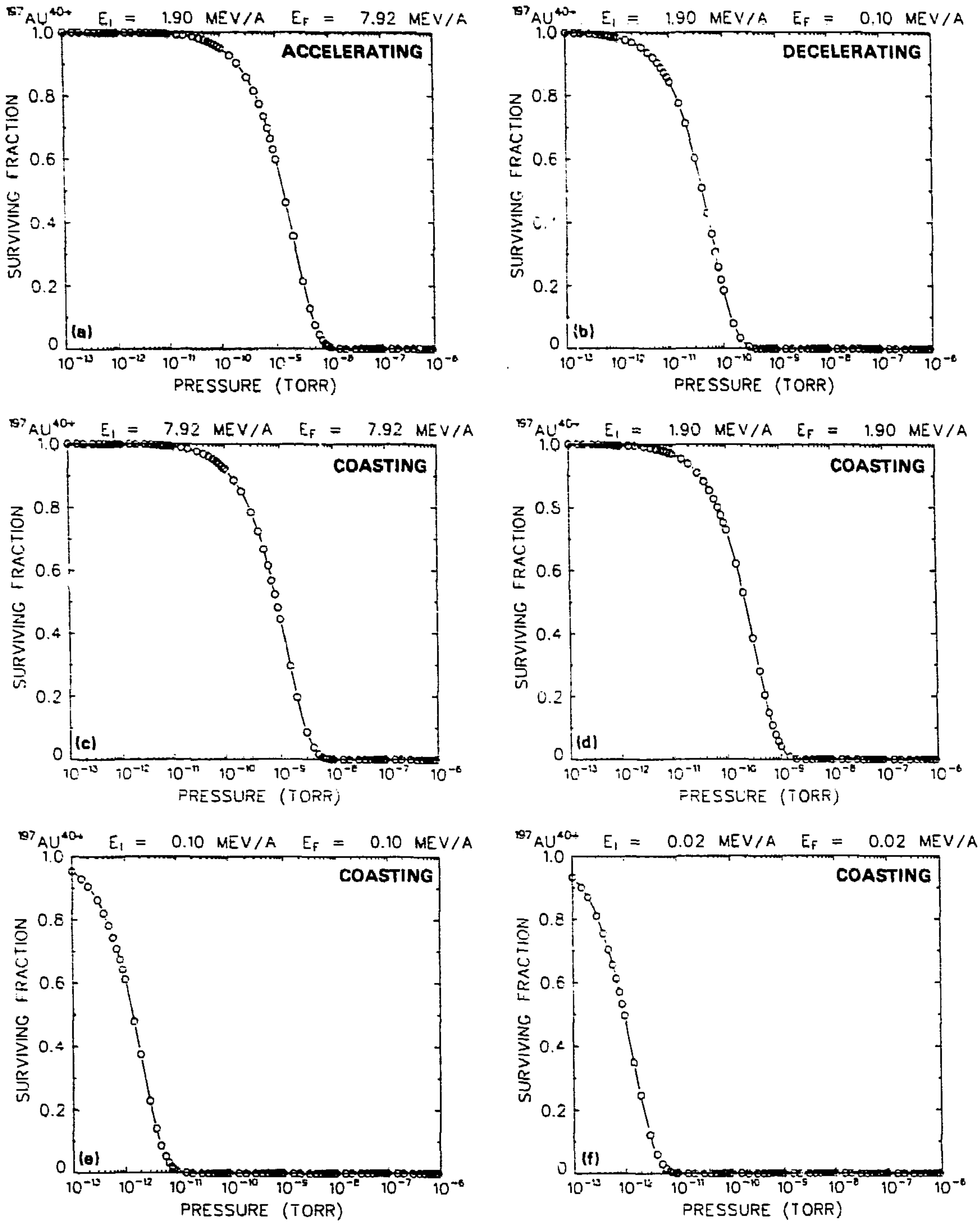
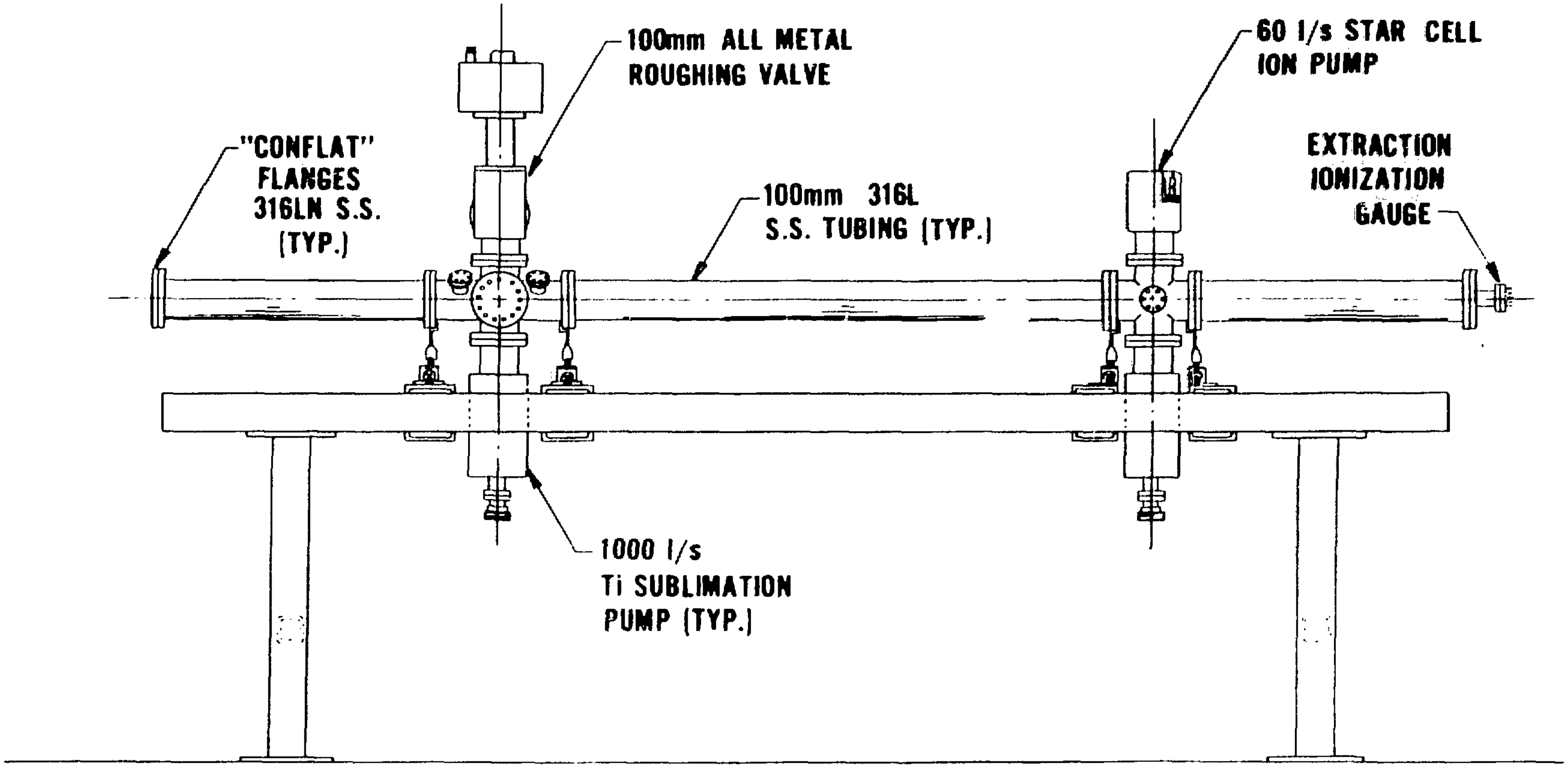


Fig. 2

ORNL-DWG 87-17720



UHV VACUUM TEST STAND

ORNL DWG 88-12586

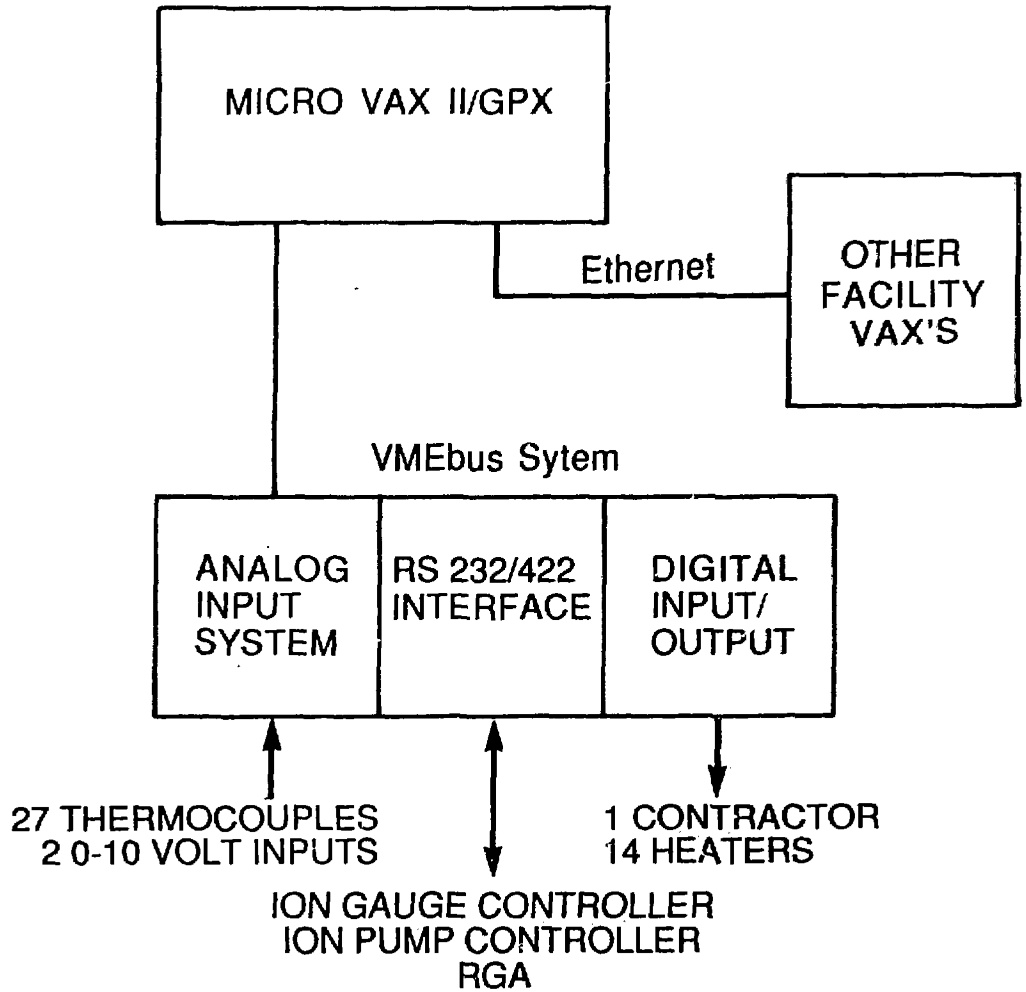


Fig. 4

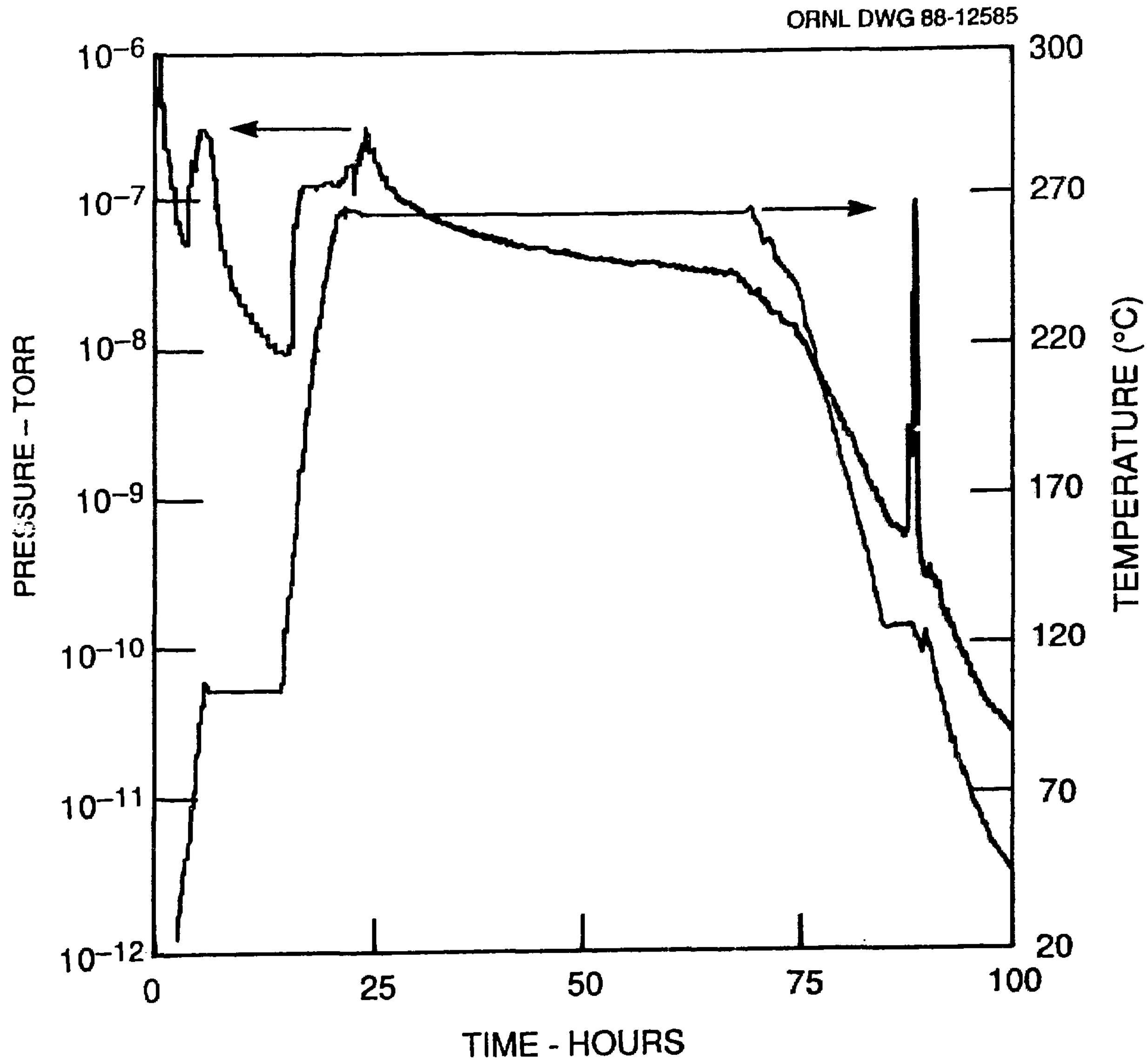

ORNL DWG 88-12585
PRESSURE – TORR
10−6
10−7
10−8
10−9
10−10
10−11
10−12
TEMPERATURE (°C)
300
270
220
170
120
70
20
0
25
50
75
100
TIME - HOURS

Fig. 5