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**ULTRA HIGH VACUUM SYSTEM FOR
ISABELLE FULL CELL**

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ULTRA HIGH VACUUM SYSTEM FOR
ISABELLE FULL CELL *

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Abstract

A vacuum system consisting of a 40 m long 8.8 cm diameter stainless steel tube, pumped by 7 pumping stations, has been assembled using automatic welding methods. All components have been fired at 950°C in a vacuum furnace at a pressure $< 1 \times 10^{-4}$ Torr. Each pumping station contains a Ti-sublimator, a 30 liter/s ion pump and an UHV gauge. After assembly, the entire system was baked out at 250°C for 24 hours. A pressure $< 1 \times 10^{-11}$ Torr was reached after titanium flash. In this paper we will discuss: a) surface treatment of stainless for 10^{-11} Torr operation, b) bake out and conditioning cycle to reach 1×10^{-11} Torr, c) leak checking at low pressures.

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I. Introduction

The vacuum system for the Intersecting Storage Accelerator (ISABELLE) is designed to operate at an average pressure of 1×10^{-11} Torr in order to satisfy various criteria of a circulating proton beam stability and low background. Basically the ISABELLE vacuum system consists of an 8.8 cm diameter stainless steel beam tube pumped by a combination of Titanium sublimation and 20 l/s ion pumps.

These pumping stations are spaced at about 5.5 meter intervals and contain besides the pumps, UHV gauges, clearing electrodes and various beam diagnostic equipment. The total length of both intersecting rings which contain 1500 pumping stations is 7500 meters. In order to provide a final test for design requirements of the ISABELLE vacuum system a full cell which is a basic building block of the ISABELLE lattice has been constructed, leak checked and baked out. The designed total pressure of $\sim 1 \times 10^{-11}$ Torr was achieved.

II. Full Cell

As seen from Fig. #1 the full cell consists of eight 8.8 cm i.d. beam tubes having a total length of 40 meters including 7 pumping stations shown in more detail in Fig. #2 and #3. The entire system including the electrodes is constructed of 304 L stainless steel with the following surface preparations.

1. Surface Preparations

Beam Tubes.

A) degreased in acetone and alcohol.

- B) Chemically cleaned in a solution of 1/3 nitric acid, 1/3 hydrofluoric acid and 1/3 water.
- C) Rinsed in water.
- D) Rinsed in alcohol.
- E) Fired in a vacuum furnace at 950°C for 2 hrs. and at a pressure of $< 1 \times 10^{-4}$ Torr.
- F) Leak checked (sensitivity 3×10^{-10} Torr l/s).
- G) Glow discharged in a separate vacuum chamber using the following procedure:
 - a) With a tube in the chamber a pressure of $< 1 \times 10^{-4}$ Torr. was reached in the system.
 - b) Bake out for ~ 18 hrs. at 200°C.
 - c) After the 200°C bake out the temperature was lowered and stabilized at 100°C.
 - d) At 100°C a bypass valve was closed to decrease the pumping speed to 1 l/s.
 - e) At this time the chamber was brought to a pressure of 50 microns with a gas mixture of 90% Ar and 10% O₂.
 - f) A tungsten wire of .020" diameter running down the center of the beam tube had 400 volts at .5 amps applied to it. Glow discharge was achieved.
 - g) The glow was maintained for 1 hr. After the system cooled to room temperature it was backfilled with N₂. The tube was removed, the ends capped with aluminum foil and bagged in plastic.

Pumping Stations

Pumping station bodies and electrodes obtain the same treatment as the beam tubes but are not glow discharged.

2. Leak Checking Procedure

Prior to installation in the tunnel the pumping stations are assembled in a clean room. Conflat flanges and silver plated copper gaskets are used. They are then leak checked with a leak detector connected between the turbomolecular pump and its roughing pump. After the air has been removed from the pumping station the roughing pump of the turbo is valved off and the leak detector is used as the back up unit.

After each component has been leak checked individually the whole pumping station is enclosed in a lucite box into which Helium is introduced. It is kept in that atmosphere for 10 minutes. The leak sensitivity of this method is better than 3×10^{-10} Torr l/s. The open ends of the beam tube connections are covered with aluminum foil and the pump station is put into a plastic bag. The stations are moved into the tunnel where beam tubes are welded to them using an astro arc automatic welder. Before welding the inside of the system is purged with argon and a continuous flow is maintained during the welding cycle. This procedure produces excellent tight clean welds. Leak testing each weld was accomplished by using a Veeco leak detector with a sensitivity of 3×10^{-10} Torr l/s which was placed between a turbo molecular pump (TMP) and roughing pump. Once the desired pressure is reached the TMP roughing valve is closed and the leak detector valve opened thus backing the TMP.

A calibrated leak was installed at the end of the beam tube opposite the leak detector, so a leak rate could be established and recorded. A clamp was placed over each weld and one atmosphere of Helium backfilled the clamp. All welds were found tight with a sensitivity of better than 3×10^{-10} Torr l/s. The electrical connections were now made to the ion pumps, Titanium sublimators, bake out heaters and UHV gauges.

Besides Varian, G. P. and Balzers nude gauges, Balzers modulated BA gauges IMR 103, having a measuring capability of 10^{-12} Torr are used in the full cell. All sputter ion pumps are powered from a single power supply. Separate high voltage relays one for each pump are used for turning on and off.

Titanium sublimators are run from a single variac, but each sublimator has its own transformer and current sensor - Ti filaments have been

degassed prior to installation. The bake out temperature of the full cell is held at a present level (adjustable up to 300°C) by snap on thermostats. Once the wiring has been completed, the bake out ovens are assembled around the full cell.

3. Bake out and conditioning cycle

A Balzer 110 1/s turbo molecular pump (TMP) which has been used to leak check the full cell, also serves as the roughing pump during the bake out. After the pressure at this pump reaches 10^{-5} Torr the bake out procedure is started. The operating temperature of 250°C is attained in ~ 2 hours. During the last 6 hours of the bake out each ion pump is turned on for 1 minute every hour, for conditioning. At the same time Ti sublimators are outgassed and kept on at 20A until the end of the bakeout cycle. Ti filament is flashed at 48 amps for 7 minutes when the system is completely cooled down.

4. Final leak check.

After the first bake out was completed, the total pressure in the full cell was too high, indicating the presence of small leaks. Using a leak detector to find these leaks would contaminate the entire system, necessitating another full bake out and conditioning cycle. Another method of leak checking namely spraying Ar around suspected leaks was employed. The leaks were readily identified and sealed by using celvaseal (CVC). After a three hour bake out at 250°C the system pressure was brought to 2×10^{-11} Torr. This is a very important result for ISABELLE since small leaks can be found and repaired without letting the entire system up to atmosphere, which would require a lengthy bake out and conditioning cycle.

III.. Results and Discussion

To understand the time required for a leak at one end of the full cell to reach the other end, where a leak detector is located, a simplified model is proposed. In this model the full cell consists of pumping stations connected to two different lengths of beam tube with inner diameter, d . From equation.

$$V \frac{dp}{dt} = - sp$$

where p , V , s , t are pressure, volume, pumping speed and time.

Since s is independent of time but is a function of the position

along the tube, we evaluate the time constant as an integration along the whole beam tube.

$$P = P_0 \exp \left(- \int \frac{dt}{(V/S)} \right) = P_0 \exp(-t/\tau)$$

$$\frac{1}{s} = \frac{1}{s_0} + \frac{1}{c}$$

$$V = \frac{\pi d^2}{4} l + n V$$

$$\tau = \int_0^L d\left(\frac{V}{s}\right)$$

Where L = the length of the full cell (cm)

V_p = the volume of pumping station (liters)

l = distance from leak detector to where the volume is calculated (cm)

n = total number of the pumping stations at the distance l .

s = the effective pumping speed at distance l (l/s)

s_0 = the pumping speed at leak detector (l/s)

C = the conductance at distance l .

τ can be rewritten as

$$\tau = \int_0^L v d\left(\frac{1}{s}\right) + \int_0^L \left(\frac{1}{s}\right) dv = \frac{\pi d^2 L}{4s} + \frac{2\pi L^2}{96.d} + V_p \frac{L}{12d^3}$$

Where V_p = total volume of the pump stations of the full cell.

Solving the equation for full cell parameters we obtain $\tau = 262$ sec. which is in good agreement with the measured τ of 280 seconds. This strongly suggests that for the best leak detection method the source of the leak and the leak detector must be as close as possible in ISABELLE. Based on this conclusion, we sprayed Ar on the suspected areas and using existing B.A. gauges as detectors, we readily found the leaks at the expected $\tau < 1$ sec.

In conclusion, the ISABELLE vacuum requirement of $\sim 1 \times 10^{-11}$ Torr has been achieved in the full cell and the leak checking procedure established and understood. After the bake out the majority of leaks come from ceramic feed throughs and these leaks are located and repaired by a method described in the paper. The surface treatment of components

and the bake out cycle proved to be adequate for ISABELLE.

Figure Captions

Figure 1. Overall view of Full Cell in tunnel.

Figure 2. Photographic drawing of UHV pumping station.

Figure 3. Schematic drawing of UHV pumping station.

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FIGURE 3