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EVALUATION OF ISABELLE FULL CELL ULTRA HIGH VACUUM SYSTEM*

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Abstract

The ISABELLE Full Cell Vacuum System consisting of a 40 m long, by 8.8 cm diameter stainless steel tube pumped by seven pumping stations was assembled and processed for 10^{-12} Torr operation. Evaluation and testing of the system and its sub-assemblies has been completed. Detail design of system components and the determination of the conditioning process was completed. The best procedure to rough pump, leak test, vacuum bake the system, condition pumps, degas gauges, turn on ion pumps and flash sublimation pumps was established. Pressures below 2×10^{-11} Torr are now routinely achieved in normal operation of the Full Cell. This includes pump down after replacement of various components and pump down after back fill with moist unfiltered air. The techniques developed for the Full Cell will be used to build the ISABELLE Ultra High Vacuum System.

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I. Introduction

The Intersecting Proton Storage Accelerator named ISABELLE being constructed at Brookhaven National Laboratory will consist of two interlacing beam tube rings, each 3.8 km in circumference. To ensure high luminosity, the pressure in the beam tubes must be maintained below 2×10^{-11} Torr to avoid beam intensity loss from excessive beam-gas collision. The Full Cell Vacuum System is a model of a typical section of the ISABELLE design used for engineering feasibility.

In the full cell only the beam tubes are installed to simulate them as they would be in the ISABELLE tunnel, superconducting coils of the ISABELLE magnet with their associated accessories surrounding the beam tube are replaced by an oven. The ovens are needed to bake the system following procedures necessary to reach the required vacuum.

The full cell consists of eight each 8.8 cm I.D. beam tubes having a total length of forty meters. Pumping stations are located between beam tubes for a total of seven pump stations. Beam tubes, pump stations, and electrodes are constructed of 304L stainless steel with special surface preparations.

II. Vacuum Behavior

Vacuum pressures of less than 2×10^{-11} Torr are routinely achieved in normal operation of the full cell. The gas residual as shown in Fig. 1 at this pressure is composed mostly of H_2 with traces of CH_4 , Ar, CO_2 and CO.

Hydrogen bulk outgassing from steel is inherent in its manufacture. The hydrogen will diffuse to the surface and combine as

H₂ in a gas phase. The outgassing of CO, CO₂ and CH₄ is strictly a surface phenomena. F₂ and H₂O peaks result from insufficient outgassing of the mass spectrometer used. The trace of Ar in the spectrum is from several possible sources. It could be left over from the 300°C bake-out, or is surface outgassing from the Ar - glow discharge surface cleaning, or is surface outgassing introduced by the accidental turn on of the sputter ion pump at high pressure. In the initial phase of the first cell testing, sputter ion pumps were used instead of the turbomolecular pump to evacuate the system during the first bake-out. During this first bake-out, one of the sublimator ceramic feed-through developed a leak which allowed argon to be pumped.

This leak was first detected by noticing two of the near by pumping stations having a higher pressure than the others. The leak was located by spraying argon at the suspected area and identified by a corresponding pressure rise in the nearby B.A. gauge on the pumping station. After this experience we began to use the turbomolecular pump system for initial pump down and during the bake-out cycle. The initial pump down is conductance limited due to the slim, long beam tube to be pumped. The turbomolecular pump can reach full speed in fifteen minutes.

After an hour of pumping the beam tube pressure reached 10⁻⁶ Torr. The oven heaters for the first cell vacuum bake were turned on and after approximately four hours the required three hundred degree temperature was attained. (See Fig. 2). The pressure rose in the

first hour to 10^{-5} Torr than gradually came down to 10^{-6} Torr. When the pressure reached equilibrium all B.A. gauge filament currents were set at 0.4 mA. There are several reasons for this operation. First, it serves as early leak detection by showing high pressure readings and by using it as a leak detector with argon. Secondly, the filament is outgassed while the system is hot which lowers the re-adsorption. Third, it monitors the pressure during the bake-out cycle.

Approximately four hours prior to the end of the twenty-four hour bake-out cycle, all titanium filaments, all ion pump electrodes, and all B.A. gauges were outgassed. Each component was outgassed in sequence until no further gas load was observed on the nearest B.A. gauge. B.A. gauge outgassing is by electron bombardment, titanium filaments by resistance heating at 20 amps, and ion pump electrodes by ion bombardment. At the end of the twenty-four hour bake-out cycle the turbo pump system is isolated from the rest of the system by an all metal valve. After seven hours the first cell is at room temperature. The ion pumps can be turned on at this time or they can be turned on immediately after the all metal valve is closed. Next, titanium is flashed in the pumping station at forty-eight amperes for seven minutes. This is equivalent to about six to seven monolayers. The pressure soon reaches the 10^{-11} Torr after twelve hours.

During the course of investigating the beam tube vacuum behavior, the duration of the bake-out was fixed at twenty four hours with bake-out temperature varied from 200°C to 300°C. No substantial

difference of ultimate pressure could be determined from the different temperature bake-outs. The heat up rate of approximately sixty degrees per hour maximum was used to prevent thermal shock to the ceramic feedthrus and other thermally sensitive components. Approximately four hours were required to heat up the system and seven hours were required for cool down.

III Vacuum Components

The vacuum components which will be used on ISABELLE were used to fabricate the vacuum full cell system. Evaluation and testing of the system and its sub assemblies has been completed. Detail design of system components and the determination of the conditioning process was completed: all the vacuum components which will be implemented in ISABELLE have been investigated seperately.

Beam Tube. Copper or a good conducting material is required as a part of the beam tube for stability of the beam. The copper is introduced on the outside of the stainless steel beam tube. Special heat treatment and surface preparation is required in order to achieve the required vacuum.

Pumping Station. The ISABELLE pumping station consists of a titanium sublimation pump, a sputter ion pump, a Bayard-Alput guage, beam electrodes, and station housing. They will be evenly distributed around each ring seperated by magnets. See Fig. 3. Fourteen hundred such stations will be required in ISABELLE.

The sublimation pump is the major structure of the pump station. It connects to the beam tubes through a five inch "T". An ion pump port and a rough pump port are attached to the sublimation pump body

through 2 3/4 conflat flanges. The sublimation pump provides about three thousand square centimeters of surface area to gather active gases such as N_2 , H_2 , O_2 and so on. A sublimation pump cartridge is used for every station. Filament type sublimation pumps were used for redundancy. Of the twenty eight feed throughs on the cartridges used, one developed a leak. Future cartridge feedthrus will be mechanically protected from surroundings and from transmitted stresses.

Bayard-Alpert Gauge. Considering the complexity of associated electronics, cost efficiency and susceptibility to the hard environment of ISABELLE, we decided to concentrate our efforts on modifying a standard B.A. gauge to meet the required pressure measurement. Two criteria were set up for selecting the gauge. Either the gauge has an equivalent X-ray limited pressure of $P_r > 1 \times 10^{-11}$ Torr with gauge sensitivity $S > 20$ Torr or it has a $P_r < S/20 \times 10^{-11}$ Torr. A modulated B.A. gauge was used successfully but due to its cost and size, it could not be used in ISABELLE. Several B.A. gauges using smaller collector designs are being investigated.

Sputter Ion Pump. The ion pump is another integrated part of the pump station. The major function of the ion pump is to pump the non-gettable gases such as, methane and argon. Residual gas constituents left in the beam tube are mainly H_2 with traces of CH_4 , Ar, CO, and CO_2 . The hydrogen, carbon dioxide and carbon monoxide are gettered quickly by the sublimation pump. Ion pump speed is drastically reduced in the pressure range required. Proper design or redesign of the penning cell will be necessary to improve the pump

speed in the range required. Several pumps have been used successfully.

Portable Pumping Station. The portable pumping station is essential for the initial pump down for ISABELLE vacuum. It will evacuate a forty meters long beam tube from atmosphere down to 10^{-6} Torr in one hour. See Fig. 2. It will also maintain the beam tube pressure around 10^{-6} Torr or less during the vacuum bake-out cycle. The heart of the station is a one hundred liter per second high performance turbo molecular pump with safety interlocks.

Vacuum Bake-Out-Ovens. Several vacuum bake-out oven designs were fabricated and evaluated on the first cell vacuum system. Box type ovens were compared with a wrapped heater and insulation wrapped bake-out system. Cost of the wrapped system is much lower than the box-type oven. Box style ovens were compared with wrapped types at vacuum bake-out temperatures from 200°C to 300°C . The box type ovens consisted of thermal insulation sandwiched between aluminum sheets to form an enclosure to contain the heat. Heat was provided by tubular electric heaters mounted within the enclosure (Fig. 4). The enclosure was held together with brackets and sheet metal screws. The wrap type ovens were constructed by first wrapping electric heater tapes around the pump stations or bore tube and tying with plain fiberglass tape. Aluminum foil backed foam insulation was wrapped over the heater tapes and held together with high temperature aluminum foil tape. The wrap type oven will be used on ISABELLE as its cost is less, works equally as well, and requires less power.

Electronic Controls For The First Cell. Initial start up and operation of the vacuum first cell was by manual control. Once a procedure was established to obtain the required pressure below 3×10^{11} Torr control was changed over to computer through an interface. Most of the power supplies and controls for the first cell were fabricated in house. The circuits were evaluated during first cell testing.

Sputter ion pump power supplies were constructed utilizing high voltage transformers of the high leakage inductive type. This type of transformer is capable of outputting a voltage of 5 kV at very high vacuum range with virtually no current drain. It can also sustain short circuit current of approximately three hundred milliamps for indefinite periods. Six ion pump were powered by one supply. No failures occurred during nine months of operation.

To supply the high current required for the sublimator pumps it was decided to use buck boost transformers. It is connected as a twelve volt maximum output, high current transformer. Output current is controlled by means of a motor driven variac on the transformer primary. An A.C. current sensor was evaluated and eventually used in the seven stations of the first cell.

One motor variac assembly was used to control the seven first cell stations. There are two modes of operation. The bake-out mode where all buck boost transformers are on at a low current, and the flash mode where one sublimator at a time is turned on at a higher sublimation current.

Heater controls were developed for the first cell pumping stations and beam tubes. Several methods were tested. The best result was by using an adjustable thermostatic controller. The controller was run in series with the heater element to control the preset temperature. Thermocouples were used to monitor temperature at various locations on the first cell.

In order to connect to the first cell computer an interface package was incorporated at each pumping station. This interface package compensated for the different characteristics associated with the equipment to be controlled.

Conclusion

Pressures below the 3×10^{-11} Torr requirement were routinely achieved within a couple of days from initial pump down. The components used on the vacuum full cell and the processes developed will form the basis for ISABELLE vacuum. These very low pressures can be produced in very large systems by proper choice of materials, construction, pumping system design, internal surface preparation, and pump down process technique.

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Figure Captions

Figure 1. Residual gas during normal operation of Vacuum First Cell.

Figure 2. General vacuum treatment and behavior.

Figure 3. Pumping Station.

Figure 4. Pump station oven for First Cell Vacuum Back System.

(a) BOX TYPE:

(b) WRAP TYPE: