VACUUM MEASUREMENTS OF THE K500 CYCLOTRON ACCELERATOR CHAMBER*

M.L. Mallory, P.S. Miller and J. Kuchar
Cyclotron Laboratory
Michigan State University
East Lansing, MI 48824-1321

E.D. Hudson
P.O. Box X
Oak Ridge National Laboratory**
Oak Ridge, TN 37830

Abstract

To evaluate the effectiveness of the unique internal cryopumping system, the pressure in the K500 superconducting cyclotron was measured as a function of radius for various gas flow rates emanating from the internal PIG source. For the test, a nude ion gauge with vertical dimension less than 2.3 cm was built and mounted on the internal beam probe. The effect of magnetic field on the ion gauge reading was determined and a method of degaussing the cyclotron was devised. Data from the normal shielded ion gauge located approximately 6 m away from the median plane was correlated with the internal vacuum measurements.

Introduction

The transmission of partially stripped heavy ions through the K500 cyclotron is dependent upon the vacuum conditions in the acceleration chamber.[1] In an effort to minimize the beam loss due to residual gas stripping, the K500 cyclotron[2] was designed with liquid helium cooled cryopanels located within one side of the accelerator dees and approximately 2.5 cm away from the magnet median plane, i.e. the acceleration region of the beam. A schematic drawing of the K500 pumping system is shown in Fig. 1. The high magnetic field of the superconducting cyclotron has made it very difficult to obtain reliable vacuum data in the acceleration chamber during normal operating conditions. The usual vacuum monitoring ion gauge is located 6 m from the magnet median plane. A program of designing a small aperture ion gauge and making various measurements was undertaken to remedy this lack of vacuum knowledge. The results obtained are described in the following sections.

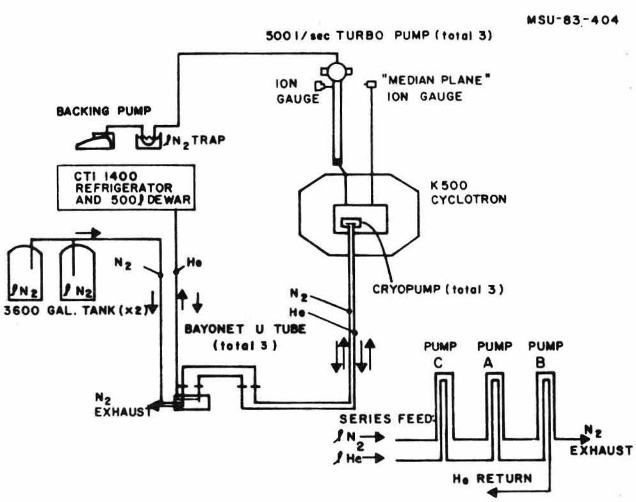

Fig. 1. A schematic drawing of the K500 vacuum system. The final vacuum is maintained by cryopumps located near the cyclotron median plane and turbomolecular pumps located ~6 meters above the magnet median plane. Because of the strong magnetic field of the superconducting magnet an ion gauge located 6 m away is normally used to monitor the cyclotron pressure.

Ion Gauge Design and Calibrating Check

To measure the pressure as a function of radius required that the ion gauge be mounted on the internal beam probe of the cyclotron. This beam probe head is mounted on a "trolley car" arrangement, and its track is located on the center of the superconducting magnet pole tip hill. The track follows the spiral of the pole tip to the beam extraction radius, where it then follows a radial path. The probe with the vacuum gauge mounted on it is shown in Fig. 2. The position of the probe head is monitored, and a computer program calculates the probe radial position and displays it as a readout in the control room.

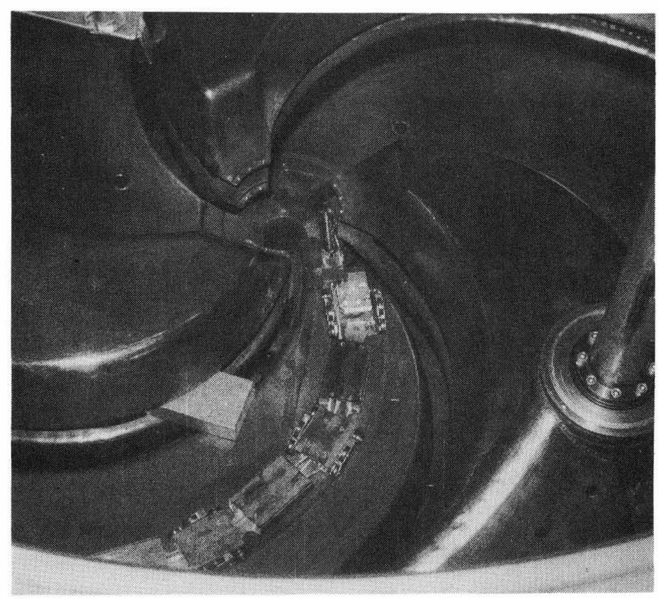

Fig. 2. Photograph of the acceleration region of the cyclotron. The PIG ion source is inserted into the hole located between the three dees. The articulated beam probe, with the nude ion gauge mounted on its end is being inserted from the bottom of the photograph and on the center of a magnet pole tip. The magnet top has been lifted up for this picture, but when lowered has a spacing less than 2.5 cm between pole tips.

The location of the probe on the center of the magnet hill requires an ion gauge that will sit in the space available between the probe track and the upper pole (2.3 cm). A Varian ion gauge (5-TDV-4-D) was modified to meet this height requirement by stripping away its outer glass envelope. The center collectorpin was reconnected to a spare base pin, so that all of the wire connections were on one end of the gauge. (Fig. 3.) (Normally the center collector pin enters the glass envelope at the end opposite the base pins.) For calibration the nude ion gauge thus created was mounted in a large vacuum chamber that also had a standard unmodified ion gauge monitoring the chamber vacuum pressure. The pressure in the chamber was varied from 1×10^{-3} Torr to 1×10^{-6} Torr and the reading differences between the nude gauge and the

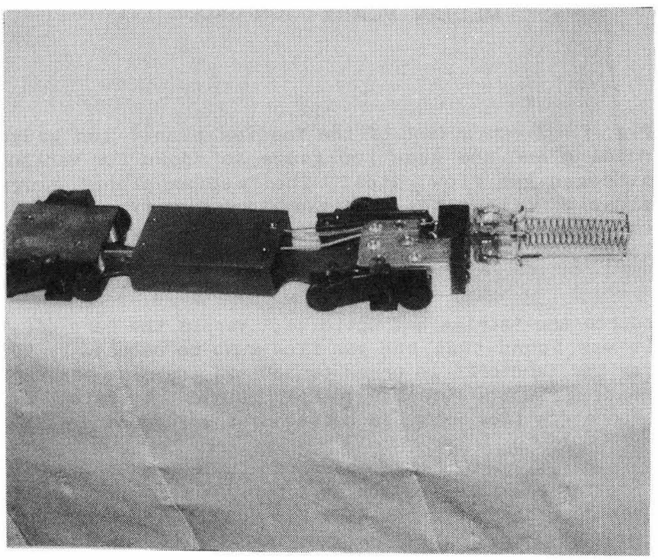

Fig. 3 Photograph of the nude ion gauge mounted on the end of the cyclotron internal beam probe. the center electrical pin collector of the ion gauge was modified to exit from the same side of the ion tube as the filament and grid connections.

standard gauge were found to vary by less than 1%, thereby assuring us that the process of modifying the gauge had not significantly changed its calibration. The current feedthroughs for the beam probe head were utilized for the ion gauge connections, using the appropriate size wires and coaxial cable. The gauge pressure was read by a standard ion gauge vacuum readout.

Magnetic Field Effect on the Ion Gauge

To measure the effect of the residual magnetic field on the internal ion gauge reading, the magnet was first cycled to reduce the residual field to a small value (Fig. 4). A Hall probe mounted in place of the ion gauge was used to determine the magnetic field profile with radius. The pressure was then measured as a function of radius with this residual field, and with the additional field of trim coil No. 12 operating at 50 amps. The field of trim coil No. 12 is shown in Fig. 4, and the pressure readings for the two conditions are shown in Fig. 5. A field of 110 gauss caused the pressure reading to change by 1.5×10^{-6} Torr. The effect of residual magnetic field during the pressure measurements is estimated to be less than 10%, so no correction was made for this.

Pressure Results

Fig. 6. is the measurement of pressure versus radius for nitrogen gas flowing into the cyclotron through the PIG ion source gas feed lines for various flow rates. The ion gauge radius is defined as the distance of the center point of the ion gauge collector pin from the center of the cyclotron magnet. The ion gauge collector pin is 5 cm long and therefore is sampling the pressure over a 5 cm radius region when the probe head is on a radial line. The vacuum in the chamber is maintained by only two dee cryopumps and three turbomolecular pumps. The temperatures of the cryopumps were 10.8 K(B) and 6.6 K(C). The pressure

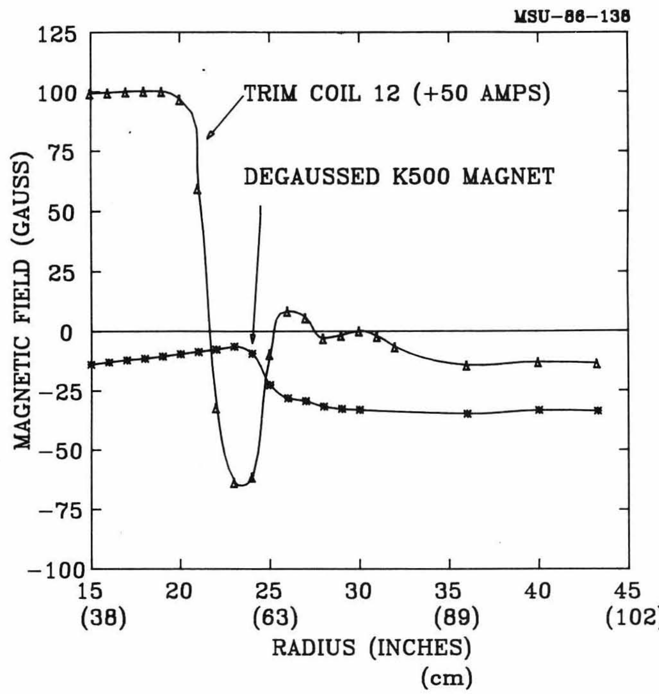

Fig. 4. The residual magnetic field in the K500 cyclotron during the pressure measurements, shown from 38 to 112 cm, is everywhere less than 30 gauss. This measurement was taken ~ 10 hours after degaussing the superconducting magnet and the coil current had decayed to near zero. The magnetic field of trim coil No. 12 at 50 amps is also shown. This coil was energized at the end of the pressure measurements to determine the effect of the residual magnetic field on the ion gauge reading.

curve for zero gas flow, the base pressure, represents the operating pressure for injected beams from the ECR ion source. This pressure can only be improved by additional pumping or by the sealing of small leaks. The pressure increases near the outside radius of the cyclotron, possibly reflecting the lack of pumping speed at this radius. As the gas flow is increased, the pressure increase is greater at the cyclotron center where the gas enters.

Figure 7 is the correlation of pressure between the "median plane" (or normal) ion gauge and the nude gauge at different flows. A separate experiment on source gas usage was performed with the "median plane" gauge and the operating PIG source. The change in gas flow to the source was determined between the

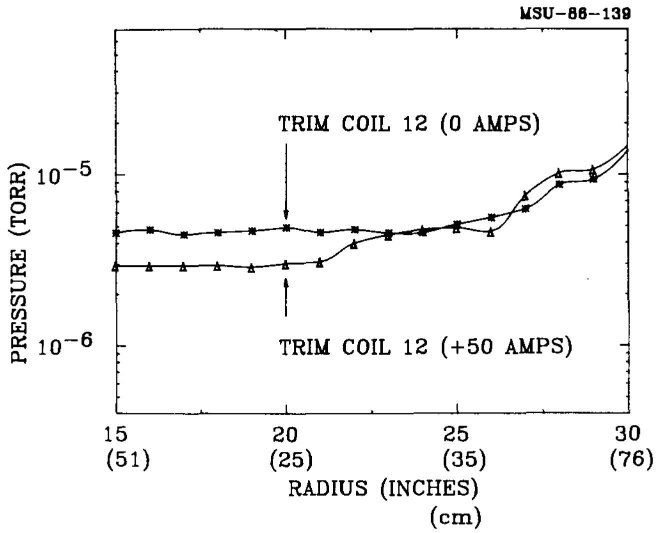

Fig. 5. The pressure versus radius in the K500 cyclotron was measured with and without the current in trim coil No. 12 energized to 50 amps. Using the fields from Fig. 4., the effect of residual magnetic field on the vacuum ion gauge was found to be less than 10% of the ion gauge reading.

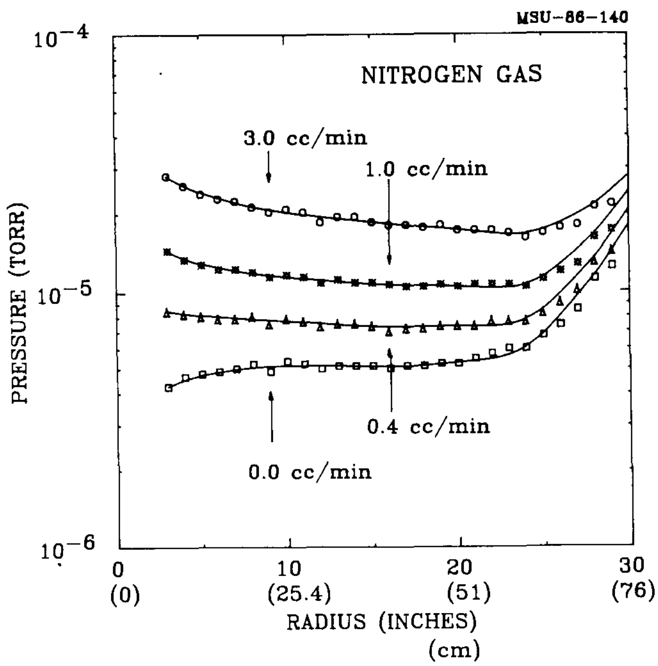

Fig. 6. Pressure versus radius for different nitrogen gas flow rates. The pressure increases more in the cyclotron center as is expected since the gas enters through the source at that location. The pressure remains fairly constant over the cryopanel region (13-60 cm), then increases at the outer radius of the cyclotron. The last internal orbit average radius is 68 cm.

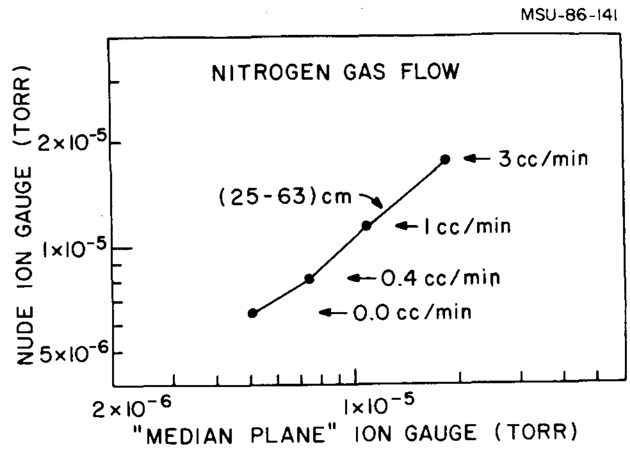

Fig. 7. A comparison of the "median plane" ion gauge reading and the nude ion gauge is shown for various nitrogen gas flow rates. The "median plane" gauge closely follows the nude gauge pressure from 25 to 63 cm for all gas flow rates. The base pressure value is lower than the "median plane" ion gauge.

source arc "strike and optimize," versus the "arc-off." It was found that the gas flow must be reduced by 50% for the "arc-off" in order to achieve the same pressure reading in the "median plane" gauge. A typical PIG source gas flow usage is between 1 and 2 cc/sec.

Conclusion

The pressure profile as a function of radius has been determined for the K500 superconducting cyclotron. This pressure profile can now be combined with theoretical beam loss cross sections and compared with measured beam attenuations. These results will aid in the decision process of any future vacuum upgrade.

---

* Supported by the National Sciences Foundation under Grant No. PHY-83-12245.

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

References

1. R.A. Gough and M.L. Mallory, IEEE Trans. on Nucl. Sci. NS-26, No. 2, 2389 (1979).
2. P.S. Miller, Tenth International Conference on Cyclotrons and Their Applications, IEEE, New York, NY, 11 (1984).