TM-989
1734.060

Fermilab

MAGNET FIELD VARIATION IN DISTRIBUTED ION PUMPS

E. Gray and J. Klen

August, 1980

MAGNET FIELD VARIATION IN DISTRIBUTED ION PUMPS

Should distributed ion pumps be used in the vacuum system for the proposed Pre-Cooler Ring or for the Tevatron Abort system Iambertson magnets? Unlike the magnetic fields in normal ion pumps, the fields in both cases will cycle over a rather wide range of values in respectively an eight second or a thirty second cycle. To make an experimental test of ion pumps with time varying fields, a spare Cooling-Ring magnet and vacuum chamber with distributed ion pumps were set up and the magnetic field ramped. The conclusion is that distributed ion pumps seem inappropriate for the Pre-Cooler Ring but may be useful in the Lambertson magnets if qualifications relating to the pressure level desired and the cutoff field of the pumps are noted.

ION PUMP OPERATION

A diode ion pump is basically a long anode Penning structure that has a magnetically confined cold-cathode gas discharge in it. The discharge produces ions of the gas to be pumped. Pumping occurs by ion burial in the cathode at lower pressures and by chemical absorbtion on the sputtered cathode material at higher pressures. Thus, for the pump to work a discharge must be established and maintained in the structure. A theorectical description of such a discharge is given by Jepsen[1] with references to earlier works on magnetron structures. As a function of magnetic field the pumping speed curve is divided into two regions. At some minimum field the discharge will start and increase with field in the low field region. The discharge will saturate and remain almost constant with field in the high field region if the pressure is less than approximately 1×10^{-7} Torr. At higher pressures a decrease with field can occur. The point of discharge is generally treated in terms of the striking voltage that is required to initiate the discharge at a constant magnetic field. For the discharge to start the so-called Townsend avalanche conditions must be met and the discharge must be self-sustaining. Several authors[2,3] referred to the "difficulty" of starting the discharge in the gauge or pump. They described the time to start as being "large and variable" and increasing at lower pressures.

EXPERIMENTAL SET-UP

A Cooling Ring dipole chamber was connected to a conductance type pumping speed measurement chamber at one end and to a 30 ℓ/s triode at the other end. The dipole chamber itself provides such a conductance limit that the pump speed cannot be measured very well. However, a semiquantitative comparison between time varying fields and constant ones can be made and the qualitative effect of varying the fields can be seen.

The pump elements have half-inch cells and have a height of 1-1/8 inch to allow the element to fit inside the two-inch chamber. There are five sets of elements two cells wide by twenty-seven cells long.

MEASUREMENTS AND RESULTS

A constant field pumping speed curve was taken as a function of field to compare to previous measurements. Figure 1 shows that curve. The break between low field and the high field region has been smoothed by the conductance limit. The speed values are as measured at the third gauge of the measuring chamber. The pump is estimated to be near 400 ℓ/s and the break point at less than 2 kg. This curve compares reasonably well with previous measurements.

The Pre-Cooler design calls for an eight-second cycle and steps at three levels above 2 kg and a minimum at .68 kg. Within the limit of the pulser and magnet power supply a cycle was chosen of five seconds at 800 amps. (4.8 kg) and two seconds at 25 amps. (.15 kg). The power supply did not invert so that current took almost a second to drop to the minimum of 25 amps. The minimum current level was adjusted and a guess at optimistic gauge readings was taken. The points of calculated speed are plotted at the current minimum of the cycle. The "speed" is seen to drop rather rapidly below about 1 kg even though only one second is spent at the low level. The pressure range for the measurements was mid 10^{-8} Torr.

Attempts at measuring response times in different pressure ranges were difficult and non-reproduceable. The general feeling was as expected that the lower pressures give slower response. Even the five second on two off seemed too fast.

After several periods of running at a 30-second ramp cycle the reason for non-reproduceable behavior was demonstrated. The dipole pump was on and the pressure was near the limit of the gauges in the mid 10^{-10} Torr range. A 30-second ramp was started with the maximum current near 1000 amps. and the minimum at 800 amps. Only very small pressure variations were seen. The minimum current was gradually lowered producing an increase in the pressure variations. However, when the minimum current was changed from 270 amps. to 250 amps (or approx. 1500 Gauss) the average pressure level was observed to drift up one decade to the mid 10^{-9} Torr. The peaks at this point were near $1\text{-}2 \times 10^{-8}$ Torr. The explanation is relatively simple and was further demonstrated by other tests. The key is the discharge does not start readily as discussed by Young, Hession[2] and Redhead[3]. If the field in the Cooling-Ring magnet goes below about 1500 Gauss, at least some of the discharge shuts off and remains off through the whole cycle. The pressure must be up at 2-3 x 10^{-8} Torr to get the pump started well. This was demonstrated by looking at the pressure after five to ten minutes. If the dipole pump was turned on at such a pressure the chamber pressure would drop to less than 5 x 10^{-10} in ten minutes. Remember that the x-ray limit of these gauges is quoted as 3 x 10^{-10} Torr. Starting the pump at lower pressures resulted in a higher base pressure typically in the low to mid 10^{-9} Torr range.

This effect was further demonstrated in the Cooling Ring. It had been known for sometime that even though the holding pumps represented only 5 percent of the total ring pumping speed, turning the distributed pumps on at the normal holding pressure of the ring (after being under vacuum for six to eight weeks the normal holding pressures are around 1 x 10^{9} Torr) results in only a factor of two or three decrease in the pressure readings. By shutting all the pumps off, the ring will drift up to about 2 x 10^{-8} Torr. When all the pumps are turned on at this pressure the resulting decrease in the base pressure after an hour or so approaches a factor of ten. Because of the limited number and placement of the gauges the average pressure would be expected to go lower than that shown by the gauges. The gauges are typically located at the same place as a holding pump.

The explanation for the ramped field test is that when the minimum field reaches a low enough level (about 1500 Gauss in this case) the pump cells start shutting off and do not come back on The pressure drifts up until the peaks are in the low 10^{-8} range which allows more cells to turn back on. The system will approach an equilibrium level between too many cells turning on and lowering the peak pressure and not enough turning on resulting in a higher pressure peak.

CONCLUSION

For the Pre-Cooler the pumps will not respond fast enough such that a cost comparison per unit effective pumping speed between distributed and commercial pumps would be unfavorable. Increased cell size will reduce the shutoff field at the expense of packing density and ecomomics. The minimum field in the Pre-Cooler will be approximately 680 Gauss or less than one-half of the observed shutoff value of the one-half inch cells. If shutoff is not avoided the achievable base pressure will be too high.

For the abort Lambertson magnets the length of the magnets (15 feet) give a conductance limit to lumped pumps in favor of distributed pumps. Also the desired average pressure of 1 x 10^{-8} Torr is favorable being at the lower edge of the observed starting range. If 1 x 10^{-9} Torr was the desired level, the pumps tested would not work because the field minimum of 1400 Gauss is below the observed shutoff value of 1500 Gauss. It would appear that a larger cell size might avoid the shutoff problem entirely. The optimum cell size for the Lambertson application must be larger than the half-inch ones used in this test. Some authors discussed a possibility of the discharge spreading from one cell to another. If this works a pump element designed with some larger cells that did not shut off might spread the discharge to the smaller more compact ones partially offsetting the lower packing density.

REFERENCES

1. R.L. Jepsen, Magnetically Confined Cold-Cathode Discharges at Low Pressures. J. Appl. Phys., Vol. 32, No. 12, p. 2619, Dec. 1961.

2. J.R. Young, F.P. Hession, A Cold Cathode Discharge Gauge for Ultra-High Vacuum Use, Trans. of the Xth. National Vacuum Symposium, p. 234, (1963).

3. P.A. Redhead, The Townsend Discharge in a Coaxial Diode with Axial Magnetic Field, Canadian J. Phys., Vol. 36, No. 3, P. 255, March 1958.

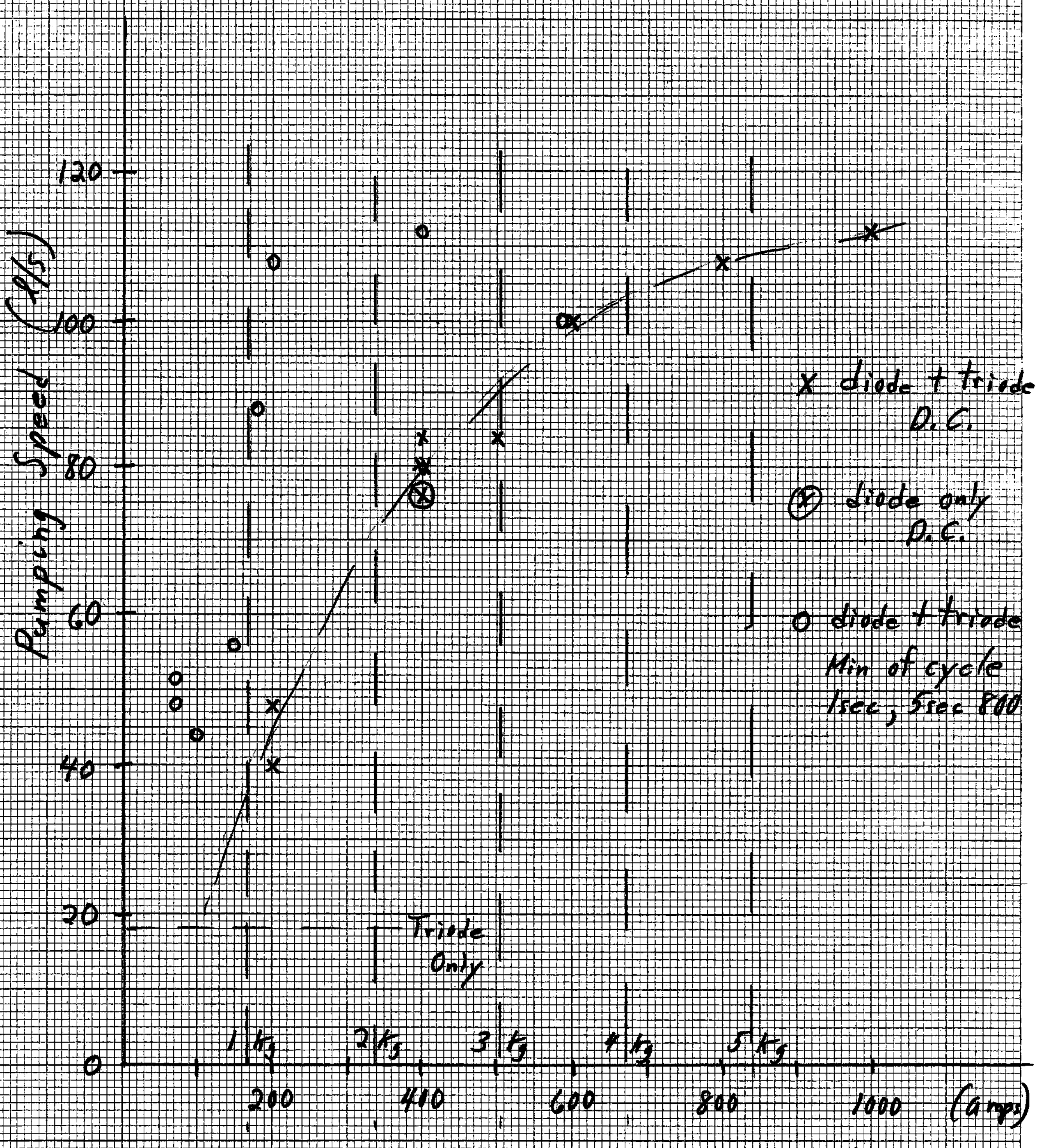

Figure 1 Pumping Speed v.s. Field

Measured in 10^{-8} Torr Range