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Test Results of Distributed Ion Pump Designs for the PEP-II Asymmetric B-Factory Collider*

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Abstract

The testing facility measurement methods and results of prototype distributed ion pump (DIP) designs for the PEP-II B-Factory High Energy Ring are presented. Two basic designs with 5- or 7-anode plates were tested at LLNL with penning cell sizes of 15, 18, and 21 mm. Direct comparison of 5- and 7-plate anodes with 18 mm holes shows increased pumping speed with the 7-plate design. The 5-plate, 18 mm and 7-plate, 15 mm designs both gave an average pumping speed of 135 l/s/m at 1 x 10^{-8} Torr nitrogen base pressure in a varying 0.18 T peak B-field. Comparison of the three hole sizes indicates that cells smaller than the 15 mm tested can be efficiently used to obtain higher pumping speeds for the same anode plate sizes used.

Introduction

Operation of the PEP-II Asymmetric B-Factory[1] collider at 9 GeV and 1.5 A places heavy requirements on the High Energy Ring (HER) vacuum pumping system from the high gas loads generated by the intense photon radiation striking the copper vacuum chamber wall. Also, additional vacuum pumping is required to provide for future operation at 3 A.

Using a gas desorption coefficient (eta) of 2 x 10^{-6} molecules/photon[1], the calculated gas load at 1.48 A operation will be 5.3 x 10^{-7} Torr l/s/m and 1.06 x 10^{-6} Torr l/s/m at 3 A. Average pressures required in the arcs are 5 nTorr at 1.48 A and 1 nTorr at 3 A. The vacuum system of a typical arc cell consists of two 6 m long dipole vacuum chambers and two quadrupole chambers 2 m long each. The quadrupole chambers will be pumped with lumped ion pumps (LIPs), but the dipole chambers at 6 m long preclude pumping from the ends, thus distributed ion pumping is planned to offset the low conductance of the beam tube calculated at 40 l/s/m.

Distributed ion pumping was chosen based on calculations and the reliability of the previous operating PEP-I design. Also, concerns about the ability to handle the huge quantities of gas expected to be generated from the high photon fluxes and uncertainties of the gas desorption properties of the chamber material precluded the use of non-evaporative gettering as the sole distributed pumping method in the arc sections of the HER. While distributed ion pumping speeds of 110 l/s/m were calculated as adequate to achieve the pressure requirement in the arcs, a pumping speed of 165 l/s/m was set as a design goal to provide a 50% safety factor based on pumping speed alone.

Pumping System Description

To achieve this pumping speed, distributed ion pump designs with plate-type anodes were chosen, as these were known to be faster than the cylindrical type[2].

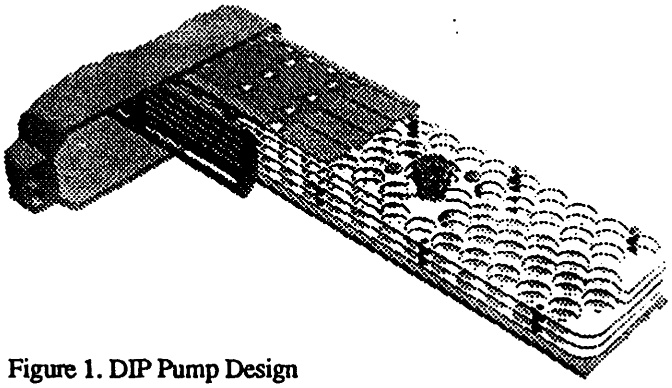

Figure 1. DIP Pump Design

The pump shown in Fig. 1 is located in a channel space 50 mm high by 83 mm wide adjacent to a 6 mm thick screen plate formed to the same shape as the far side of the beam tube. Slots tested were 0.23 cm high and 9 cm wide in patterns of six, and are pitched at 10 cm along the length of the screen. Insofar as possible, the slots in the screen were positioned to align with the spacing of the anode plates.

The pumps operate in a 0.18 T field produced by the same dipole magnets that were used in the former PEP ring. To obtain the maximum possible pumping, we elected to utilize a portion of the field (Fig. 2) beyond the magnet pole as deemed acceptable, but the width of the pump is such that only two of the four rows of Penning cells in the 18 mm anode are in an 1800 G field while the third and fourth rows are in curved field line regions of 1600 and 1450 G. Angling the cells to align with the curved field lines was considered but not utilized.

The basic features of the pump such as cell diameter, cell length and the spacing of the anode from the cathode were

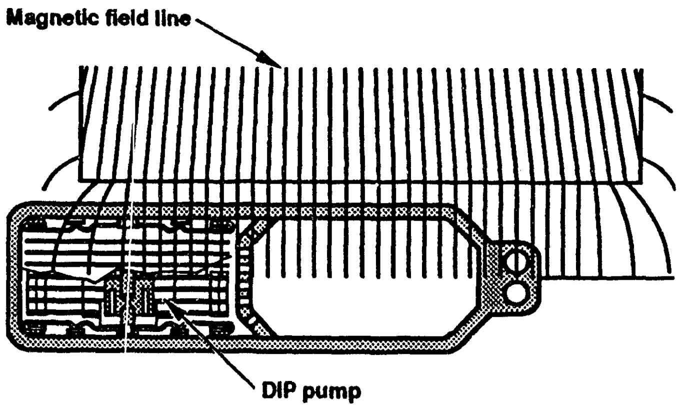

Figure 2. DIP Pump within Copper Screened Chamber within a 0.18 T peak magnetic dipole field.

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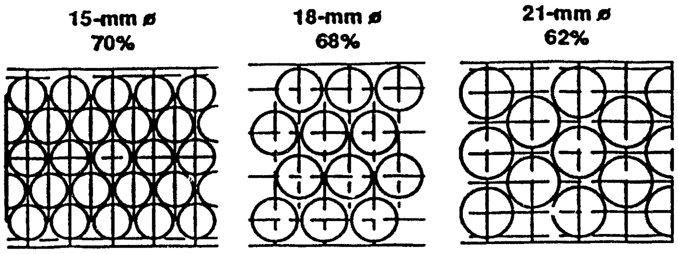

Figure 3. Three Anode Hole Patterns Tested

calculated from Hartwig and Kouptsidis[3] although these formulas have been derived primarily for the calculation of cylindrical-type anode designs.

Distributed Ion Pump Description

The basic design (Fig. 3) has a pattern of four rows of 18 mm dia, 31 mm high cells with a 4.5 mm cathode-to-anode gap. Although theory states the cell diameter should increase as the field lessens to maintain the same pumping speed, we elected to maintain a uniform cell diameter in order to maximize the total number of cells in the pump.

The cathodes of the pump are made of pure titanium, 1.5 mm thick by 80.4 mm wide and 1 m long. The cathode plates (Figs. 1 and 2) were shaped to provide the stiffness needed to resist the spring forces generated by the spring contact plates located between the chamber wall and the cathodes. The contact plates, calculated to conduct a heat flux of 0.01 W/cm^2 at a chamber pressure of 1 x 10^{-7} Torr[4], were not actually used because of the final close fit between the pump and the test chamber. Subsequent conditioning at gas loads as high as 1 x 10^{-4} Torr l/s showed that thermal cooling of the cathode plates was not required.

Because of the uncertainty about how pumping speed would respond to electric field uniformity, 5- and 7-plate anode assemblies were fabricated. The anode plates are 316 stainless steel 1 mm thick, except for the center plate which is 1.5 mm thick as it is used to support the cathode plates with three alumina columns passing through clearance holes in the top and bottom anode plates. A minimum gap of 4 mm was maintained throughout to prevent arcing. In addition to the basic anode design with 18 mm dia holes, anodes with larger and smaller holes, 21 and 15 mm, were tested. These anode hole patterns (Fig. 3) show cell area-to-plate area percentages ranging from 62% for the large size to 70% for the smaller size.

Test Facility

A test facility[5] was constructed to test the various pump designs. The basic design was patterned after a design by T.S. Chou "Design studies of distributed ion pumps"[6].

A PEP-II dipole magnet provides the magnetic field and the SS chamber geometry closely simulates the PEP-II ring conditions. Test pumps and other screen designs are inserted through a 15 cm port at the end which is otherwise used as a viewing port. A gas flow system is located at the center line position of the test pump to aid in leveling out the gas flow to the pump.

The chamber and pump is baked to 200 C with a heating system installed in the narrow spaces between the chamber and the magnet pole faces. A data acquisition system is programmed to monitor, log and display pressures, gas flows, ion current, voltages and pumping speed all as a function of time.

Measurement Method

A constant pressure measurement system is used to measure flow rates, Q, into the pump chamber where the pressure differences P1 and P2 are measured across a known conductance C of an orifice according to:

$$Q = C(P1-P2)$$

For the system, C was calculated for nitrogen at 1.26 l/s. The pumping speed is then:

$$S = C(P1-P2)/Po$$

where Po is the pressure measured at the pump. Pressure Pbar, taken by four Bayard-Alpert gauges arranged in front of the test pump, is an average pressure as earlier calculations[5] had shown the pressure profile to be fairly level along the length of the pump and chamber.

A second gas flow system measuring pressure differences in a known volume as a function of time gave flow as:

$$Q = V(P1-P2)/t \quad \text{Torr l/s}$$

The two systems tracked within 15% for flow rates between 5 x 10^{-5} and 1 x 10^{-6} Torr l/s to pressures around 1 x 10^{-8} Torr, then diverged by about 35% at 5 x 10^{-9} Torr largely due to temperature sensitivity.

Preparation

After cleaning, the stainless steel and titanium parts were vacuum baked separately to 800 C for the stainless steel or 900 C for the titanium parts. Upon attaining temperature, the parts were "soaked" until the pressure in the vessel leveled off. After cooling down to 25 C, the chamber was vented to nitrogen gas and the parts removed. All subsequent part transferring was made in closed containers back-filled with nitrogen gas until the pump was assembled in a clean room to ensure as clean a process as practical.

Testing Description and Results

Four pump module types were tested (5-plate, 18 mm; 5-plate, 21 mm; 5-plate, 15 mm and finally 7-plate, 18 mm). After a 24 h bake at 200 C and 4 h conditioning at high voltage, all the pumps were first tested at PEP-II operating parameters with the dipole field set at 1800 G and the anode voltage at 5500 V. Pump speed measurements were made at gas flows of 5 x 10^{-7} and 1 x 10^{-6} Torr l/s, calculated gas loads corresponding to HER pressure requirements, and also at 5 x 10^{-6}, 1 x 10^{-5} and 5 x 10^{-5} Torr l/s to establish trends. After each of these gas flows, the ion pump was turned off and the system pumped with the turbomolecular pump to a stabile pressure and a pumping speed check was made to a known value of about 40 l/s before going to the next flow rate. Prior to each test run, the system was based out, ion gauges degassed, the pressure stabilized and a reference base pressure (Po) reestablished for each run.

An example plot of these runs showing saturated pumping speeds and pressure versus time can be seen in Fig. 4. In a second test, pumping speed versus magnetic field was measured with anode voltages held constant at 3, 4, 5, 6 and 7 kV with a constant gas flow of 1 x 10^{-6} Torr l/s corresponding to the PEP-II maximum current operation of 3 A. For these runs, the field was ramped down from 2600 to 500 G at a rate of about 400 G/min. An example plot of these measurements at the various voltages is shown in Fig. 5.

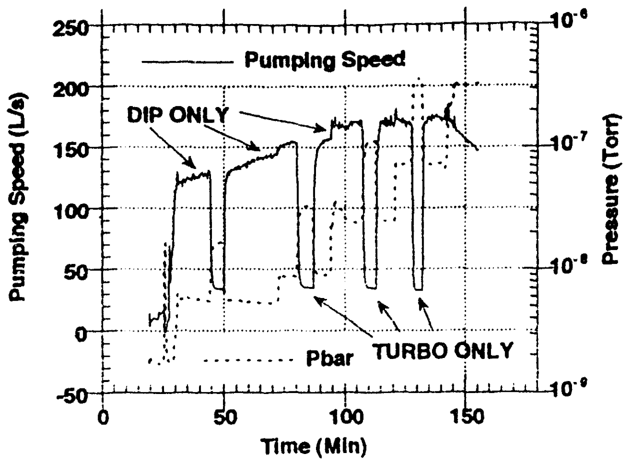

Figure 4. Pumping Speed and Pressure versus Time for a 7-Plate 1.8 cm DIP after 200 C bake and conditioning

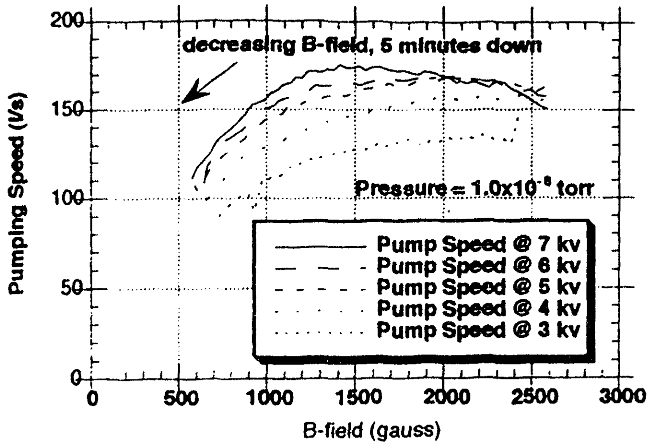

Figure 5. Pumping Speed versus B-Field for Constant Voltages for a conditioned 7-plate 1.8 cm DIP

Pumping speed results of all 5- and 7-plate anodes are shown in the table. The basic design, a 5-plate anode with 18 mm dia cell holes, was tested first. Designs with larger and smaller holes at 21 and 15 mm dia were later tested to check for cell diameter dependence although the number of holes in the available area of the anode varied. A 7-plate anode design was tested to observe any possible effects relating to electric field uniformity.

As seen in the table, the 7-plate anode with 18 mm holes and the 5-plate anode with 15 mm holes produced the best results with an approximate average saturated pumping speed of 135 l/s/m at a pressure of 1×10^{-8} Torr base pressure. High pumping speeds for freshly conditioned pumps are identified by a single asterisk.

The 7-plate pump was later repositioned in a totally uniform B-field of the dipole magnet to enable us to measure a maximum possible pumping speed of 166 l/s for this geometry at 1×10^{-8} Torr base pressure. A pumping speed/cell was calculated at 0.88 l/s/cell.

Conclusions

An analysis of the data provides two main observations for future designs:

(1) Direct comparison of 5- and 7-plate anodes with 18 mm dia holes shows increased pumping speed with a more uniform electric field provided by the 7-plate geometry. This is thought to be because of the disrupted penning cell electric field caused by the grounded screen next to the high positive anode voltage.

(2) In a second observation of Fig. 5 and similar curves for other geometries not included in this paper, the pumping speed peaks and drops off at fields much lower than the 1800 G field at which PEP-II nominal operation is planned. Therefore cell holes smaller than the 15 mm tested can be efficiently used and therefore higher pumping speeds should be attainable for the same anode plate sizes used because the total number of pumping cells increases with smaller diameters for the same geometry.

Table. DIP Testing Summary of Results

Design	Hole Size (mm)	Numbers of Holes	Gas Flows (Torr l/s) 5e-7 / Gas Pressure (Torr) 5e-9 / Pumping Speed (l/s/m)	1e-6 / 1e-8	5e-6 / 5e-8
5-plate basic	18	188	101	106	114
5-plate large	21	114	124	135	140
"	"	"	115	120	134
5-plate small	15	272	106	140	163
"	"	"	112	137	149
7-plate basic*	18	188	142	154	163
"	"	"	112	128	140
"	"	"	119	131	147
"	"	"	113	132	143
7-plate basic*	18	188	134	156	171
7-plate basic**	18	188	142	166	172

Note: *After vacuum bake and conditioning
**DIP pump in uniform 1800 gauss field

Optimization for maximum pumping speed needs to take into account the combined effect of both of these factors.

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References

[1] PEP-II, An Asymmetric B Factory, Conceptual Design Report, June 1993
[2] Y. Suetsugu and M. Nakagawa, Vacuum/Volume 42/1991, Great Britain
[3] H. Hartwig and Kouptsidis, J. Vac. Sci. Technol., Vol. 11, (6), 1974 and private communication
[4] M. D. Malev and E. M. Trachtenberg, Vacuum/volume 23/number 11, Pergamon Press Ltd, Great Britain
[5] Distributed Ion Pump Testing for PEP-II Asymmetric B-Factory Collider, Proc. 1993 Particle Accelerator Conf.
[6] T. S. Chou, J. Vac. Sci. Technol., A5 (6), Nov./Dec 1987

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