

Research and Development for the PEP-II Vacuum System

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ABSTRACT

Significant research and development activities have been carried out during the past year to optimize the vacuum system design for the SLAC-LBL-LLNL PEP-II B Factory. Detailed evaluations of design, materials, and manufacturing are reported, and the resulting changes from the original CDR design are described. Results of vacuum, thermal, and mechanical analyses are presented, and their relationship to machine performance requirements detailed. The results of extensive manufacturing prototype testing, which verify the proposed design concepts, are reported.

1. INTRODUCTION

The PEP-II B Factory consists of two new storage rings to be constructed in the existing PEP tunnel with a single detector to be located at existing PEP Interaction Region 2. Figure 1 shows the low energy ring (LER), carrying positrons at 3.1 GeV, located above the high energy ring (HER), carrying electrons at 9.0 GeV. Each ring consists of six 240 m arc regions separated by six 120 m straight sections. The ring vacuum systems are separate except at the interaction region (IR) where the LER beam is bent down to collide with the

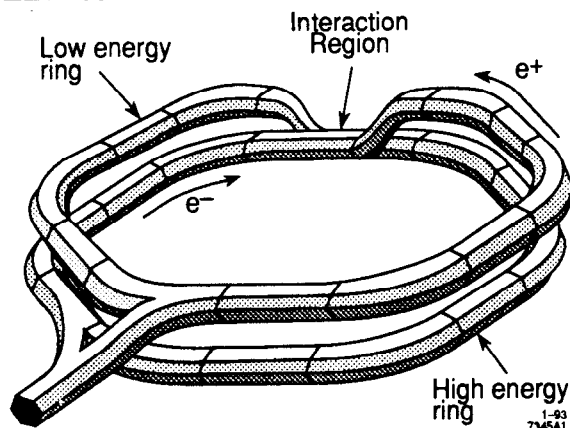


Fig. 1 View of the two rings.

HER beam, then back up into the orbit plane of the LER arcs. The design luminosity for PEP-II, $3 \times 10^{33} \text{ cm}^{-2} \text{ sec}^{-1}$, is 30 times higher than that of PEP-I. This high luminosity is achieved by obtaining high stored beam currents, up to 3.0 A, in 1658 bunches in each ring. This high stored current makes design of the vacuum system very challenging, as very high heat and gas loads are generated by synchrotron radiation produced in the bend magnets.

2. VACUUM SYSTEM REQUIREMENTS

In order to operate efficiently as a B Factory, PEP-II must maintain a high luminosity over long running periods and achieve low detector background levels. These operating requirements determine the vacuum system design parameters:

- A. We must maintain low vacuum pressure despite high gas loads. The design vacuum pressure for PEP-II is specified to be $\leq 1 \times 10^{-8}$ Torr in the arc regions, $\leq 3 \times 10^{-9}$ Torr in the straight sections, and $\leq 2 \times 10^{-10}$ Torr in the Interaction Region.
- B. We must provide sufficient power absorption and cooling to dissipate significant heat loads from synchrotron radiation and higher-order-mode losses.

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- C. We must achieve a low broadband impedance ($< 1\Omega$) to avoid beam instabilities and minimize higher-order-mode heating.
- D. The vacuum chamber should be self-shielding so that adjacent components such as magnet coils and electrical cables are not damaged by synchrotron radiation.
- E. We must provide a beam-stay-clear that allows for efficient injection and adequate beam lifetimes.

3. VACUUM SYSTEM DESIGN

The two most significant problems in the design of vacuum chambers for PEP-II are absorbing the large amount of synchrotron radiation power generated, and achieving the desired vacuum pressure in the face of high photon-stimulated gas desorption. Since the synchrotron radiation power scales with energy, the greater problems are found in the HER. Each of the bending magnets in the HER arcs generates 55 kW of synchrotron radiation (SR) power at a maximum operating current of 3 A. As photons strike the outer wall of the vacuum chamber, the wall is heated and a large number of gas molecules are desorbed, thus increasing vacuum system pressure. The design beam current in PEP-II is much greater than PEP-I (3.0 A versus 0.092 A per beam), but the beam energy is lower (9 GeV versus 18 GeV). The synchrotron radiation linear power density in the PEP-II HER arcs is a factor of 2 higher than PEP-I. The number of photons emitted in PEP-II, however, is approximately 15 times greater than PEP-I. The gas desorption resulting from this high photon flux is a challenging problem to solve. The synchrotron radiation photon flux in the HER arcs is 1.5×10^{19} photons per second per meter, resulting in a

dynamic gas load of 1×10^{-6} Torr-liters per second per meter. These two factors, thermal load and gas load, drive the design of the vacuum system for the PEP-II collider.

The vacuum system for PEP-II may be divided into 3 units - the LER system, the HER system, and the IR system. We consider the IR vacuum system to include the vacuum chambers of the detector as well as the straight chambers extending ± 60 m from the interaction point, as the design of all these vacuum chambers critically affects the operation of the detector.

3.1 Low Energy Ring Vacuum System Design

The LER vacuum system has changed considerably from that first proposed in the PEP-II Conceptual Design Report (CDR). Optimization of the LER magnetic lattice and modifications to the bend magnet design have resulted in extensive changes in the LER arc vacuum system. The bending magnet radius was decreased from 30 to 13.75 m, resulting in a factor of 2 increase in emitted synchrotron radiation power. The arc region vacuum chambers, as shown in Fig. 2, consist of sixteen standard cells of bend magnet chambers with 4 m, straight pumping chambers between magnet groups. The arc chambers are now made from the single wall copper extrusion shown in Fig. 3 with an extruded copper cooling bar electron-beam welded to the outer wall of the beam passage. The new configuration is a simpler design than the CDR concept, is less costly to fabricate, and has greater net vacuum conductance. Further, the wider cross section decreases the incident angle between the synchrotron radiation and the vacuum chamber wall which lowers the linear power density. The peak SR linear power density is calculated

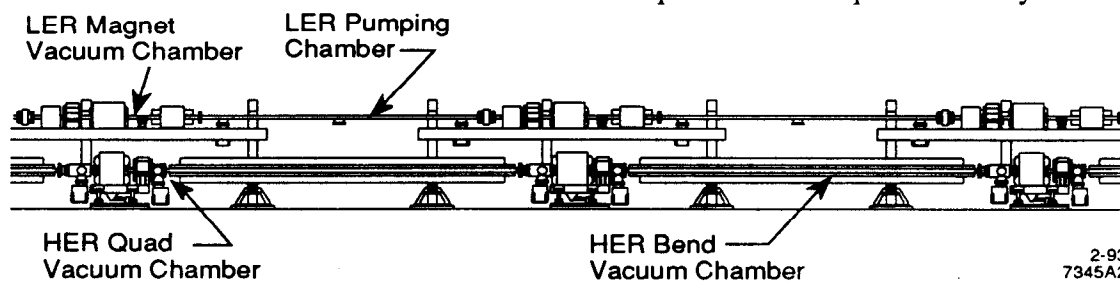
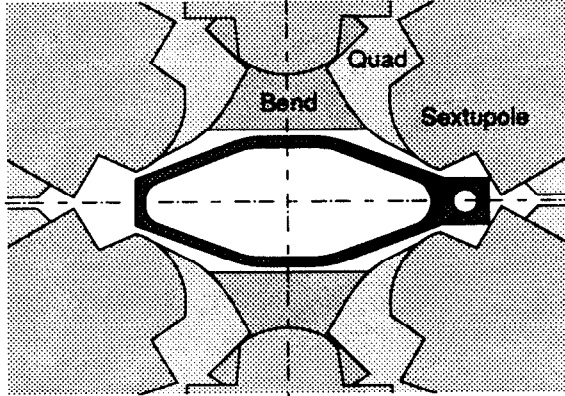


Fig. 2 View of a standard arc cell.



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 Fig. 3 Cross section view of the LER arc vacuum chamber and magnet profiles.

to be 45 W/cm at 3.1 GeV and 3.0 A beam current[1]. The peak wall temperature at the point of SR incidence has been calculated to be approximately 100°C with a maximum thermal stress of 6.9 MPa [2]. Detailed vacuum pressure calculations show an average pressure of approximately 5×10^{-9} Torr. Distributed ion pumps (DIPs) are not practical due to the short length of the bend magnet (45 cm), so vacuum pumping is provided by conventional lumped sputter ion pumps (LIPs). The vacuum chambers in the 120 m straight sections will be made from round stainless steel tubing.

3.2 Interaction Region Vacuum System Design

The vacuum chambers for the IR are particularly complex due to the many components that must occupy a relatively limited space[3]. Low vacuum pressures are especially important in the IR to prevent excessive beam-gas backgrounds from interfering with detector operation. A considerable amount of synchrotron radiation is produced in the horizontal and vertical bend magnets that bend the beams into collision. This power must be absorbed in masks and the vacuum chamber walls and removed by cooling water. Linear power densities as high as 500 W/cm are calculated for IR masks. In addition to the thermal gas background, rather high localized dynamic gas loads occur as a result of photon stimulated gas desorption at the synchrotron radiation masking surfaces. Sputter ion pumps will be installed to provide noble-gas pumping and to maintain vacuum system pressure in the

absence of beam. It is expected, however, that sputter ion pumps alone will not provide enough pumping speed to maintain sufficiently low vacuum system pressure during accelerator operation. Therefore, we expect that some combination of titanium sublimator pumps (TSPs) and non-evaporable getter (NEG) pumps also will be used to provide the high pumping speed required at low vacuum pressures. Present plans call for the vacuum chambers to be fabricated from stainless steel and copper tubing, with the central detector vacuum chamber made of beryllium. Clearly a high strength, high conductivity absorber material such as GLIDCOP® is required for masks due to the high thermal stresses.

3.3 High Energy Ring Vacuum System Design

The present design for the HER vacuum system is similar to that proposed in the PEP-II CDR. Some modifications have been made as a result of detailed engineering studies of wall heating and vacuum pressure, and the design has been optimized for cost-effective fabrication. A detailed fabrication plan has been generated, critical factors have been identified, and prototype testing is in progress to verify our design solutions and fabrication plans. Figure 2 shows the arrangement of magnets and vacuum chambers in the HER arc region. The standard HER arc cell consists of a 1.5 m long quadrupole vacuum chamber located between 6 m long bending magnet vacuum chambers. Both the quadrupole and bend chambers are fabricated from copper extrusions. Different cross-sections are used, however, due to the need for distributed ion pumps in the bend chamber. The beam passage is identical in the bend and quadrupole chambers, so the beam sees a constant cross section as it passes through the arc vacuum chambers.

The bend chamber shown in Fig. 4 consists of a single copper extrusion, which forms the vacuum envelope, with an extruded copper cooling bar, which removes heat generated by synchrotron radiation. The cooling bar is attached via electron-beam welding to minimize annealing of the chamber walls. The bend chamber is curved to a 165 m radius in order to conform to the curvature of the beam in its path

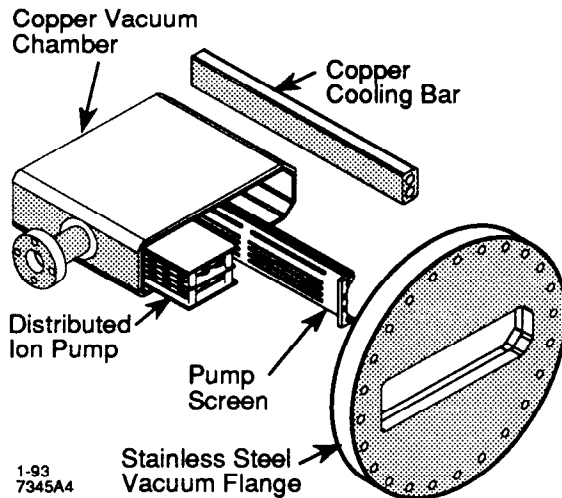


Fig. 4 Exploded view of the HER bend magnet vacuum chamber.

through the bend magnet. A copper “screen” is inserted into the larger extrusion to divide it into a beam passage and a distributed ion pump passage. Gas molecules are conducted through slots in the screen to the DIP. The bend magnets take up a large percentage of the total beam line circumference leaving little room for vacuum pumps other than distributed ion pumps. Further, efficient magnet designs dictate small magnet bores and a relatively small vacuum chamber cross-section with limited vacuum conductance. Lumped sputter ion pumps (LIPs) at the ends of the bend magnet have limited effect on the pressure in the arc. The pumping speed of the distributed ion pumps takes on considerable importance in the HER vacuum system design.

The 1.5 m area between bend magnets, in addition to the quadrupole, sextupole, and corrector magnets, contains many vacuum elements — beam position monitors, bellows, LIPs, masks, supports, and vacuum flanges with the need for both vacuum and RF seals. The need to fully integrate all of these components in a functional, reliable, and cost-effective design makes the quadrupole vacuum chambers a critical design component of the PEP-II arc regions. The distributed ion pumps proposed in the CDR for the quadrupole chambers have been replaced by two lumped differential sputter ion pumps mounted on the quadrupole chamber via a high conductance pumping cell.

These pumps will provide noble-gas pumping, maintain vacuum pressure when the bend magnets are turned off (the DIPs will not operate without magnetic field), and maintain vacuum pressure in the quadrupole chambers during machine operation. Detailed calculations show that a higher pumping speed and lower cost were obtained with the LIPs than were with quadrupole DIPs. The usable quadrupole field strength and, therefore, the DIP pumping speed, were limited, and the need to change quadrupole field strength for optics reasons was considered an undesirable complication. The need to shield vacuum flanges and to cool SR power absorbing surfaces inside the pumping cells has led to the use of discrete masks in the quadrupole chamber. These water-cooled masks absorb SR power that would otherwise hit bellows, BPM's, flanges and the small uncooled area at the chamber ends. The SR power density on these masks is calculated to be ~ 250 W/cm.

4. Research and Development for the PEP-II Vacuum System

An aggressive research and development program is under way for the PEP-II vacuum system. The goals are to validate our design assumptions and to optimize the cost-benefit ratio of our design solutions. Within the PEP-II project, a high priority has been given to the HER vacuum system R&D, as the HER will be constructed and commissioned first. Our expectation is that the design concepts and fabrication techniques developed for the HER will be applied later to the LER and IR vacuum chambers. HER vacuum chamber designs have been studied in detail and critical design and fabrication factors have been identified. Prototype testing is under way for each of these critical factors. Our designs will be optimized and a full scale arc cell prototype will be fabricated based on the results of this testing. This will allow us to perform mechanical testing on the overall system and will serve as a final confirmation of our design solutions. Further, the arc cell prototype will allow us to test installation and alignment techniques in a realistic setting. The PEP-II vacuum system R&D activities have concentrated on the following areas.

4.1 Engineering Analysis

Significant engineering analysis has been completed for both storage rings using EXCEL, ANSYS, IDEAS, and EGS4 in order to evaluate the synchrotron radiation power distribution, the resulting heat and gas loads, vacuum pressure profiles, static and thermal stresses, and radiation shielding requirements.

The peak SR linear power flux for the HER is calculated to be 102 W/cm at a beam energy of 9.0 GeV and beam current of 3.0 A. Finite-element calculations of temperature and stress show the maximum wall temperature at the point of peak SR incidence to be about 100°C, with an average wall temperature of 60°C. Stresses due to heating and cooling are calculated to be about ± 41.4 MPa [4] with the expected yield strength for annealed OF copper about 83 MPa. The combination of residual stresses from fabrication and thermal stresses is calculated to be sufficiently below the endurance limit for the material that fatigue cracking will not be a problem. Calculations show the average vacuum pressure in the HER arcs to be comfortably below the design pressure of 1×10^{-8} Torr (N_2 equivalent). The exposure of beam line components such as magnet coils and cable insulation to harmful radiation effects is always a concern in accelerator design. The effects of radiation shielding in PEP-II were evaluated using EGS4 [5]. The vacuum chamber wall of 5 mm thick copper was found to be fully self-shielding, that is, all synchrotron radiation produced in the vacuum chamber is contained in the chamber walls. No additional radiation shielding will be required in either ring.

4.2 Photodesorption Testing

Maintaining acceptably low vacuum pressure is a critical factor in achieving long beam lifetimes and high luminosity in a storage ring. Ensuring acceptable vacuum pressures in the PEP-II storage rings, with the high photon doses calculated, requires an accurate understanding of the photo-desorption coefficient (η), the efficiency with which impinging photons liberate gas molecules which contribute to vacuum system pressure. Based on the works

of Gröbner, Halama, and others, a reasonable photo-desorption rate for a copper vacuum chamber was taken to be 2×10^{-6} molecules per photon (N_2 equivalent) in the HER. This value is significantly lower than has previously been used in storage ring design. A test program was carried out at the NSLS facility at the Brookhaven National Laboratory by C. Foerster, M. Calderon, et al.[6] to confirm the validity of this assumed value. A series of copper samples, from various manufacturers and with various pre-treatments, was exposed to photon beams in the VUV (0.5 keV, 110 mrad) beam line, and the rates of photo-desorption were measured for photon doses up to 10^{23} photons per meter. These measurements confirm that the assumed η value of 2×10^{-6} molecules per photon is a conservative design value for a high-current machine such as PEP-II. In order to confirm our chemical cleaning and fabrication techniques, a test vacuum chamber was fabricated using the planned techniques and installed in the beam line at NSLS for photodesorption testing. Subsequent measurements verified that our surface preparations were acceptable, and that our fabrication techniques would not degrade the prepared vacuum surfaces.

4.3 Vacuum Chamber Materials

Given the design requirements and engineering problems discussed above, the choice of material for the vacuum chambers is of critical importance. A number of materials were considered, and studies were carried out to evaluate conformance to engineering requirements, ease of fabrication, costs, etc. Based on a cost-benefit analysis, OF copper alloy C10100 in a half-hard temper has been chosen for the arc vacuum chambers in both the HER and LER. Copper gives excellent heat conductivity, a low photo-desorption coefficient, and good radiation shielding. A half-hard copper-phosphorous alloy C10300 was chosen for the cooling bar for its ease of fabrication of this non-vacuum part. Our engineering evaluation shows that OF copper will meet our requirements while giving the lowest measured photo-desorption coefficient. Despite its low cost and ease of fabrication, aluminum was ruled out as we believe that aluminum will not

reach a sufficiently low rate of photo-desorption in an acceptable commissioning time. Further, calculated thermal stresses in the chamber wall from synchrotron radiation were significantly higher than for copper and were unacceptably close to the fatigue limit. A stainless steel chamber with brazed copper synchrotron radiation absorber was also ruled out, as the skin resistivity of the stainless steel was too high. (Calculations showed that, as a result, a beam instability developed after only a small number of beam orbits in the storage ring.) Several methods were evaluated for coating a stainless steel vacuum chamber inner surface with a more conductive material — copper plating, a brazed copper liner, and copper clad stainless steel. Cost estimates show that, for our system requirements, the cost to procure high quality stainless steel with low magnetic permeability and to coat it with copper in a way consistent with stringent UHV requirements is more expensive than to fabricate a copper chamber.

Vacuum flanges for interconnecting chambers, bellows, etc. will be fabricated from 316LN stainless steel in order to minimize magnetic permeability and allow for the option of brazing flange sub-assemblies at reasonably high temperatures (up to about 1000° C). As noted above, stainless steel tubing in a 304 or 316 alloy will be used for the vacuum chambers in the 120 m straight sections, and masks will be made from a dispersion hardened copper such as GLIDCOP®.

4.4 Vacuum Chamber Fabrication

The choice of copper for our chamber material dictates the development of new fabrication methods. The only large accelerator in the world with copper vacuum chambers is HERA at the DESY Laboratory in Hamburg, Germany. The engineering requirements of PEP-II are sufficiently different that the methods pioneered with such success at DESY will not work for us. An extensive research and testing program has been carried out to develop cost effective fabrication methods that will result in an acceptable vacuum chamber design. It is critical that our fabrication technique not anneal the copper, so that the inherent material

strength in the vacuum chamber walls is retained. All of our fabrication steps must be carried out in strict conformity to the need for UHV clean chambers. Various fabrication techniques to obtain the desired shape were explored— roll-forming, break press forming, and extruding. A number of joining techniques were also evaluated, such as brazing, TIG welding, electron-beam welding, and diffusion bonding. As a result of these studies, a fabrication scenario has been developed that calls for an extruded copper vacuum chamber joined via a combination of TIG and electron-beam welding of major components, with hydrogen furnace brazing of sub-assemblies. Critical factors in this scenario have been identified, and thorough prototype testing is in progress to confirm our fabrication plans.

- A. Prototype extrusions have been ordered for evaluation. These will undergo chemical analysis and mechanical tests, then be used in fabrication of full-size prototype vacuum chambers.
- B. Chamber bending tests were performed to optimize a technique for forming the bend magnet vacuum chamber to the required 165 m radius. Several methods have been tested. The vacuum chamber cross section is quite broad and presents considerable resistance to forming. Rolling of the chamber with a 3-roll device failed, as the force required to form the chamber was greater than the strength of the chamber wall, and the wall buckled. A pin-press technique was successfully employed whereby a hydraulic cylinder applied force opposite two fixed supports. Three 30 cm “shoes” were used to distribute the forming force more evenly along the length of the wall. The chamber was given a series of small bends along its length to approximate a smooth radius. While successful, this was a time consuming, trial and error technique. Also, the chamber had to be significantly over bent and allowed to spring back to the desired radius. The resulting residual stresses were felt to be undesirably high. The third method tested (Fig. 5), the technique expected to be employed for PEP-II production, is stretch-forming. The bend vacuum chamber is pulled by its ends and stretched uniformly until the copper reaches its yield point.

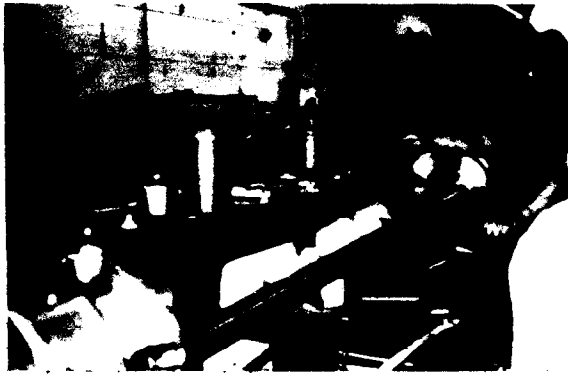


Fig. 5. Photo of a prototype HER bend chamber during stretch bending.

While in this condition, very little lateral force is required to form the chamber. The chamber is moved laterally and formed against an aluminum mandrel pre-shaped with a 165 m radius. There is very little spring-back, so residual stresses are low. Further, residual stresses from previous electron beam welding of the cooling bar are also relieved. The result is a relatively stress-free chamber accurately formed to the required radius. This technique can be readily employed on a production basis.

- C. Tests of electron-beam welding the cooling bar to the beam chamber have been successfully completed. Further testing will be done during prototype chamber fabrication to optimize weld parameters.
- D. Tests are in progress to develop techniques for reliably TIG welding stainless steel vacuum flanges directly to the extruded copper chamber body. Preliminary testing has been completed with considerable success, and more detailed testing is underway.

4.5 DIP Screen Installation and Attachment

One of the critical factors in the present bend vacuum chamber design is the distributed ion pump screen. This screen is required to maintain a low impedance in the beam passage, prevent ions from the ion pump and the pump electrical field from affecting the beam, yet allow high transmission probability of gas molecules into the DIP. An effective compromise between these important but conflicting requirements is necessary, as the DIP pumping speed is the dominant factor in achieving the desired vacuum pressures in the arc regions.

Some higher-order-mode heating is expected in the DIP screen as well as heating from reflected synchrotron radiation power. Reasonable thermal contact is thus required to conduct this heat out to the chamber walls. Once the screen is mechanically installed, full chemical cleaning of the chamber is impossible due to trapped volumes. The screen must therefore be installed in a UHV clean condition. We expect considerable resistance to sliding as the screen is installed into the chamber body. A series of tests is now under way to install the screen in the 6 m bend chamber and to attach the screen to the vacuum chamber walls.

4.6 HOM Impedance Testing

Beam impedance is an important factor in the design of PEP-II vacuum chambers. In order to verify that we are adhering to our calculated impedance budget, testing is being done at the Lawrence Berkeley Laboratory (LBL). Sample lengths of vacuum components such as bellows, a bend chamber with DIP screen, beam position monitor, etc. have been fabricated. These are installed in a test fixture with a wire through the center of the chamber and excited at various frequencies by an RF generator. The response is measured and compared to a reference length of smooth chamber to approximate the specific energy loss for that section. A representative section of each PEP-II vacuum component will be tested in this fashion.

4.7 Distributed Ion Pump Testing

As mentioned above, the pumping speed of the bend chamber distributed ion pump is the dominant factor in achieving the desired vacuum pressure in the arc regions. Our desire for high pumping speed requires that we install as many cells as will fit in the space available. A detailed design study has been completed [7,8], using the relations of Hartwig and Kouptsidis, which indicates that that our pumping speed goal of 165 l/s/m is reasonable. This value will be tested in a series of pump speed measurements planned at the Lawrence Livermore Laboratory (LLNL) during early 1993. Pump modules and test vacuum chambers are now in fabrication and a test facility is being prepared.

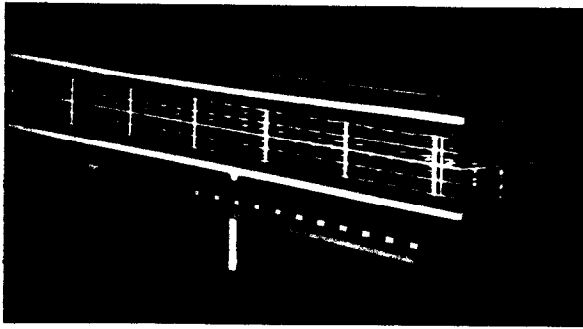


Fig. 6 Model of HER distributed ion pump.

A series of ion pump modules with varying design features will be tested to optimize our design for maximum pump speed. The parallel plate anode design shown in Fig. 6 was chosen over the more traditional tubular cell anode used in PEP-I. While fewer pumping cells can be installed in a plate design, calculations show that the increased conductance of gas into the pump more than compensates for the lost cells and results in a higher net pumping speed. Pure titanium will be used for the cathodes, while both stainless steel and titanium will be tested for the anodes. The pumping speed of a similarly sized tube-type anode will also be measured for comparison.

4.8 Flexible Bellows

A flexible bellows is required in the PEP-II vacuum system to allow for tolerances in fabrication and alignment, and to provide compliance for thermal growth. The high stored beam current in PEP-II requires a shield inside of the bellows section to give a low impedance in the beam passage and minimize higher-order-mode heating in the bellows while still allowing flexibility in the assembled unit. A number of shielded bellows designs are successfully in use at various accelerators worldwide, but at considerably lower beam currents than PEP-II. Our plan is to extrapolate an existing concept for use at the high PEP-II beam current. We evaluated bellows designs from many laboratories, including the PEP-I design. Our most promising design concept is an adaptation of the bellows screen used in LEP. A stainless steel bellows is TIG welded to stainless steel adapter rings which are brazed to the copper beam chamber. The beryllium-cop-

per screen is fixed rigidly at one end with the opposite end free to slide in the beam direction. The screen is slit in the beam direction to make "fingers" which give the screen flexibility and allow transverse movement. An extension spring around the free ends of the fingers maintains contact between the fingers and the wall to insure acceptable ground contact. A mask brazed into the up beam end of the bellows assembly absorbs synchrotron radiation that would otherwise strike the bellows screen and vacuum flange. Computer simulations of impedance have been performed, and impedance test models are in fabrication for testing at LBL this winter. Based on these preliminary tests, several full prototypes will be fabricated for extensive impedance and lifetime tests under simulated operational conditions.

4.9 Beam Position Monitor

Approximately 150 beam position monitors will be installed in each PEP-II storage ring, 96 in each arc, with the remainder in the straight sections and interaction region. A number of beam position monitor designs are successfully used at various accelerators worldwide. Again, our plan is to extrapolate a proven concept for use in PEP-II. We evaluated many beam position monitor designs from SLAC and other laboratories. The design we have chosen is based on a beam position monitor feedthrough concept used in ELETTRA, ESRF, APS, and other machines. Small lateral ports will be welded into the quadrupole chamber, and the feedthrough will be connected to the quadrupole chamber by miniConflat-type flanges. The mini-flange mounted feedthrough assembly integrates a ceramic insulator, a one centimeter diameter metallic active button, and a type-N connector in an electrically smooth 50 Ω unit. Prototype feedthroughs are on order from two manufacturers for bench tests this winter. A preliminary prototype will be installed in the SLAC linac for tests with electron and positron beams.

5. FUTURE RESEARCH AND DEVELOPMENT ACTIVITIES

The goal of our vacuum system R&D activities is to be ready to begin production of the HER vacuum system in October, 1993. We will continue to work on the LER and IR vacuum systems, but the HER vacuum system will be our prime focus. As designs for the standard vacuum chambers are finalized, we will begin to look at machine diagnostics such as optical monitors, beam current monitors, etc. One of our highest priorities will be to complete the DIP pumping speed measurements and our photo-desorption testing so that the HER vacuum pumping configuration can be finalized. Completion of our fabrication tests will allow us to finalize arc chamber fabrication plans and build full-size prototype vacuum chambers. With the completion of beam position monitor and bellows development, we will assemble prototype arc chambers in the PEP-II arc cell mockup. This will allow us to check clearances with magnets and supports as well as provide a check of tooling and procedures for installation and alignment. As a final verification of our designs, we will perform in situ mechanical testing such as natural frequency response, chamber and support response to heating, and measurements of DIP speed in an extruded copper chamber.

6. SUMMARY

A conservative vacuum system design for the PEP-II arcs is nearing completion. Critical factors in the design and fabrication have been identified for R&D evaluation. Each of those critical factors has been studied, design solutions found, and testing is now in progress to confirm our solutions. Based on these tests, our designs will be optimized to insure proper function and system reliability. Prototype vacuum chambers will then be fabricated and installed in the PEP-II arc cell mockup to verify our design solutions.

ACKNOWLEDGMENTS

The author wishes to acknowledge the many people, too numerous to list, who have contributed to the PEP-II vacuum system and whose creative talents have developed the vacuum system design presented herein.

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