

APS Storage Ring Vacuum System Development*

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Abstract

The Advanced Photon Source synchrotron radiation facility, under construction at the Argonne National Laboratory, incorporates a large ring for the storage of 7 GeV positrons for the generation of photon beams for the facility's materials research program. The Storage Ring's 1104 m circumference is divided into 40 sectors which contain vacuum, beam transport, control, rf and insertion device systems. The vacuum system will operate at a pressure of 1 nTorr and is fabricated from aluminum. The system includes distributed NeG pumping, photon absorbers with lumped pumping, beam position monitors, vacuum diagnostics and valving. An overview of the vacuum system design and details of selected development program results are presented.

I. INTRODUCTION

The Advanced Photon Source (APS) incorporates a 7-GeV positron storage ring, 1104 m in circumference. The storage ring vacuum system is designed to maintain a pressure of 1 nTorr or less with a circulating current of 300 mA to enable minimum beam lifetimes of 10 hours.[1,2] The system employs Non-evaporable Getter (NeG) strips as the primary source of distributed pumping. Lumped NeG modules and/or ion pumps are employed at photon absorber locations.

The design effort has been augmented by an extensive development program for the evaluation of component and subsystem performance.

II. DESIGN

A. Storage Ring Sectors

The storage ring is divided into forty 27.6 m long sectors. Each sector consists of 6 sections, 5 of which are for beam transport with the other section containing either rf, diagnostics, injection, abort or insertion devices. A total of 69 experimental area photon beams are possible, 34 generated by insertion devices and 35 by bending magnets.

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B. Vacuum Chamber

The chamber consists of three regions, the positron beam chamber, the pump antechamber, and the photon beam channel which connects them. The antechamber entraps the outgassing that permeates from the absorber locations. High-speed antechamber NeG pumping assures efficient removal of both photon and thermal desorbed gases.

The chamber is a 6063 T5 aluminum extrusion. It contains water passages for cooling and bakeout. The extrusions are chemically processed after machining and prior to welding to provide a clean vacuum surface. The 2219 aluminum end flanges, photon exit port blocks and UHV joint flanges are joined to the chamber extrusions with full penetration weldments. These exacting weldments are done with computer-controlled TIG welding machines.

C. Vacuum Chamber Supports

Three supports are used per section. One support is rigid and serves as an anchor. The other two supports are leaf springs permitting chamber thermal expansion during the vacuum bake cycle. The chambers are free to thermally expand with negligible forces placed on them. The support system ensures that the chambers are not stressed significantly and return to their original location, size, shape and geometry.

D. Photon Absorbers

Non-experimental area synchrotron radiation is absorbed by photon absorbers to control the number of photons striking the vacuum chamber surfaces. The curved chambers include crotch photon absorbers and pumps at their ends. The straight chambers contain downstream end absorbers and pumps. The largest gas desorption loads are located at the absorbers and are pumped locally by high capacity pumps. Photon absorber details are presented in a companion paper at this conference.[3]

E. Pumping

Non-evaporable Getter (NeG) constantan strips are the primary source of distributed pumping. The NeG is a constantan strip coated with an alloy of Zr V Fe. This alloy forms thermally stable chemical compounds with most of the

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active gases (O_2 , N_2 , CO and CO_2), while the absorption of H_2 is thermally reversible. To become effective as a pump, the strip is activated by heating after pumpdown.

Lumped pumps are installed at photon absorber locations to pump the desorbed gas loads. The NeG strips do not pump CH_4 and noble gases such as Ar and He, therefore, ion pumps are required.

For initial pumpdown, oil-free pumps evacuate the system to turbomolecular pump starting pressure. Turbomolecular pumps further reduce the pressure to ion pump starting pressure.

F. Valving

The storage ring is equipped with valving for both transient and steady-state operations. The valves are of all metal construction, contain no organic materials and are bakeable to $300^\circ C$. Each sector is equipped with two ring isolation rf gate valves which have a valve open geometry identical to the elliptical shape of the vacuum chamber and include rf contacts that maintain electrical continuity between the valve and its mating connections. Each experimental area beam line is equipped with an isolation gate valve. Each sector is equipped with two right angle pumpdown isolation valves.

G. Bellows

Bellows are installed between storage ring sections and between the storage ring and the experimental area beamlines. The bellows are required for installation, alignment flexibility, operations and bake thermal motion. The bellows are formed as non-magnetic stainless steel with stainless steel flanges. The positron beam chamber bellows are equipped with rf liners to replicate the rf impedance of the elliptical beam chamber.

H. Flanges & Seals

Flanges welded to the storage ring chamber are aluminum Conflat flanges. The flanges incorporate an aluminum seal.

I. Monitoring

Ionization gauges are distributed around the storage ring. Since the ion pumps are situated in areas of highest desorption rates, their currents, i.e., pressures, are monitored continuously. Gas analyzers, strategically placed around the ring, monitor residual gas composition. High-pressure gauges are installed in each sector to shut down the NeG power supplies in the event of a vacuum failure during activation and conditioning periods.

J. Special Features

Transition connections are installed in the positron beam channel between the storage ring and insertion device

vacuum chambers. These connections provide a gradual rf transition between two chambers having different cross sections. The transitions are water cooled to absorb photon wall interaction heat loads and may incorporate NeG pumping to absorb a portion of local photon induced desorption gas loads.

Special chambers for beam injection, abort and accelerator diagnostics will be incorporated in the storage ring. The designs of these chambers are being developed.

III. DEVELOPMENT

A. Cleaning

An x-ray photoemission spectroscopic study of the vacuum chamber surface cleanliness was undertaken to determine whether water based lubricants could be used for extrusion machining. The study determined that the selected cleaning procedure adequately removes any lubricant residue. Machining with water based lubricants will reduce machining time and lower costs.

A study has determined that the 2219 aluminum components can be cleaned using detergents rather than solvents. As a result, the cleaning facility safety and environmental measures and solutions reclamation costs will be reduced.

B. Chamber Construction

Vacuum chamber construction requires the successful integration of several process technologies, which include extruding, forming, machining, cleaning, welding, inspection and vacuum testing.[4] The development program considered each of these and conducted trials in order to establish the validity of procedures. The information obtained is transferred to the individual fabrication steps, and will be combined with efficient work flow patterns and resource management to produce chamber sections to performance specifications.

Extruding. Aluminum was selected for the chamber sections, in part because it can be economically extruded and machined. The geometry and tolerances of the vacuum chamber demanded precise extruding dies and close process control. Chamber sections were successfully extruded and evaluated for dimensional and material quality.

Forming. After extruding and prior to machining, the bending magnet sections are formed to a 38.96 m radius. Forming is accomplished using standard shop equipment. The photon beam channel gap is reduced during forming, requiring a subsequent pressurizing of the interior of the extrusion to expand to the specified dimension.

Machining. The vacuum chamber sections have a substantial amount of weld joints preparation machining. The sequence of fabrication is unusual in that no machining is done after welding. Final dimensions and position accuracies must be maintained during the welding operation. This requires a high degree of machining precision.

Development provided machining sequences and tooling necessary to maintain critical chamber geometry dimensions.

Cleaning. Cleaning is required prior to welding to remove all residue from machining and handling and to remove oxide layers on the vacuum and weld joint surfaces. Degreasers and an etchant were used to clean the 6063 aluminum extrusion, while the 2219 aluminum components were cleaned with solvents.

Welding. Aluminum joining is done with TIG welding. The vacuum and rf requirements imposed upon the weld joints, combined with the contoured weld joint geometry, were evaluated. Two material combinations were studied, 6063 to 2219 aluminum, and 2219 to 2219 aluminum. A substantial effort was required to determine weld program parameters necessary to produce repeatable results. Specific tooling and procedures were developed to maintain critical chamber dimensions.

Inspection and Testing. Inspection of prototype vacuum chambers after welding was limited to verification of major overall dimensions. Some inspection of critical tolerances was performed on the weld coupon samples, as proper inspection equipment was not available during this phase of the development program. This was sufficient, however, to qualify the tooling and procedures used during machining and welding.

C. Chamber UHV Joint Performance

The performance of chamber UHV joints was studied extensively. The details of these evaluations are presented in a companion paper at this conference.[5]

D. Chamber Vacuum Performance

Individual chamber vacuum performance evaluations were made. The sections were assembled with storage ring instrumentation and diagnostic equipment. The sections were roughed with a turbomolecular pump and 150°C baked, using heating tapes, with the turbo-molecular pumping until the pressure stabilized, generally after 25 to 36 hours. At that point, the instrumentation was outgassed before cooldown commenced and the NeG strips were activated. An ultimate pressure of 3×10^{-11} Torr was achieved, the x-ray limit of the ion gauge was reached, so the pressure was also measured with an extractor gauge suitable for pressures down to 1×10^{-12} Torr. The pressure was confirmed to be 3×10^{-11} Torr.

Evaluations are currently underway with the full development sector sections connected together. Included are assembly and installation procedures, pumpdown, bakeout, alignment stability and base pressure.

E. Alignment Thermal Stability

The dimensional stability of the vacuum chamber sections: i.e., beam position monitor locations and their supports, with respect to bake cycles, was evaluated. The sections were instrumented to monitor temperature, fluid

flow, fluid pressure and position. Stability tests were initially conducted on two sections connected in series. The results indicate a position stability of $\pm 25 \mu\text{m}$. Subsequent tests consider five sections joined together as a full sector.

F. Photon Absorbers

Evaluations of the design, construction and performance of photon absorbers is underway. The details of these evaluations are presented in a companion paper at this conference.[3]

IV. CONCLUSIONS

The design of the APS Storage Ring Vacuum System is well advanced. The ongoing development program provides verification of design assumptions and carries out performance measurements of components and subsystems. Development program results indicate the suitability of the design for construction.

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