VACUUM SYSTEM FOR THE SYNCHROTRON X-RAY SOURCE AT ARGONNE*

R. Wehrle, J. Moenich, S. Kim, and R. Nielsen
Argonne National Laboratory
9700 S. Cass Avenue
Argonne, IL 60439-4814

Abstract: The vacuum system of the APS storage ring is designed to maintain a beam-on operating pressure of 1 nTorr or less in order to achieve a positron beam lifetime of approximately 20 hours. The vacuum chamber is an aluminum extrusion containing a beam chamber and antechamber. The primary source of the pumping is with NeG strips. The design and location of the crotches and strip absorbers are based on the distribution of the bending magnet synchrotron radiations.

Introduction

The Advanced Photon Source (APS) features a positron storage ring approximately 1060 m in circumference. The vacuum chamber for the storage ring requires a beam-on operating pressure of 1 nTorr or less to achieve a beam lifetime of approximately 20 hours. The vacuum system to attain these pressures is described for the case of the highest synchrotron radiation at a positron energy of 7 GeV and a current of 300 mA. The descriptions of photon absorbers and the vacuum system elements placed for the optimum pumping efficiency are included. Based on the distribution of the photon radiation depositions within the vacuum chamber, vacuum pressure variations along the chamber are analyzed.

Vacuum Chamber

The cross-sectional view of the aluminum vacuum chamber is shown in Fig. 1. The chamber consists of two main parts, positron beam aperture and antechamber, which are connected by a gap of 10 mm.

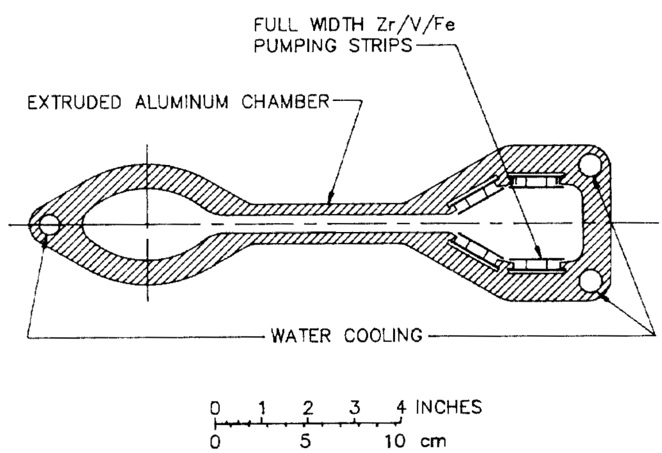

Fig. 1. Vacuum chamber cross-section.

This gap is wide enough for low energy synchrotron radiation to go through to the antechamber and narrow enough so that the rf leakage is negligible. The outside dimension of the chamber varies somewhat depending on its location in the storage ring lattice. The antechamber is shown with the non-evaporable getter (NeG) strips in place. The NeG strips are the primary pumping source of the storage ring and they pump at room temperature. The antechamber entraps the outgassing that permeates from the absorber locations. The high speed pumping in the antechamber assures efficient removal of both photon and thermal desorbed gases. The enlarged cross-section of the antechamber improves the conductance of locally desorbed gases to the pumping surface of the NeG pumps. Details of the NeG strip are described in Ref. [1].

The vacuum chamber in Fig. 1 also contains cooling channels. Bake-out of the chamber is achieved by disconnecting the cooling circuit from the main water system and connecting it to mobile water heating units which bring the temperature of the chamber up to 150°C. Bake-out by this procedure results in uniform temperature with a minimum risk of overheating. The chamber is thermally insulated with a 2-mm thickness of Kapton films. The ion pumps, gauges, valves and bellows are baked using electrical heating tapes.

Ion pumps are located in areas of highest desorption rate, and their currents are monitored continuously, which should provide adequate pressure measurements down to 1 nTorr. Ionization gauges installed in the vacuum chambers may not all need to be monitored simultaneously. Gas analyzers, strategically placed around the ring and connected to the central computer control system, are used to monitor the composition of the residual gas. Electrical power for the NeG strip during activation or conditioning is turned off automatically to prevent NeG strip damage should high pressure conditions occur. Portable sorption pumps and mobile turbo-molecular pumping stations are used for initial pumpdown from atmosphere.

Sector Storage Ring Vacuum System

A 26.5-m long sector of the storage ring is shown in Fig. 2. It identifies bending magnets, crotches, absorbers, and end wall strip absorbers. The straight section (SS) is provided at each end of the sector. The vacuum chamber dimensions for the SS are different from the cross-section shown in Fig. 1, and depend on the use of insertion devices[2] or rf cavities. The chambers of one sector excluding the SS part is made of three straight and two curved lengths. The length of each chamber is determined from the consideration of lattice design and for the accomodation of vacuum components. For an efficient use of the sector space the vacuum chamber contains integral distributed NeG strip pumps in the antechamber. This scheme does not impinge on the space requirements for magnets and other components. The largest gas desorption loads are located at the photon absorbers and must be pumped by local high capacity pumps.

The crotch absorbers bridge the gap between the positron beam and the photon beam lines, and absorb most of the synchrotron radiation from the preceeding bend magnet. Consequently most of the gases are desorbed within the same regions. The end

*This work is supported by the U. S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

CH2387-9/87/0000-1669 $1.00 © IEEE
PAC 1987

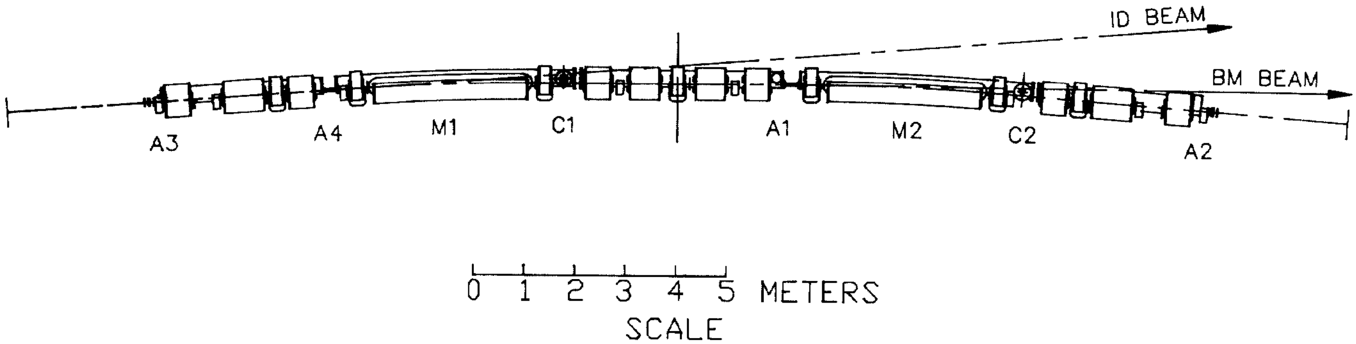

Fig. 2. Storage ring sector with bending magnets M1 and M2, crotch absorbers C1 and C2, and end wall absorbers A1 through A4.

wall strip absorbers downstream of the crotches then absorb the remaining photons thus desorbing gases in those immediate areas as well. Large ion and NeG modular getter pumps are mounted directly above and below the areas to capture the bulk of the gases as they are generated. Also appreciable amounts of these and other photon desorbed and thermal desorbed gases permeate within the chamber and are subsequently pumped by the distributed NeG strip pumps in the antechamber.

The use of integrated ion pumps is impractical in the storage ring because only 18% of the ring is occupied with bending magnets. This is why the vacuum system relies on the NeG strips as the primary source of distributed pumping in both the bending magnets and straight sections and in the lumped NeG modular pumps at the crotch and end wall locations. The lumped ion pumps are also used in these latter locations because the NeG pumps do not pump the noble or organic gases which occur in relatively small quantities.

Photon-Induced Desorption

The synchrotron radiation power from one bending magnet is 20.5 kW, which results in a total photon flux for the 7-GeV storage ring 1.82 x 10^{-21} photons/s. The photon-induced outgassing rate is given by $2n^{\circ}(\eta\gamma)K$,[3] where $K = 3.11 \times 10^{-20}$ Torr·ℓ/mol, n° = number of photons/s, and $\eta\gamma = 2 \times 10^{-7}$ mol/photon after 150 Ah of bombardment. The total photon desorption gas load for the storage ring is therefore 2.26×10^{-5} Torr·ℓ/s. In addition the thermal outgassing load of the chamber, 1.4×10^{-5} Torr·ℓ/s, makes the total gas load of 3.66×10^{-5} Torr·ℓ/sec. The thermal outgassing of the chamber is estimated from a unit outgassing value of 3×10^{-12} Torr·ℓ/sec/cm^2. The synchrotron-radiation-related gas-load distribution is based on the percentage of photons intercepted by the crotch and end wall strip absorbers downstream of the bending magnet from which the photons originated.

Figure 2 shows the typical area immediately following dipole magnet M1. The crotch absorber C1 is shown in place just downstream of the dipole magnet. It is positioned so as to intercept the maximum fraction of the synchrotron radiation from M1 without interruption to experimental requirements or interference with the positron beam steering. In each sector about 65% of the radiation from M1 is intercepted by the crotch (C1) at the exit of the M1 dipole, about 54% of the M2 radiation by the crotch (C2) at the exit of the M2 dipole. A water-cooled end wall strip absorber (A1) is located in front of M2 and absorbs 25% of the M1 radiation. Another water-cooled end wall absorber (A2) at the beginning of the insertion straight section absorbs 22% of the M2 radiation. The small fraction of the M2 radiation that bypasses the crotches and absorbers is picked-up by the crotches in the following sector. Fig. 3 shows these relative values.

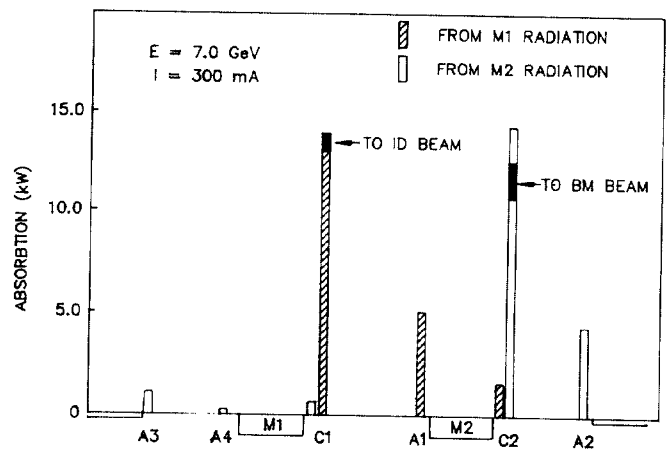

Fig. 3. Photon absorption distribution.

Figure 4 shows the water-cooled crotch absorber with lumped modular NeG and ion pumps typical of C1 and C2. With the small bending angle per dipole, localized absorption of synchrotron radiation on the crotches occurs. With localized absorption, the total surface that needs to be cleaned to minimize outgassing by synchrotron radiation is greatly reduced.

Vacuum Chamber Pumping Impedance and Pressures

The irregular distribution of synchrotron radiation, hence outgassing rate, around the storage ring, and the variation of vacuum impedances due to changes in chamber cross section complicate the determination of pressure gradients around the chamber. A computer program was developed for finite element analysis of the vacuum system. By dividing the unit sector of the vacuum system into 26 elements, conductance, pumping speed, and thermal and photon desorptions after 150 Ah were calculated.

Figure 5 illustrates the expected pressure gradient through each cell as given by the program. The curves show typical pressures after 1 Ah, 10 Ah and 100 Ah of pumpdown following the initial beam conditioning pumpdown of 150 Ah followed by venting to atmosphere with dry N_2. The abundant pumping of the NeG strips in the antechamber sections is clearly

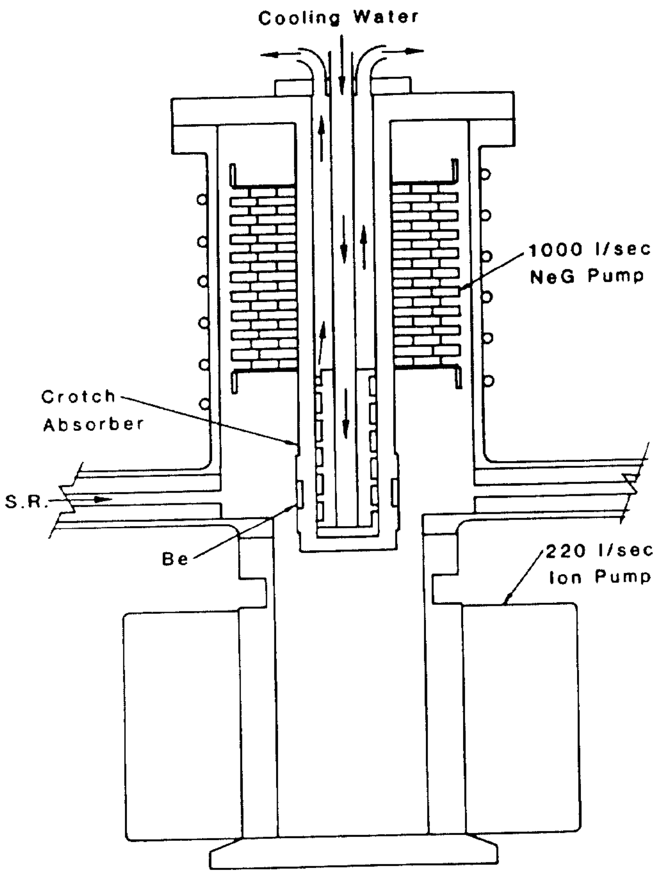

Fig. 4. Water cooled crotch absorber

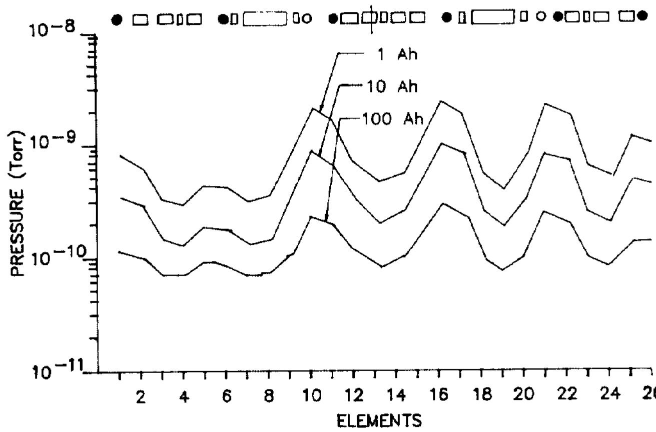

Fig. 5. Finite element analysis of pressure gradient.

evident in the pressures below 0.1 nTorr. This distributed NeG pumping and conductance of the chamber cross-section also contribute to the achievement of pressures in the low 0.1 nTorr region in the crotch and strip photon absorber sections.

References

[1] R. Nielsen, J. Moenich, and R. Wehrle, "Vacuum Chamber Development for the Synchrotron X-Ray Source at Argonne," in these proceedings.

[2] S. Kim, R. Wehrle, and L. Genens, "Vacuum Chamber for an Undulator Straight Section," in these proceedings.

[3] S. Tazzari, "Synchrotron Radiation Distribution along the Vacuum Chamber," European Synchrotron Radiation Project Report, ESRP-IRM-32/84 (1984).