VACUUM SYSTEM OF THE APS: OPERATION EXPERIENCE AND STATUS REPORT*

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Abstract

There are 236 vacuum chambers and 23 special insertion device vacuum chambers installed at the Advanced Photon Source storage ring. Each is fabricated from an aluminum extrusion, followed by machining and welding. The standard vacuum chambers have a vertical aperture of 42 mm with a synchrotron radiation extraction channel of 10 mm, while 21 of the insertion device chambers have an 8 mm vertical aperture with an outside dimension of 10 mm, and two insertion device chambers have a 5 mm vertical aperture with an outside dimension of 8 mm. Minimum pole gap in the insertion devices is 10.5 mm and 8.5 mm, respectively.

The standard vacuum chambers are installed and aligned to ± 150 microns, while the insertion device chambers are aligned to ± 75 microns. All chambers have distributed NEG strip pumping, with ion pumps and lumped NEG pumps at locations of high gas loads, such as absorbers. During construction, all vacuum chambers were certified for use at 2 x 10^{-10} Torr. During operation, vacuum with 100 mA beam current is about 3 x 10^{-10} Torr. Without beam, vacuum is in the 10^{-11} Torr range. Both chamber types incorporate an antechamber design. The so-called "NEG dust" effect has not been observed. We have over five years of commissioning and operations experience at the APS, without any sign of aging of all the major components. Important design features and operations experience are discussed.

1 INTRODUCTION

The APS storage ring design goal was operation with a 7 GeV 100 mA positron beam with beam lifetime greater than 20 hours. The 1104 m circumference ring consists of 40 sectors, each sector having six vacuum chambers of an aluminum extrusion design [1]. Five of the six chambers are essentially of the same cross section, (Fig. 1), having a vertical aperture of 42 mm. The sixth chamber is an insertion device chamber with a vertical aperture of either 8 or 5 mm, shown in Fig. 2. In four places, the insertion device chamber space is taken up by the rf cavities, and a fifth location is devoted to the injection region. The chambers are connected by Inconel bellows assemblies having flexible beryllium copper fingers inside for the rf continuity.

* Supported by the US Department of Energy under contract No W-31-109-Eng-38.
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Each sector can be isolated by all-metal gate valves. Each of the aluminum vacuum chambers has a 220 l/sec ion pump and a 1000 l/s NEG cartridge pump at the location of a photon absorber. In addition, there are NEG strip assemblies installed at two locations in the antechamber region of the vacuum chamber, allowing for approximately 2000 m of NEG pumping.

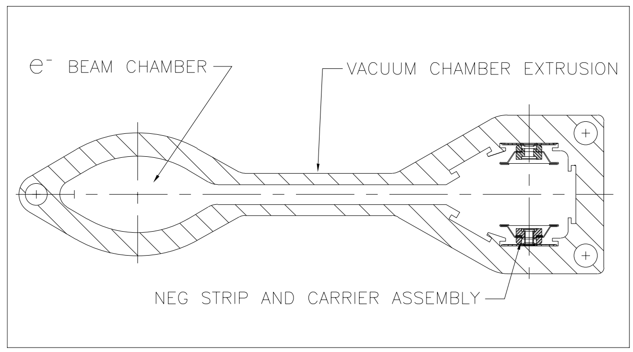

Figure 1: APS vacuum chamber cross section.

2 ID VACUUM CHAMBERS

Insertion device vacuum chambers (ID VC) with the vertical aperture for the beam of 5 or 8 mm have outside vertical dimensions of 8 or 10 mm, correspondingly [2]. The majority of all ID VC have an 8 mm aperture. Recently we designed and fabricated a 5 mm vacuum chamber with an outside dimension of 7 mm for the Swiss Light Source. All types of the ID VC have deflection under atmospheric pressure less than 100 microns per wall in the center of the aperture. The quality of all types of extrusion for the ID VC was very consistent. It allows us to have a wall thickness after machining of 1±0.1 mm. We were also able to achieve flatness of the VC installed on a three pillar support better than ±75 microns along the 5 meter length. As a result, the minimum operational pole gap in the insertion devices is only 0.5 mm larger than the outside dimension of the VC. One has to take into account that in this case the clearance between the pole tips and the VC itself is only 250 microns. This clearance has to be enough to accommodate all the mistakes in alignment of the VC and the ID itself and also provide room for the software stop, limit switch stop, and hard stop.

Each ID VC has two almost identical end boxes, which contain a tapered rf-transition from the ID VC aperture to the standard VC aperture, lumped 220 l/s NEG pump and 40 l/s ion-pump, photon absorber, feed-through for the activation of the distributed NEG strips, ports for rough pumping and vacuum diagnostic. Stainless steel end boxes are welded to the aluminum ID VC through the bimetallic wall (2219 AL alloy and 316L stainless steel) [2].

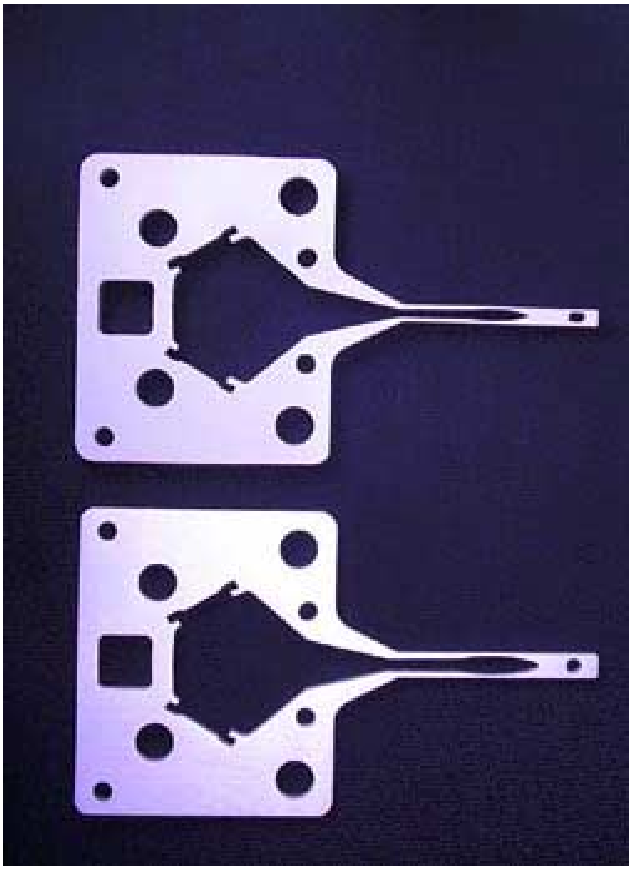

Figure 2: ID VC cross section.

We have not experienced leaks inside the bimetal joint since we started to use the explosion-bonded bimetal material provided by Atlas Technologies. All welding joints between the end boxes and the ID VC were made on a robotic welding machine. At each run, the welding program has been checked on the welding samples fully imitating the actual welding joint. The trickiest part of the whole welding procedure is to get full penetration and no underbead, which might block the beam aperture (Fig. 3). We have never experienced leaks in the welding joint of any ID VC installed in the storage ring.

All ID VC have four beam position monitors (BPM) – two on each end of the vacuum chamber – with a "Helicoflex"-type seal. These seals turned out to be the most sensitive components. Very careful hand polishing is required to avoid any cross scratches and to get a reliable vacuum joint. We also use Bellville springs under each screw to compensate for the differences in the thermo-expansion coefficients between the BPM body made of stainless steel and aluminum vacuum chamber itself.

We provided two possibilities to bake ID VC in situ – 1) using special heaters and blankets, or 2) using high-temperature pressurized water. Our experience shows that for ID VC the more convenient way is to use outside heaters and blankets. It is also easier to maintain the temperature gradient across the bimetal joint. The standard time for the baking cycle is about 7 days total, three days for the baking itself.

The three pillar support system allows us not only very precise alignment of the ID VC, but it is also very rigid and stable. We usually align the supporting brackets before baking and then finally align the ID VC after baking.

We have never noticed the so-called "NEG-dust" phenomena, described by ESRF [3]. One has to take in account that, during the commissioning stage, we replaced all NEG strips inside the storage ring vacuum chambers in situ so we might have produced enough dust during this procedure to induce this. Also, having an ID VC with a very small vertical aperture (less than 5 mm), we should have discovered this effect very quickly.

3 VACUUM SYSTEM PERFORMANCE

The first synchrotron radiation produced at the APS occurred in March 1995. Since that time, the facility has continued to meet user's needs with constant increases in scheduled user hours, x-ray availability, and delivered integrated beam current. There are currently 36 operating beam lines supplied by the storage ring. The machine was reconfigured in October 1998 to store electrons instead of positrons. The synchrotron radiation fan does not come into contact with the NEG strip assemblies in any of the chambers, and there has been no degradation in vacuum system performance over time. There has been no evidence of an "electron cloud" effect on beam lifetime during standard operations. The NEG strips have been activated only a few times, at initial chamber vacuum testing and certification, after installation and in situ bakeout, and after bakeouts following in situ vacuum components repair.

There are several reasons for this consistent level of vacuum performance. There are approximately 2400 UHV aluminum welds in the storage ring. The welding was done using automatic equipment and formal procedures. Combined with a simple cleaning procedure, chambers were certified for use at 2 x 10^{-10} Torr. There were no chambers rejected for use as a result of a welding defect.

There are approximately 1800 aluminum-to-stainless-steel flanged Conflat connections in the storage ring. These are for bellows assemblies between chambers, ion pumps, and vacuum gauges. The standard chambers are baked out if opened to atmosphere by a hot water bakeout system, providing circulating deionized water at 130°C. A procedure for monitoring and controlling the rate of temperature increase and decrease during a bakeout has been developed to accommodate the difference in the coefficient of thermal expansion between aluminum and stainless steel, providing a flange seal failure rate below 0.15% after baking.

The vacuum system is continuously monitored for problem areas. The machine areas are not accessible during normal operation periods (10-12 week duration). Vacuum system status is available via EPICS, the APS accelerator control system that includes a UNIX-based X-windows graphical user interface.

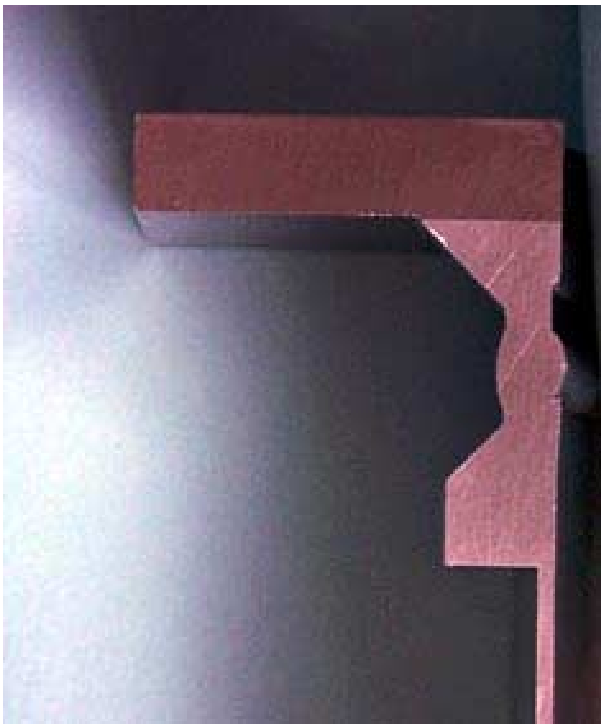

Figure 3: Welding joint between the ID VC and the end box.

Trend analysis by chamber or sector dictates possible remedial action during a subsequent maintenance period. In addition, the entire storage ring undergoes a manual leak check every year. Since January 1997, there have been 19 flange gasket leaks repaired (1% of the Conflat connections), 4 bad ion pumps (1.6% of ion pumps), and 1 bellows assembly replaced. No lumped NEG pumps or NEG strip assemblies have required replacement, and only chambers opened to atmosphere have required re-activation of NEG strips.

The average ring pressure without beam in March of 1999 was 8.0 x 10^{-11} Torr, while now without beam it is 7.6 x 10^{-11} Torr. The average ring pressure at this time with beam on is 2.7 x 10^{-10} Torr with 100 mA in the storage ring. The beam lifetime at 100 mA stored current is more complex because lifetime is a convolution of Touschek lifetime and residual gas scattering [4]. Touschek lifetime is the limiting factor now. Assuming an average pressure of 0.5 nT, beam lifetime is 200 hours approximately excluding Touschek, and approximately 20 hours with Touschek, with 100 mA in 27 bunches [5].

4 CONCLUSION

After six years of operating experience, the APS storage ring remains a reliable system, providing beam in excess of 5000 scheduled user hours per year, with system availability exceeding 95%. There has been no degradation of the vacuum system over this time, and the NEG pumping elements have performed well. In the near future, it is planned to replace all of the ion pump power supplies as a result of obsolescence of the existing power supplies.

5 REFERENCES

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