Journal of the Korean Vacuum Society
Vol. 1, No. 3, October 1992 pp. 336-340

〈연구논문〉

Performance of a Prototype Sector Chamber of the PLS Storage Ring

C.D. Park, Y.J. Han, H.J. Kim, H.S. Youn and W.C. Choi

Pohang Lignt Source Project, Pohang Accelator Lab.
Pohang Institute of Science and Technology
(Received September 7, 1992)

포항가속기 저장링 초도품 진공챔버에 대한 실험결과

박종도 · 한영진 · 김형종 · 윤화식 · 최우천

포항가속기연구소, 포항공과대학
(1992년 9월 7일 접수)

Abstract—A prototype sector vacuum chamber has been fabricated, assembled and tested for the purpose of predicting the performance of the vacuum system of the PLS storage ring. The chamber has been pumped by five combination pumps consisting of a 60 l/s sputter ion pump and non-evaporable getter module(s), and a 200 l/s turbomolecular pump for roughing. The pressure obtained is low 10^{-10} Torr which is the designed vacuum. After the chamber assembly and the vacuum system are briefly described, the performance of the vacuum system is presented.

요 약—포항가속기 저장링 진공시스템의 성능을 예견하기 위하여, 초도품 진공 챔버를 제작, 조립 및 테스트를 하였다. 비휘발성 흡착펌프와 이온펌프로 구성되어 있는 다섯대의 혼합펌프와 한대의 터보펌프를 사용하였다. 그 결과 낮은 10^{-10} Torr를 얻음으로서 설계된 진공도를 성취하였다.

1. Introduction

The 2 GeV Pohang Light Source(PLS) is a dedicated synchrotron radiation facility and is being at Pohang Accelator Laboratory. The PLS consists of a 2 Gev Linac as a full energy injetor and a 2 GeV electron storage ring with a circumferene of 280 m. The storage ring is made up of 24 sector vacuum chambers and 12 straight vacuum chambers. The PLS sector vacuum chambers will be made by machining two halves from aluminium plates and welding two halves together at the mid plane, while the straight chambers will be made by extrusion. The materials for the sector chambers and the straight chambers are Al 5083-H321 and Al 6063-T5, respectively. Details of the vacuum chamber design has been reported eslewhere[1].

A prototype sector vacuum chamber has been fabricated, assembled and tested in order to gain experience on product chamber fabrication. In this paper, the vacuum system of a prototype sector chamber designed to maintain a pressure of low 10^{-10} Torr is described. Then the assembly works and the test experences of the chamber are presented. The test results are discussed in terms of the pumping speed, the vacuum seals, the outgassing rate, and the ultimate pressure.

2. Vacuum System

The prototype sector chamber which is made by welding two machined aluminium plates, is about

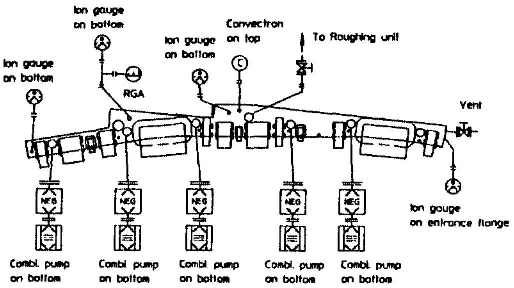

Fig. 1. Layout of a prototype sector vacuum chamber.

10 meters long. The total surface area of the chamber is approximately $6\times10^4\,cm^2$. A specific thermal outgassing rate of 5×10^{-12} Torr l/s/cm^2 is assumed. Then a total thermal gas load is 3×10^{-7} Torr l/s. Since the vacuum system for the sector chamber has been designed to maintain an average static pressure of low 10^{-10} Torr, the total pumping speed should be in the range of 2000 l/s. To achieve this ultra high vacuum(UHV), five combination pumps consisting of a 60 l/s sputter ion pump(SIP) and non-evaporable getter(NEG) module(s), and a 200 l/s turbomolecular pump are used. Fig. 1 shows the layout of the prototype sector chamber.

Vacuum monitoring is done by one convectron, three ion gauges, and five SIP current measurements. A convectron gauge is mounted to monitor the chamber pressure from atmosphere down to 1×10^{-4} Torr. Pressures in the ultra-high vacuum range are read with Bayard-Alpert ionization gauges. The ion pump currents are also monitored to see the local pressures. A residual gas analyzer is installed to monitor partial pressures.

Metal O-rings, so-called Helicoflex seals, are used between the aluminium vacuum chamber and stainless steel spools or aluminium blank off flanges. Vacuum components such as vacuum pumps and gauges are connected to sector chamber *via* spool pieces.

3. Chamber Assembly

After the two halves of the chamber were machined, a non-immersion chemical cleaning was carried out due to the large size of the chamber. The procedure used was : steam clean for oil

Table 1. PLS sector chamber assembly procedure

Production sector chamber delivered
Inspect, measure top and bottom pieces
Complete handwork as required
Chemical clean top and bottom pieces
Setup top and bottom pices for welding and weld them together
Weld exit port flanges
Install BPM's, valves, spools, photon stops and port covers
Perform leak test and install bakeout utility
Mount chamber on girder
Install remaining components and vacuum pumps
Rough down the chamber and leak test again
Vacuum bakeout for 24 hours at 150℃
Activate NEG pumps for 45 minitues at 450℃
Pump down while cooling down

removal, scrub the surface with alkaline cleaner, rinse with copious amounts of de-ionized water, and blow dry with liquid nitrogen boil-off.

The two halves were aligned together before welding to reduce alignment errors. The two halves were welded using a tungsten inert gas weld. End plates and flanges were then welded to the chamber.

Stainless steel spool pieces, aluminium blank off flanges, and vacuum valves were installed and leak tested with a detection limit of 1×10^{-10} Torr l/s for helium. The chamer was then installed on the girder using chamber supports. Finally, combination pumps, vacuum gauges, and roughing units were attached on the chamber and leak tested again.

It took about one month to assemble the chamber. However, the assembly time can be shortened for the production chambers. From these experiences, the assembly procedure for the production chambers

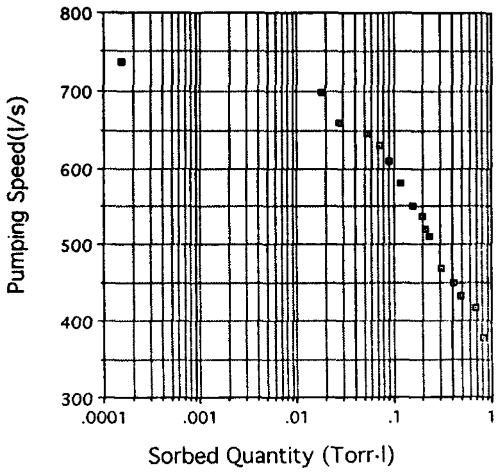

Fig. 2. Pumping speed with respect to the sorbed quantity for a gas mixture of 90% H_2 and 10% CO.

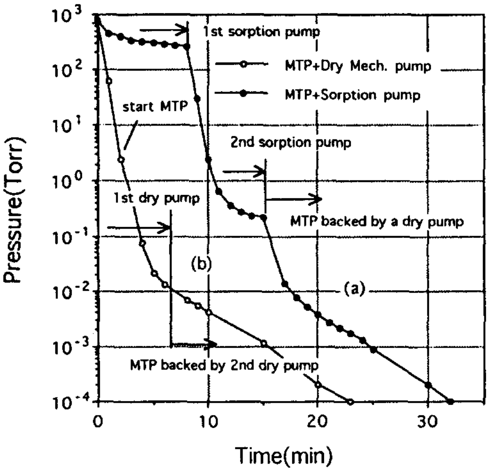

Fig. 3. Typical roughing down curves for a prototype chamber. (a) Roughing with a magnetically suspended turbo pump (MTP) backed by a two-stage sorption pump and (b) roughing with a MTP backed by a dry mechnical pump.

was set as shown in Table 1.

4. Vacuum Test and Performance

4.1. Pumping Speed of a Combination Pump

First of all, the pumping speed of a combination pump has been measured using a throughput method. The pump comprises a 60 1/s SIP and three NEG wafer modules (SAES, WP950). The measured initial pumping speeds of a combination pump are appromixately 1200 1/s and 500 1/s for hydrogen (H_2) and carbon monoxide (CO), respectively. The pumping speed for H_2 is almost constant because of H_2 diffusion into the bulk, while that for CO decrease rapidly as the NEG surfaces becomes saturated with sorbed gases. Since the real gas composition of an UHV system is H_2, H_2O, CO and CO_2, a gas mixture of 90% H_2 and 10% CO has been assumeed in order to estimate the pumping speed of a combination pump as a storage ring vacuum pump. In this case, the initial pumping speed is about 700 1/s for the gas mixture mentioned above as shown in Fig. 2. The pumping speed change with respect to the sorbed quantity is smiliar to that for CO. This indicates that the pumping speed depends on the CO sorbed quantity on the NEG surfaces which acts as a H_2 diffusion barrier.

4.2. Roughing and Bakeout

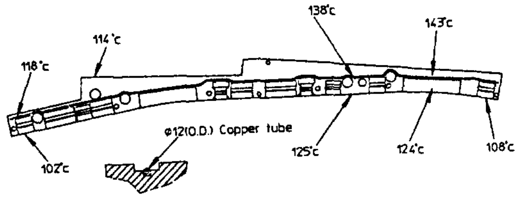

Fig. 4. Temperature distributions during 150℃ bakeout.

Roughing from the atmospheric pressure down to below 10^{-5} Torr was done by an oil-free pumping unit. The roughing unit used was a magnetically suspended turbomolecular pump(MTP) backed by either a two-stage sorption pump or a dry mechanical pump. Fig. 3 shows the typical roughing down curves. As shown in Fig. 3, the roughing cycle was completed in two stages; from atmospheric pressure to $\sim 10^{-1}$ Torr, and from $\sim 10^{-1}$ Torr to below 10^{-5} Torr. A 11 1/s dry mechnical pump or a sorption pump was used for pumping the chamber from the atmosphere pressure to 10^{-1} Torr, at which pressure a MTP started to pump down to below 10^{-5} Torr.

The vacuum chamber was vacuum-baked to 150℃ using pressurized hot water circulating through two copper tubes embedded on the top and bottom

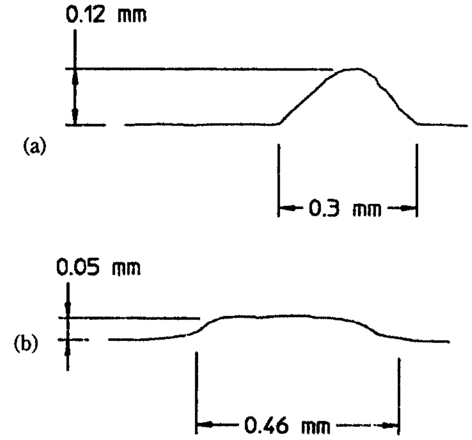

Fig. 5. Measured crossectional view of the knifé-edge of Helicoflex seals.

chamber surfaces. The temperature distributions without thermal insulators show the highest of 143℃ and the lowest of 102℃ as shown in Fig. 4. The temperature gradients were considered acceptable. During a bakeout, the chamber expanded 25 mm longitudinally and deflected 3.5 mm transversally at the end of the chamber. The thermal expansions or deflections at the end ,of the chamber were measured to redesign magnet pockets in order to prevent the chamber from interfering with magnets.

4.3. NEG Activation

In general, lumped NEG modules were activated at the end of bakeout. The chamber pressure was maintained less than 2×10^{-5} Torr during actvation. The time required for activation was typically 6 hours. The modules were connected each other in series to keep the current low and activated simultaneously with one big power supply. The current was set at 37 amperes to activate NEGs at 450℃. The temperature anywhere in the chamber during activation was kept below 150℃. This means no additional cooling is required.

4.4. Vacuum Seals

At the first test, the ultimate pressure obtained was 3×10^{-9} Torr. Air leaks through Helicoflex seals were found after bakeout. It turned out that Helicoflex seals used are defective. The cross-section of the knife-edge of Heicoflex seals (delta type) were measured and is shown in Fig. 5. The upper Helocoflex shows a clear knife-edge which is approximately 0.12 mm high and 0.3 mm wide. The seals with this profile proved to be leak-tight after several bakeouts. However, it would be necessary to bake out at least 10 times at 150℃ to insure the vacuum-tightness of the Helicoflex seals. The Helicoflex (b) has a bad knife-edge and developed leaks after bakeout. It is considered that the important parameters which affect the sealing performance are; the profile of the knife-edge, the material and pretrement of the inner spring which is directly related to a maximum bakeout temperature, and the roughness of the sealing surfaces. Various tests of Helicoflex seals are in process in order to get data for a proper vacuum sealing.

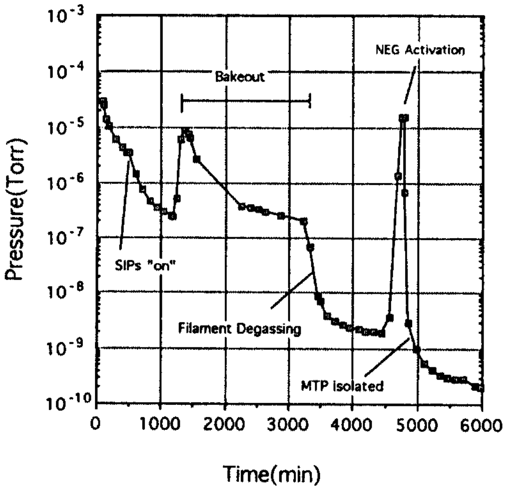

Fig. 6. Typical pumping down curve for a prototype sector chamber.

An alternative sealing method, using aluminium half nipples called Al-flanges instead of Helicoflex seals, is now being tested to minimize the use of Helicoflex seals. Aluminium half nipples with conflat flanges made of Al 2219 will be directly welded on the chamber where a small welding deformation is acceptable.

4.5. Outgassing Rate

After 20 hour pumping down following a bakeout at 125℃ for 30 hours, the hydrogen outgassing rate of the chamber was measured to be approximately 1×10^{-11} Torr l/s/cm^2 at the chamber pressure of

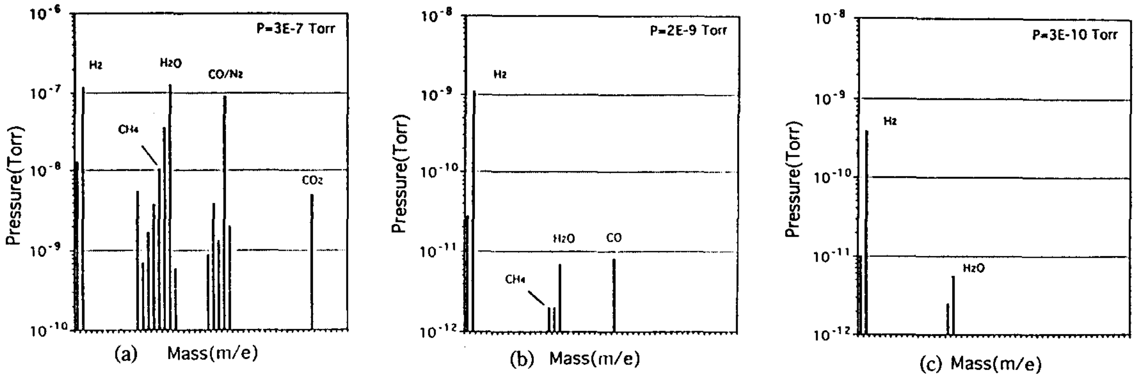

Fig. 7. Residual gas spectra obtained; (a) after 20 hour evacuation, (b) after 20 hour pimping down following a bakeout at 125℃, and (c) after 20 hour pumping following a NEG activation for 45 minitues at 450℃.

2×10^{-9} Torr. The measured value was based on achieving the pressure of 2×10^{-9} Torr using total pumping speed and the geometrical surface area. It is considered that this relatively high outgassing rate is due to the high outgassing of the chamber itself as well as insufficient bakeout temperature of the NEG modules. Various chemical cleaning methods are now being tried to lower the outgassing rate of the sector chamber. Precise measurements of the outgassing rate will be done using a throughput method.

4.6. Ultimate Pressure

The pressure variations and the residual gas compositions of the prototype chamber were measured at various pumping down stages. The typical pumping down curve is shown in Fig. 6. A vacuum bakeout of the chamber was carried out after 20 hour evacuation at which the pressure reached 3×10^{-7} Torr. Fig. 7(a) shows the residual gas spectrum that is typical for an unbaked vacuum system. The pressure with SIP alone reached 2×10^{-9} Torr after 20 hour pumping down following a bakeout. The residual gas spectrum shows the peaks corresponding to H_2, CH_4, H_2O and CO as usual for a baked UHV system. The NEG modules were then activated for 45 minitues at 450℃. The average pressure of 3×10^{-10} Torr obtained, after 20 hour pumping down following a NEG activation. The measurements were done using three Bayard-Alpert ion gauges. The difference between the pressure with NEG activated and that of without NEG shows the effectiveness of the combination pump. However the pressure with NEG modules alone increased to 1×10^{-8} Torr with a buildup of argone, methane and small amount of helium which can not be pumped by NEG modules. The residual gas spectrum (Fig. 7(c)) represents a clean vacuum system in which H_2 and H_2O are the only residual gases. Finally the ultimate pressure of the chamber reached 1×10^{-10} Torr with the combination pumps.

5. Conclusions

A prototype sector vacuum chamber for the PLS storage ring was fabricated and the performance of the vacuum system has been studied. The vacuum chamber had several problems, such as a vacuum sealing and the chamber deformations, and has been solved. The vacuum chamber has a relatively high outgassing rate which is the result of machining. An ultimate pressure of low 10^{-10} Torr has been achieved which is the designed vacuum. The preliminary test of an extruded Al 6063 vacuum chamber is now being done. In addition, the performance test of the chamber with/without a strip NEG or TSPs will be followed soon. The results of these experiments will be applied to the PLS production sector chambers.

References

1. C.K. Kim, K.H. Kil, W.C. Choi and S.Y. Park, *J. Kor. Vac. Sci.* V1(1), 24 (1992).