OPERATION EXPERIENCES FOR PLS VACUUM SYSTEM*

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Abstract

The ultra-high vacuum system of the PLS electron storage ring was successfully commissioned in July 1995. Since then, it routinely provides a dynamic pressure of about 7×10^{-10} Torr. The measured beam lifetime is more than 10 hours with 100 mA beam at 2 GeV. The rapid recovery of normal operation after installation of new components is achieved without *in-situ* bakeout by using a dry venting system. We present operation experiences with the NEG pumps and the performance of the vacuum system.

1 INTRODUCTION

The Pohang Light Source (PLS) of the Pohang Accelerator Laboratory is a third generation synchrotron light source with a nominal electron beam energy of 2 GeV. The PLS started its commissioning in September 1994. The PLS was successfully commissioned in July 1995 and opened to users in September 1995. The storage ring (SR) vacuum system of the PLS has been operated since September 1994. The design, fabrication, testing and installation of the vacuum system have been reported elsewhere [1,2]. In brief, the vacuum system is made of either machined A5083 and extruded A6063 aluminum alloy vacuum chambers. The system is mainly pumped by combination pumps which consist of non-evaporable getter (NEG) pumps and sputter ion pumps (SIPs). The PLS vacuum is now so good that improving it would have almost no effect on beam lifetime; lifetime is mainly limited by intra-bunch scattering of electrons, not by electrons scattering with residual gas molecules. The average pressure of the SR is around 3×10^{-10} Torr without beam and about 7×10^{-10} Torr with 100mA of stored beam at 2 GeV. In this article, the operation experiences of the vacuum system, including NEG operations, recovery works, and the performance of the vacuum system are described

2 COMMISSIONG OF THE VACUUM SYSTEM

The installation of the SR vacuum system was completed on June 7, 1994. The vacuum system underwent two operational phases according to the storage ring commissioning [3]. At the SR phase I commissioning, the vacuum system was pumped only by SIPs without NEG activation and without bakeout. Before the first beam injection on September 1, 1994, the ultimate static vacuum reached about 8×10^{-9} Torr. With the beam stored, the pressures increased abruptly due to the photon induced gas loads (PIDs). The specific pressure rise was measured as high as 2×10^{-7} Torr/mA initially and reduced to 1×10^{-9} Torr/mA at the end of phase I commissioning.

After the phase I commissioning, efforts were made to improve beam lifetime due to the gas scattering in two ways; by enhancing the pumping speed and by accumulating beam dose. Firstly, the SR vacuum system was baked at about 90^{o}C for 48 hours. Although the PLS aluminum vacuum chambers could be baked to 150^{o}C by using pressurized hot water, the transverse deflection at the end of the chamber was so large that the bakeout temperature was reduced practically to less than 100^{o}C to prevent RF shielded bellows from breaking down. The NEG pumps were activated at 450^{o}C for about 45 min. at the end of bakeout period. The average static vacuum was then low 10^{-10} Torr, and the specific pressure rise due to the PID decreased immediately after the NEG activation. The phase II commissioning began on April 4, 1995. During this period, the beam was stored as high as possible in the night in order to clean up the photon irradiating surfaces by accumulating the beam dose and hence to lower beam-gas scattering. As a result, a rapid increase in lifetime from 150 min. to 10 hours at 100 mA was achieved at the end of the phase II commissioning.

On September 1, 1995, the first beam was delivered to users. During the user service period, there was a machine shut down due to the water leak at the brazed interface with copper to stainless steel in the strip photon absorber on October 19, 1995. The machine resumed to store beam on November 13, 1995 after the repair work. An operation efficiency of the scheduled beam time was 65% in 1995 due to the water leak. But the system has been in normal operation since 1996 and an operation efficiency of more than 90% is routinely achieved.

3 VACUUM PERFORMANCE

Fig. 1 shows the reduction of specific pressure rise due to the PID measured as a function of the accumulated beam dose (Amp.hr). The specific pressure rise was 6×10^{-9} Torr/mA at 1 AH and gradually reduced due to the beam self-cleaning effect to 1×10^{-9} Torr/mA at 7 AH where the system was pumped by SIPs only. After the NEG activation, the specific pressure rise reduced immediately to 1×10^{-10} Torr/mA at 12 AH and finally reached 3×10^{-11} Torr/mA with a slope of about -0.7 at the end of commissioning.

Fig. 2 shows the residual gas spectra with and without the beam. The composition of the residual gas

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has drastically changed with the beam stored. The gases desorbed were, in order of importance, H_2 followed by CO, CO_2, and CH_4 with small traces of Ar. After enough beam dose(>600AH), H_2 was still the predominant component, followed by CO, CO_2, and CH_4, while H_2O was effectively cleaned up.

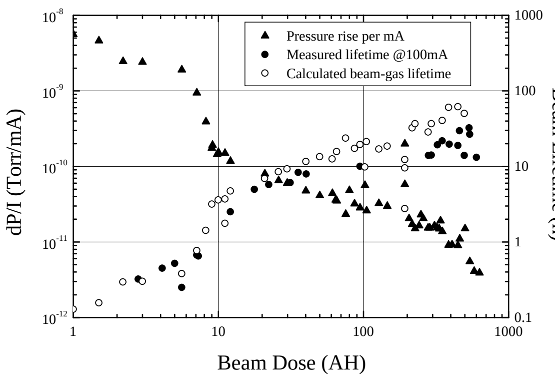

Figure 1: Reduction of pressure rise along with measured beam lifetime with respect to the accumulated beam dose.

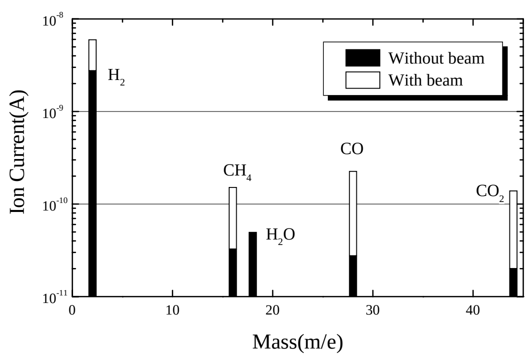

Figure 2: Typical residual gas spectra; without beam and with 100mA stored beam.

Fig. 1 also shows the measured and calculated beam lifetimes. The beam-gas lifetime calculated with the gas compositions described in Ref 3. The measured lifetime at 100mA beam current was in good agreement with the calculated one for low beam dose, meaning that the beam lifetime was limited by beam-gas scattering, *i.e.*, Coulomb and Bremsstrahlung scatterings. The measured lifetime during the phase I commissioning was less than 50 min. at 100mA. After the chamber bakeout and the NEG activation, the lifetime jumped to about 150 min. and finally reached to about 10 hours with 100 mA beam by the end of the commissioning.

As shown in Fig. 1, the vacuum system reached its designed value of low 10^{-9} Torr with lifetime in excess of 10 hours after the accumulated beam dose of 50AH. The scattered data in lifetime between 200~600 AH reflects the machine operation parameters. For example, the beam lifetime increases to more than 30 hours when the filling pattern of the electron beam is uniformly distributed, and decreases to about 10 hours at 100mA when the machine is operated to reduce the beam instability. After the beam dose of 400AH, the lifetime does not vary with the pressure, which strongly suggests that the lifetime is limited by pressure independent Touschek effect.

4 NEG OPERATION

The lumped NEG wafer module(WP950) used for the PLS is ST707(made by SAES Getters. The NEG is activated typically at 450^{o}C for 45min. Since the installation of the vacuum system in September 1994, the NEG pumps of the complete ring have been reconditioned twice. The first time was after the phase I commissioning (after 7 AH of beam dose) with *in-situ* bakeout, and the second time was after about 320 AH accumulated beam dose. Additional reconditionings have been carried out in sectors opened for repairs and new beamline front-end installations.

After the absorption of 0.1 Torr(l per module, the pumping speed of the NEG drops below 60% of its initial value with the gas composition of 90% H_2 and 10% CO [2]. Assuming the total operation time about 5,000 hours per year, the sorbed quantity is comparable to the point where the speed drops to 60% of its initial speed. And the distributions of the gas loads, and hence pressures, are somewhat varies around the SR due to the thermal load, leaks, and the PID. So, the periodical regeneration is necessary to keep the maximum performance. The reconditioning is planed yearly in the summer maintenance period.

The reconditioning procedure consists of closing of sector valves and switching off the SIPs to avoid the degradation of its performance. The typical operation takes about 4 hours. The NEG pumps are activated by heating them gradually to the predefined temperature. The NEG modules are connected each other in series to keep the current low from one power supply. The current is set at 37 amps to activate NEG at 450^{o}C. After the ion gauges are degassed, the SIPs are switched on at pressures below 10^{-7} Torr. A mobile pumping system is then disconnected at about 5×10^{-9} Torr due to the poor H_2 compression ratio of a magnetic turbo pump backed by a dry mechanical pump.

In order to find an optimum regeneration condition, we have made several measurements with different activation temperatures. The regeneration is carried out as a function of the activation temperature. The results are shown in Fig. 3. The NEG pumping speeds are restored when the regeneration temperature is higher than 310^{o}C and the pressure improvements are comparable with various temperatures. However, the pressure improvement after reconditioning is significant when the pressure before reconditioning is in the range of 10^{-10} Torr. This means that the pumping speed of some parts of the SR drops to a very low value. It can be seen from Fig. 3 that the periodic regeneration is necessary and the regeneration at 350^{o}C for about 45 min. is the most effective way to restore the NEG pumping speed.

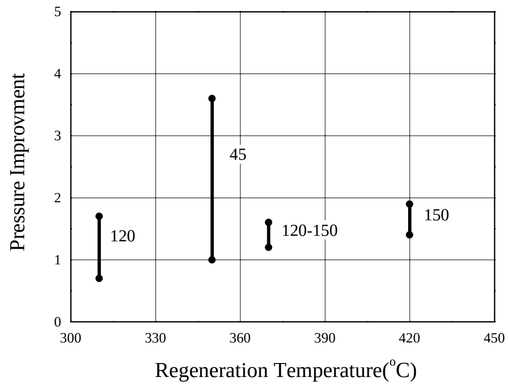

Figure 3: Pressure improvement; the ratio of pressure before the regenerations to pressure after the regenerations. Numerics stand for the duration of regeneration in min.

5 VACUUM RECOVERY

The PLS requires extremely clean vacuum and the normal operation condition should be recovered even without bakeout in a reasonably short time. Backfilling of the vacuum system should be done with a moisture-free nitrogen gas. To meet this requirement, a dry venting system (DVS) has been used since the machine start-up [4]. Recently, new DVS has been developed in the laboratory. It consists of a LN_2 Dewar, an evaporator, and a diffuser. The DVS works without bakeout in such a way that moisture is frozen out at LN_2 temperatures and then pure N_2 gas is introduced into the chamber. Fig. 4 compares typical pump down curves measured with different venting gases; ambient air, liquid nitrogen boil-off, and dry nitrogen. The venting effectiveness is apparent as seen from Fig. 4. So far, 10 sectors have been let up to dry nitrogen for repairs and new components installations. The relatively rapid recovery could be obtained using a procedure that includes dry venting, heating of SIPs, 1 hour NEG activation at 450°C and subsequent 24-hour pump down. It usually takes two or three days. After 1~2 AH of accumulated beam dose in case of a photon absorber replacement, the beam lifetime was almost the same as before the venting as shown in Fig. 5. This means that the dry venting is quite good and only PID from the new component appears to cause the pressure rise. Further to minimize the new component effect, a special surface treatment for the vacuum components is necessary and its study is under way.

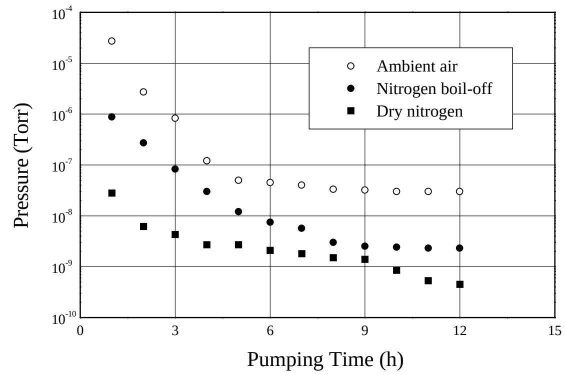

Figure 4: Pump down curves with different venting gases.

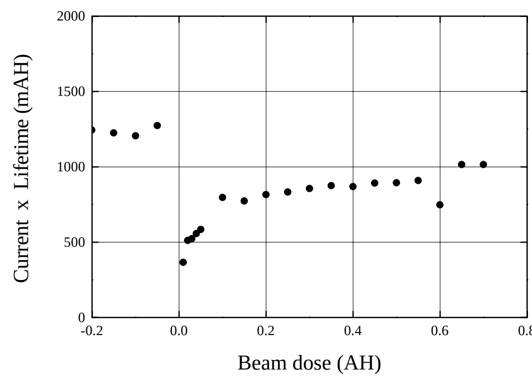

Figure 5: Typical recovery of beam lifetime after a photon absorber replacement

6 SUMMARY

The operation experiences as well as the performances of the vacuum system for the PLS storage ring have been described. The relatively fast recovery of normal operation condition is achieved by a dry venting without bakeout. But we often perform a mild bakeout after a long shut down. Now 10-hour beam lifetime is achieved within 4 days with the stored beam of 100 mA at 2 GeV.

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