MEASUREMENT OF THE PRESSURE IN THE TPS BOOSTER RING*

Chia-Mu Cheng, Che-Kai Chan, Gao-Yu Hsiung, Yingtzu Huang, I-Ching Sheng, Ling-Hui Wu, I-Chen Yang

NSRRC, Hsinchu, Taiwan

Abstract

The booster ring of Taiwan Photon Source (TPS) is designed to provide full energy injection 3 GeV ramped up from 150 MeV with a small beam emittance. It is a synchrotron accelerator of circumference 496.8 m. The vacuum chamber through the magnets is made of thin stainless-steel tube extruded to an elliptical cross section of inner diameters 35 mm and 20 mm, and thickness 0.7 mm. The other chambers have standard 35CF round tube. The vacuum system was baked in the first installation. Because the residual stress of the stainless-steel elliptical tubing caused the magnetic field to become unstable, all elliptical tubing was removed for annealing to proceed, and reinstalled without baking. The ultimate pressure and data for the residual gas are shown as follows.

INTRODUCTION

The booster ring of Taiwan Photon Source (TPS) is a synchrotron accelerator that is designed for full energy injection 3 GeV ramped up from 150 MeV. Its circumference is 496.8 m, and it is concentric with the electron storage ring in the same tunnel.

The vacuum system of the booster is divided into six super-periods with ten pumping stations in each period. A sputter-ion pump (Starcell 150) and cold-cathode gauge (IKR 070) were mounted on each pumping station. The total numbers of ion pumps and gauges on the booster ring are 60 and 49, respectively. In each period, two gauges are installed on pumping station number three and eight for the valve-interlock system. The distribution of gauges is listed in table 1.

The average distance between pumping stations is about 8 m, with maximum and minimum distances 11.8 and 3.4 m. The vacuum chambers through the dipole, quadrupole and sextupole magnets are elliptical tubes. The elliptical cross section has inner diameters 35 mm and 20 mm; the thickness is 0.7 mm [1]. The other vacuum chambers are standard DN40 round tube.

Table 1: Gauge distribution on the TPS booster ring

IP_1	CCG1	IP_6	none
IP_2	CCG2	IP_7	CCG6
IP_3	CCG3,4	IP_8	CCG7,8
IP_4	CCG5	IP_9	none
IP_5	none	IP_10	CCG9(BR03)

COMMISSIONING AND REASSEMBLY

The booster vacuum chamber between two gate valves was completely installed and pumped down with a turbo-molecular pump and a dry mechanical pump. After leakage tests, the sputter-ion pump was turned on and the turbo-molecular pump was isolated. Before the TPS booster ring was commissioned, the vacuum system was baked to 150 ^{o}C for about 6 h.

At the beginning of commissioning of the booster ring, electrons could not be stored in this ring. The vacuum chamber was realigned and new screen monitors and beam position monitors were installed, but without significant improvement. The main problem was eventually discovered to be that the permeability of the elliptical vacuum tube made of stainless steel was too large, caused by cold working on the SUS304 steel. It caused the magnetic field to become unstable. The only solution was annealing. [2]

All elliptical vacuum tubing was removed, and cut to a suitable length if longer than 2 m. The elliptical tubing was heated to 1050 ^{o}C for 2 h in a vacuum furnace; the pressure in that furnace was about 10^{-4} torr. Figure 1 shows transport of the vacuum tubing into the vacuum furnace of length 2.2 m.

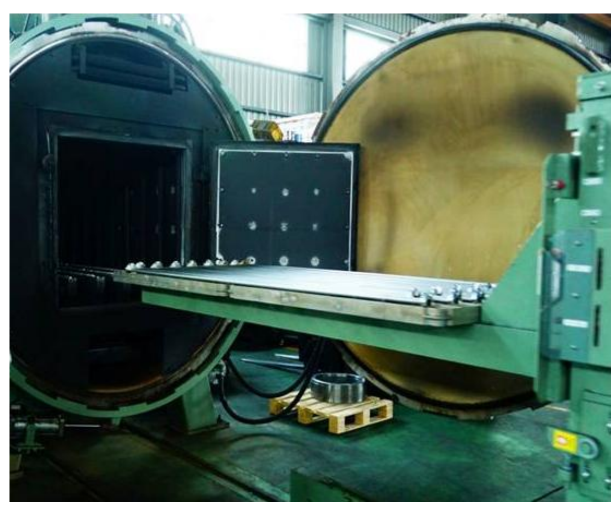

Figure 1: The SUS304 elliptical tube is transported into a vacuum furnace of length 2.2 m.

After the stainless-steel tube was annealed, the entire

ISBN 978-3-95450-147-2

elliptical chamber was directly reinstalled and pumped down with leakage testing, section by section. The TPS booster ring successfully stored an electron beam that was injected into the storage ring at the end of year 2014.

AVERAGE PRESSURE

The average pressure of the TPS booster vacuum system is the average shown by 49 cold-cathode gauges. The average pressure of the first assembly without baking was about 6×10^{-7} Pa. The average pressure of the first assembly after baking the system became about 2×10^{-7} Pa, which showed that the baking was inefficient. Because of the space limit between the dipole magnet and the vacuum chamber, it was difficult to implement uniform heating on the vacuum chamber.

Figure 2 is the pumping curve of one section of the booster vacuum system. The average pressure after reassembly with the elliptical tube following annealing was about 6.7×10^{-7} Pa, almost the same as with the first assembly. The pressure at the middle of the longest tube was about 50 to 100 times that at the pumping station.

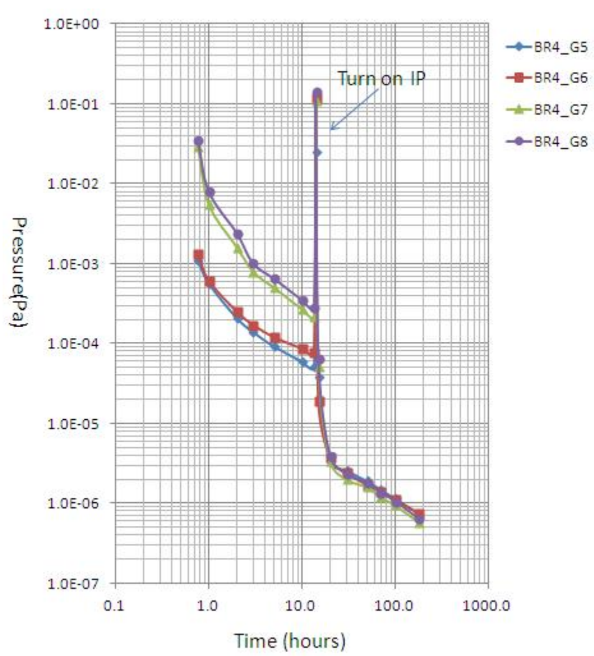

Figure 2: Pumping curve for one section of the TPS booster vacuum system

PRESSURE DURING OPEARATION

During tests of the TPS booster ring machine, the average pressure was ramped to about 10^{-6} Pa when the electron beam was loss with high energy (1~2 GeV).

The average pressure without an electron beam stored in the booster ring decreased from 6.7×10^{-7} Pa to 1.5×10^{-7} Pa after the booster ring began operation. The decreasing trend of the average pressure is shown in figure 3. The average pressure increased about 30 % when electrons were injected from the LINAC to the booster ring. This fraction did not decrease with the average pressure for no electron beam. Figure 4 shows the pressure ramped up when the storage ring was in the top-up mode at 150 mA.

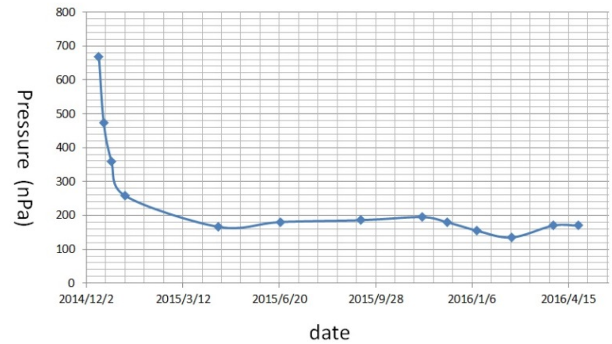

Figure 3: Decreasing trend of average pressure with no electron beam stored in the booster ring

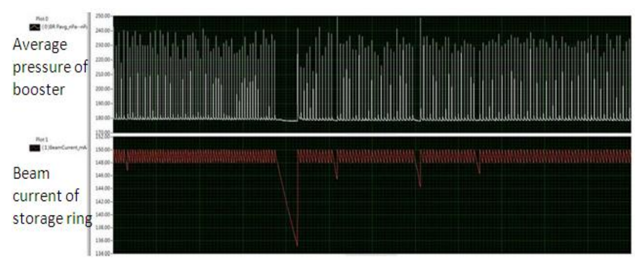

Figure 4: Average pressure of the booster ramped up when the storage ring was in the top-up mode at 150mA

CONCLUSION

The vacuum system of booster is divided into six super-periods with ten pumping stations in each period. Sputter-ion pumps (Starcell 150) and cold-cathode gauges (IKR 070) were installed at each pumping station. Each period has eight gauges; the distribution satisfies the demands of the interlock system.

The vacuum tubes through the magnets have elliptical cross sections with inner diameters 35 mm and 20 mm; the thickness is 0.7 mm. The other vacuum chambers are standard DN40 round tube. The average distance between pumping stations is about 8 m.

Before commission of the TPS booster ring, the vacuum system was baked to 150 °C for about 6 h. At the initial commissioning of the booster ring, electrons could not be stored in the booster ring. The main problem was that the permeability of the elliptical vacuum tubing, made of stainless steel, was too large, caused by cold working on the SUS304 steel. The elliptical tubing was heated to 1050 °C for 2 h in a vacuum furnace and was directly reinstalled and pumped down. The TPS booster ring successfully stored an electron beam, which was injected into the storage ring at the end of year 2014.

The average pressure of the first assembly without baking was about 6×10^{-7} Pa, which decreased to about 2×10^{-7} Pa after baking. Baking was inefficient because of the space limit between the dipole magnet and the vacuum chamber, such that it was difficult to obtain uniform heating on the vacuum chamber. The average pressure after reassembly of the elliptical tube following annealing was about 6.7×10^{-7} Pa, almost the same as with the first assembly. The pressure at the middle of the longest tube was about 50 to 100 times greater than at the pumping station.

The average pressure with no electron beam stored in the booster ring decreased from 6.7×10^{-7} Pa to 1.5×10^{-7} Pa after the booster ring began operation. The average pressure increased about 30 % when electrons were injected from the LINAC into the booster ring.

ACKNOWLEDGMENT

We thank colleagues for assistance in solving problems during commissioning of the TPS booster ring, especially all members of the NSRRC vacuum group for reinstalling the vacuum system in such a short time.

REFERENCE

[1] H. C. Chao, H. P. Chang, H. J. Tsai, P. J. Chou, G. H. Luo and C. C. Kuo, Proceedings of IPAC09, Vancouver, BC Canada, WE5RFP001, 2258 (2009).
[2] Norman Wilson and Paul Bush, (2009).IEEE PAC1991, p.2322-2324 (1991)

ISBN 978-3-95450-147-2