Vacuum Characteristics of TRISTAN Ring

K. Kanazawa, Y. Suetsugu and H. Hisamatsu
KEK National Laboratory for High Energy Physics
1-1 Oho, Tsukuba-shi, Ibaraki-ken, 305 Japan.

Introduction

The construction of the TRISTAN ring had been completed in 1986. The vacuum system is essentially all-aluminum and unbaked. The present beam lifetime is 4.4 hours for 6.5 GeV, 20 mA in the accumulation ring (AR) and 4 hours for 30.4 GeV, 9 mA in the main ring (MR). These lifetimes are short in order to use AR as a synchrotron radiation source or to obtain a high integrated luminosity in MR. The design value of the lifetime was about one day for both rings[1]. Whether these lifetimes are mainly due to the scattering on residual gas molecules is not an easy question to answer. Because the vacuum gauges are not in the proper position for the direct measurement of the pressure in the beam duct and the estimation of the pressure with ion pumps does not have enough reliability due to the variety of the discharge character. In the following, the estimation of the base pressure, the desorption rate by the synchrotron radiation, and the pumping speed of the main distributed pump are reported. They are obtained partly from the direct measurement and partly from the indirect measurement. The reliability of the results is checked by the comparison of the result with the reliable data of other storage ring or the consistency between the results.

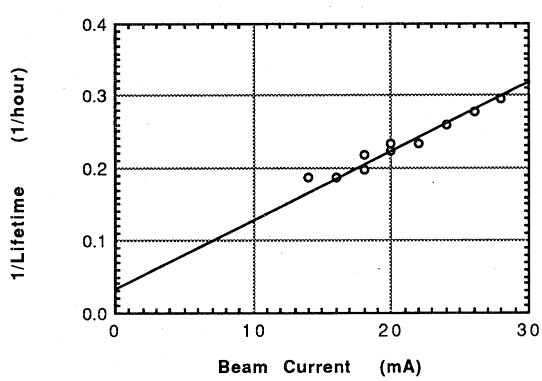

Fig. 1 The relation of the beam lifetime and the beam current in AR. The beam energy is 6.5 GeV.

AR

Fig.1 shows the dependence of the beam lifetime on the beam current with the energy of 6.5 GeV (Oct. 20, 1989 at the beam dose of 130 A.h). If the machine is tuned well, the beam lifetime consists of a quantum lifetime and a collision time with gas molecules. The quantum lifetime of AR is much longer than a day. So the observed beam lifetime is thought to be equal to the collision time. As is well-known, in an electron storage machine, synchrotron radiation from circulating electrons causes the desorption of molecules. The pressure rise due to the desorption is proportional to the beam current and decreases with the integrated photon dose. The linear dependence of the inverse of the beam lifetime in Fig.1 on the beam current reflects this pressure rise. The beam lifetime at I=0 corresponds to the lifetime at the base pressure. The main process which contributes the beam lifetime in AR is the loss from the RF bucket by the bremsstrahlung. The collision cross section is proportional to $Z(Z+1)$, where Z is the charge of an atomic nuclei. Among residual molecules, CO (Carbon monoxide) has a dominating effect on the beam lifetime. The base pressure of CO estimated from Fig.1 is 1.7×10^{-7} Pa. With beam the pressure is in the range of 10^{-6} Pa. And the pressure rise per beam current is 5.4×10^{-8} Pa/mA. These values are an average over the whole ring but almost equal to the value in the arc sections, because the length of the arc section is 80% of the total circumference.

Table 1 is the direct measurement of the pressure rise in the arc section with B-A gauge (Jul. 30, 1988 at the beam dose of 77.5 A.h)[2]. The base pressure was not reliable because of the outgassing from the gauge. The gauges are placed in the port directly connected to the beam duct. Though the date of measurement is different from that of Fig.1 and the measured value is the total pressure (CO is about 80% of the total pressure), the result is consistent with the result from Fig.1. So The information on the base pressure in Fig.1 is also considered to be reliable. The molecular desorption rate η is estimated from the result of Table1 as about 2×10^{-5} molecules/photon, assuming a pumping speed of a DIP (Distributed Ion Pump) is 50 l/s/m. This is consistent with the value of PF (Photon Factory)[3]: $\eta=1\times10^{-6}$ at the beam dose of 400 A.h. Therefore the effective distributed pumping speed in the arc section is about 40 l/s/m in the range of 10^{-6} Pa.

Fig. 2 is the decrease of pressure rise in the arc section. The original data was obtained with cold cathode gauges which are placed at the end of the pumping space of the DIP. The pressure rise is corrected based on the measurement of Table 1.

Table 1

Gauge	ΔP/I at 6.5 GeV (Pa/mA)	ΔP/I at 2.5 GeV (Pa/mA)
G3	4.99×10^{-8}	1.22×10^{-8}
G4	1.02×10^{-7}	1.22×10^{-8}
G6	6.54×10^{-8}	2.22×10^{-8}

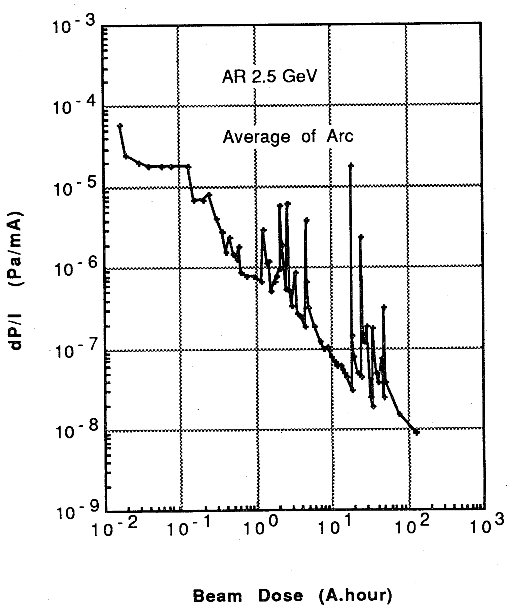

Fig. 2 The average pressure rise of the arc section due to synchrotron radiation in AR. The beam energy is 2.5 GeV. The pressure rise for a 6.5 GeV beam is about 2 times larger.

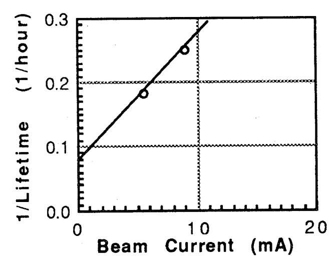

Fig. 3 The relation of the beam lifetime and the beam current in MR. The beam energy is 30.4 GeV.

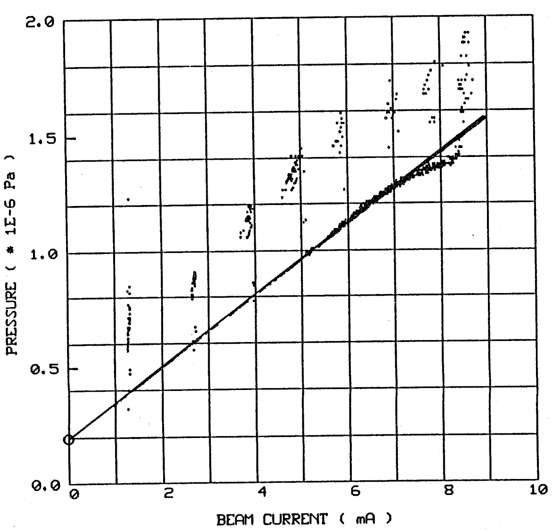

Fig. 4 The pressure rise of CO in the arc section. The beam energy is 26 GeV. The beam current is the sum of electron and positron.

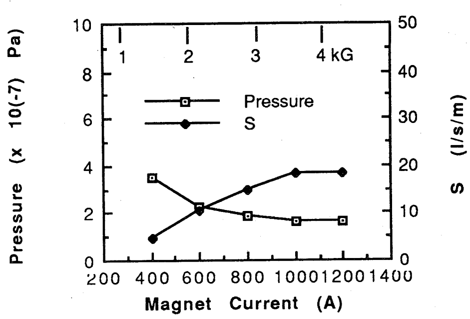

Fig. 5 The measurement of the pumping speed of a MR DIP. The pumping speed is estimated with a calculation of the pressure distribution assuming the outgassing rate from the chamber wall is constant.

MR

Fig.3 is the relation of the beam lifetime and the beam current in MR (Jul. 13, 1989 at the beam dose of 34.2 A.h). Along with a similar discussion as for AR, Fig.3 gives the base pressure of 1.7×10^{-7} Pa and the pressure rise of 1.4×10^{-7} Pa/mA assuming the quantum lifetime is 24 hour. The pressure with or without beam lies in the same range as AR. So is the beam lifetime. Fig.4 is the measurement of the partial pressure of CO at the point of the arc section (Jul. 19, 1987 at the beam dose of 5.7 A.h)[4]. Fig.4 gives the pressure rise of 1.5×10^{-7} Pa/mA. Though the beam dose of Fig.3 is 6 times the dose of Fig.4, the decrease of the pressure rise is quite small. This is seen in Fig. 6 and mainly due to the continuous grade up of machine energy. So the estimation from Fig.3 and the result of Fig.4 are consistent. In MR the length of the arc section is 74% of the total circumference.

Fig.5 is the measurement of the pumping speed of a DIP in MR. The measurement is done by observing base pressures while varying the magnetic field. So this is not the constant pressure measurement. Fig.5 tells that the transition field is about 3 kG, the maximum pumping speed in a low 10^{-7} Pa range is about 20 l/s/m and at the injection energy of MR which corresponds to about 1kG there is no pumping speed. The maximum pumping speed of an unbaked DIP is consistent with the result of a bench test[5]. But the designed value of the transition field is 2 kG. This was confirmed in the bench test. This discrepancy is due to the fact that the DIP in the main ring is placed along the edge of the dipole magnet. So the effective field is lower than the nominal field and the transition field looks higher than the case of the bench test. This also explain a quite low pumping speed at the injection where the DIP is working in a LMF mode[6]. The effective distributed pumping speed when a DIP is in a HMF mode is 16 l/s/m in a low 10^{-7} Pa range.

Fig.6 shows the variation of the pressure rise in the arc section. the data is also corrected based on the data of Fig.4.

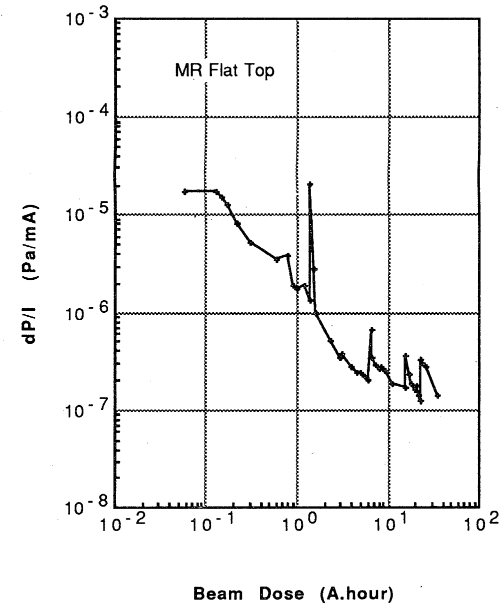

Fig. 6 The average pressure rise of the arc section due to synchrotron radiation in MR. The beam energy is the colliding energy. The colliding energy is increased gradually from 21 GeV to 30 GeV. The pressure rise at the injection energy is larger than this because of a poor pumping speed of DIP's.

Summary and Discussion

The beam lifetime in the TRISTAN ring is limited by the pressure. The base pressure of TRISTAN ring is in the order of 10^{-7} Pa. The pressure with beam lies in the range of 10^{-6} Pa. To realize the designed beam lifetime, the operating pressure of 10^{-7} Pa must be achieved. Then the base pressure should be in a low 10^{-8} Pa range. The experience of the TRISTAN ring shows that without baking the pressure of 10^{-8} Pa cannot be achieved within a reasonable operation time, even with the complete aluminum system. The baking will also raise the pumping speed of a DIP[5] by a factor 2. At present the pumping speed of a DIP is 50 l/s/m at around 10^{-6} Pa in AR and 20 l/s/m at around 10^{-7} Pa in MR. The pumping speed of a AR DIP will be 30 l/s/m in a 10^{-7} Pa range. So the effective distributed pumping speed is 24 l/s/m for AR and 16 l/s/m for MR in a 10^{-7} Pa range. These values will be twice by baking. But in MR, according to the calculation based on a experimental formula[6], it is shown that the pumping speed of a DIP at the injection energy cannot exceed 20 l/s/m (Fig.7). This is a serious defect against the future grade-up to a high luminosity machine. In AR the situation is much better. The newly designed DIP for AR is reported in this proceedings[7].

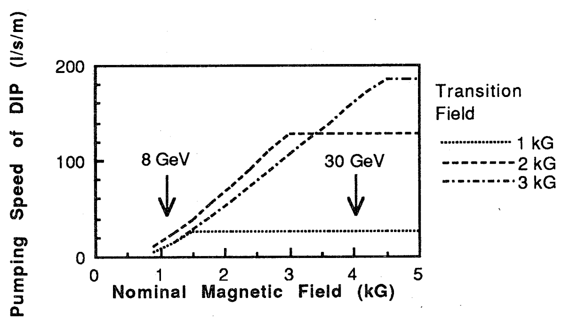

Fig. 7 The model calculation of the pumping speed of a DIP. The calculation is done for DIP's with different transition fields. The space for the DIP is assumed to be the same as the present DIP room.

Acknowledgement

The data of the beam lifetime is afforded by the software programed by Dr. M. Tejima.

References

1. TRISTAN Project Group, "TRISTAN Electron-Positron Colliding Beam Project", KEK Report 86-14 (1987).
2. K. Kanazawa, "Proceedings of 7th meeting on UHV for accelerators", KEK Report 89-2 (1989), p.1, in Japanese.
3. M. Kobayashi, AIP Conference proceedings No.171, "Vacuum Design of Advanced and Compact Synchrotron Light Source", (AIP., New York, 1988), p.155.
4. K. Kanazawa, H. Hisamatsu and M. Tejima, "Proceedings of the 6th Symposium on Accelerator Science and Technology", (IONICS, Tokyo,1987), p.144
5. T. Momose, J. R. Chen, K. Kanazawa, H. Hisamatsu, and H. Ishimaru, J. Vac. Sci. Technol. **A 7**, 3098 (1989).
6. H. Hartwig and J. S. Kouptsidis, J. Vac. Sci. Technol., **11**, 1154 (1974).
7. Y. Suetsugu, This proceedings.