VACUUM CHARACTERISTICS OF THE RF CAVITY FOR TRISTAN MAIN RING

H. Mizuno, M. Akemoto, S. Sakai, Y. Yamazaki, T. Higo, Y. Morozumi and K. Takata
National Laboratory for High Energy Physics
Oho-machi, Tsukuba-gun, Ibaraki-ken, 305, Japan

Introduction

In the TRISTAN main ring 52 accelerating units of alternating periodic structure (APS)[1] are to be installed into the 6 straight sections around the Fuji, Tsukuba and Oho experimental areas. An accelerating unit which is 5365 mm long is composed of two 9 accelerating cell structures. At present (Jan. 1987) 32 units have been installed and under operation at a beam energy of 25 GeV. The remaining 20 units will be set up in this summer.

To achieve the necessary beam life longer than 5 hours, the cavity sections should be pumped down to the pressure less than 5×10^{-9} Torr with an operating RF power of 200 kW per each 9-cell cavity and the e± beam. For this purpose a sufficient baking which is the most efficient method of reducing the outgassing rates of the parts of vacuum system is required for the APS cavity. A circulating water boiler system with electric heaters and a water pump was developed for the easy operation and maintenance of the RF vacuum system.

The cavity unit is made of low-carbon steel S25C, and inner surface is electro-plated with copper of 100 μm thickness in a pyrophosphorous-acid bath. The area of inner surface and the volume of the cavity are about 18 m^2 and 1 m^3, respectively. The unit is baked at 135°C by circulating 145°C hot water in the cooling channel. After the bake-out process for 24 hours the outgassing rate is dominated by the hydrogen permeation from the cooling water channel through the iron wall into the vacuum. To suppress this permeation, the anti-corrosion agent is added to the water by 5 % in volume. All of the units were baked for 10 days at 135°C before they were installed into the straight sections.

Outgassing Characteristics of the Test APS Cavity

For outgassing measurements, a 2-cell test APS cavity with the surface area of 2.0×10^4 cm^2 was made by the exactly same fabrication method as the TRISTAN APS units. The outgassing rate of the test cavity was measured by the through-put method[2] as shown in Fig. 1.

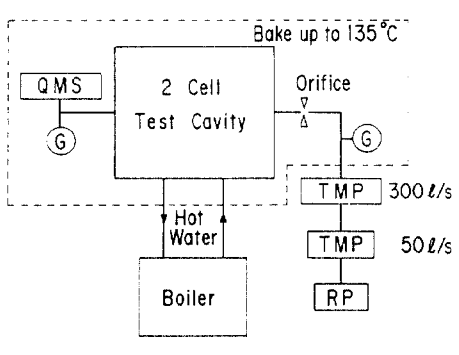


Fig. 1 The measurement system of the outgassing rate in a 2 cell test cavity.

Two Bayard-Alpert ionization gauges (G) were set at the upstream and downstream sections of an orifice, respectively. The conductance of the orifice calculated for N_2 at 298°K was 11.2 ℓ/s. The pumping system is composed of 300 ℓ/s and 50 ℓ/s turbo-molecular pumps (TMP) in series. With this system the measurable lower limit of the outgassing rate was considered to be 1×10^{-13} Torr·ℓ/sec·cm^2 (note that the pressure and outgassing rate are so-called nitrogen equivalent values in the following.) The quadrupole mass spectrometer (QMS), set at the upstream section of the orifice, was used for the partial pressure measurement. However, it was switched on during bake-out period only, and off after bake-out to avoid possible disturbance to the final outgassing measurement at room temperature.

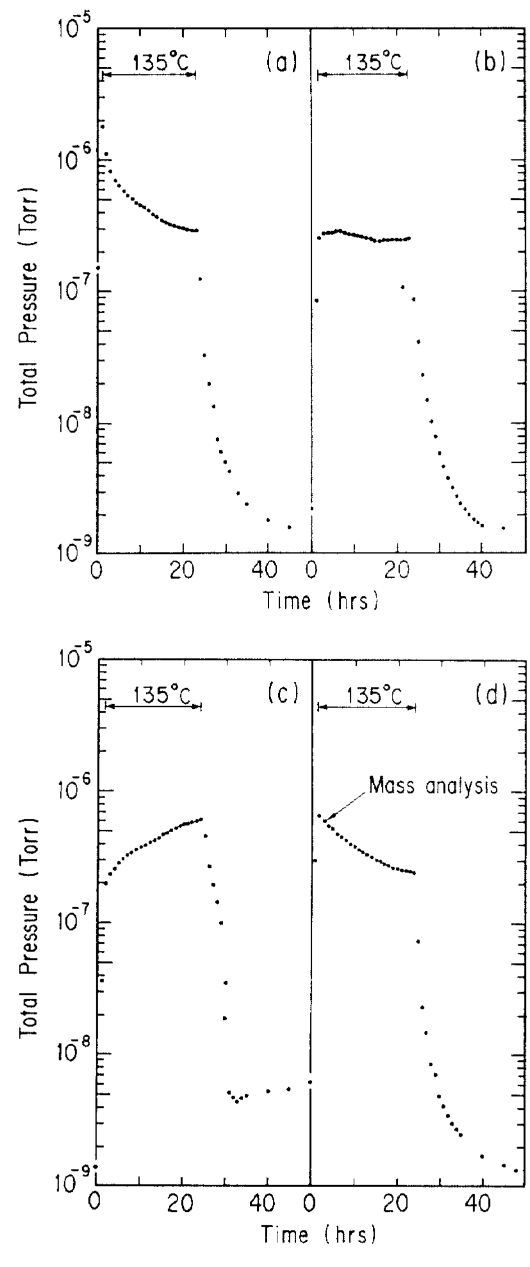


Fig. 2 The pressure variation in the test cavity, the heating liquid is (a) ethylen glycol, (b) and (c) pure water and (d) pure water with 2 % organic anti-corrosion agent.

The test cavity was baked also by using the hot water boiler system. Prior to the outgassing rate measurements several series of bakeout procedures were

CH2387-9/87/0000- PAC 1987 © IEEE

carried out at 135°C to 160°C for a total of more than 10 days to test the bake-out system and also to take preliminary data. Then, four cycles of bake-out at 135°C for 24 hours and consecutive cooling period of 1 or 2 days were carried out in succession. Each time the heating liquid was changed: ethylene glycol for the first cycle, pure water for the second and third, and pure water with 2 % in volume of organic anti-corrosion agent for automobile engines for the fourth cycles. The pressure variation in the test cavity during these four successive bake-out cycles are shown in Fig. 2(a)-(d), respectively. Here, the system was never exposed to the atmosphere, being pumped continuously. The ultimate pressure at the head of the turbo-molecular pump was 3×10^{-10} Torr.

The most distinctive feature is shown in Fig. 2-(c) corresponding to the 2nd bake-out cycle by pure water. In this 24 hour heating cycle at 135°C, the total pressure increased continuously and after cooling down the final pressure of the system remains higher than that of 4th bake-out cycle. On the other hand, in the 4th bake-out cycle using pure water with 2 % anti-corrosion agent, as shown in Fig. 2-(d), the pres- sure during bake-out decreased smoothly and reached a value lower than that in the previous bake-out cycle.

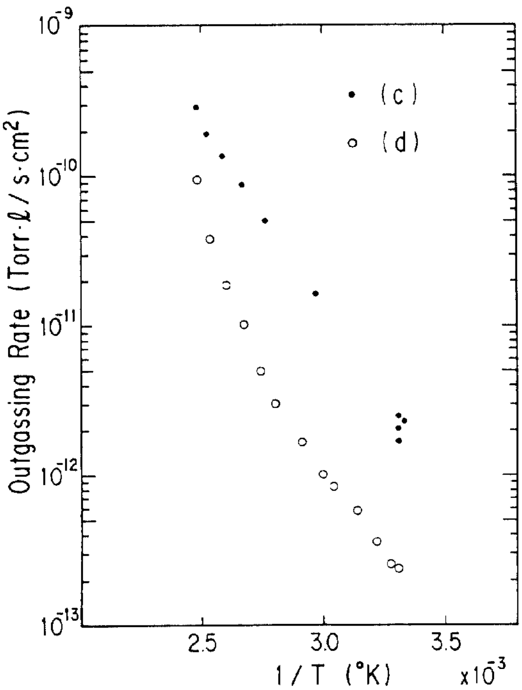


Fig. 3 The temperature dependence of the outgassing rates after 3rd and 4th bake-out cycle.

Fig. 3 shows the temperature dependence of the outgassing rates after 3rd and 4th bake-out cycle. The outgassing rate at room temperature of the 4th bake-out procedure is 2×10^{-13} Torr·ℓ/sec·cm^2 and about one tenth of the corresponding value after the 3rd bake-out. This value is small enough to achieve the required low pressure. Therefore, this baking is an efficient method for reducing the outgassing rate of the APS cavity. Fig. 4 shows the mass spectrum in the 4th bake-out cycle (see Fig. 2-(d)). The most characteristic feature is that the hydrogen is more than 80 % of the total outgas. This means that the hydrogen is supplied from the outside of the cavity. It is therefore considered that the hydrogen atoms are made at the surface of the water channel by an iron-water reaction and diffused through the wall. The result of the 4th bake-out cycle also shows that this iron-water reaction can be effectively suppressed by adding 2 % in volume of anti-corrosion agent to the pure water.

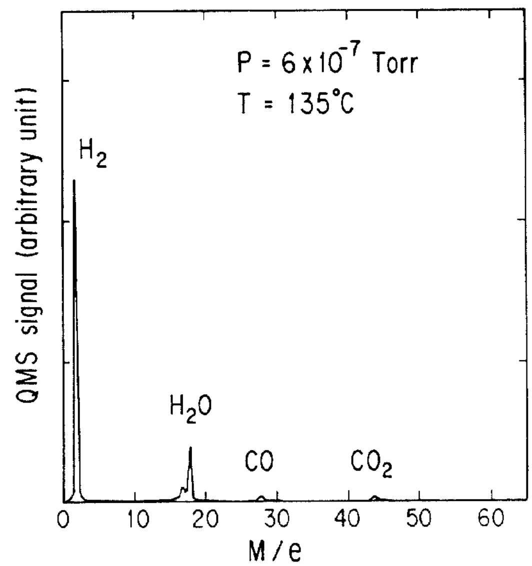


Fig. 4 The mass spectrum while the 4th bake-out period.

Baking System of the APS Cavity

The outer surface of the APS cavity is covered with an inorganic thermal insulator to suppress the heat dissipation. Its thickness is 50 mm for the main body and about 20 to 30 mm for the tuner ports and cooling water pipings, respectively. The cavity with this thermal insulator can be heated up to 145°C by 30 kW heating power of the boiler. As a heating power source, this specially developed closed-water-boiler system with an electric heater and a circulating water pump has the following advantages: (1) a boiler system can easily be transported to any section in the tunnel and the total cost of heat sources and necessary insulators can be saved compared to the ordinary bake-out system using the ohmic heater sheets stuck on the cavity surface. (2) the uniformity of the temperature distribution in the cavity is excellent. (3) easy maintenance: in case of troubles in the heating power source, the boiler system can easily be removed out of the tunnel and repaired. The specification of the boiler is summarized in the following table.

Table

Heater	200 V 3ϕ 30 kW (15 kW × 2) P.I.D., SCR control
Circulating pump	200 V 3ϕ 1.5 kW flow rate 34 ℓ/min operating temp. 180°C Max
Reservoir tank	57.9 ℓ (water ∿ 35 ℓ) pressurized by bottle N_2 up to 9.8 kg/cm (Max) 7.5 kg (150°C operation) relief valve 10 kg/cm^2
Safety valve	12 kg/cm^2

In the APS cavity cooling system, copper and its soldering material are also employed in input couplers. Therefore organic and inorganic anti-corrosion agent and pure water were tested on copper, soldering material and iron. The inorganic agent showed the best result and was determined to be employed. According to the specification from the supplier (NIPPON OIL CO. LTD.), the cooling water is added by 5 % in volume of this organic anti-corrosion agent.

One standard 18-cell unit was tested by this boiler system in the following ways: (1) the cavity was baked for 10 days at 135°C in order to degas the hydrogen solved in the iron wall of the cavity, (2) the cavity was exposed to atomosphere for 24 hours, (3) prior to the RF power test the cavity was baked at 135°C for 24 hours. After these processes the ultimate pressure of the cavity pumped by four 300 ℓ/s ion pumps was usually 6×10^{-10} Torr, and after 24 hours of RF conditioning, the pressure decreased down to the value of 5×10^{-9} Torr with an RF power of 300 kW on. This result shows that the 10 days bake-out process is effective to reduce the hydrogen outgassing rate from the iron structure.

RF Vacuum System and Operation in the TRISTAN Main Ring

Fig. 5 shows the 18-cell APS unit with RF vacuum system in the TRISTAN main ring. It has four 300 ℓ/s ion pumps[3] in the vertically down position as a main pumping system, a 300 ℓ/s turbo-molecular pump with a 250 ℓ/min oil rotary pump for the rough pumping and three gauge ports attached at accelerating cells in the horizontal position. The rough pumping system is composed of a ICF-152 metal sealed L-valve driven by an electric torque-controlled motor. Each gauge port with a size of ICF-152 has two cold-cathode gauges, one to measure the total pressure in the cavity and the other as a reserve.

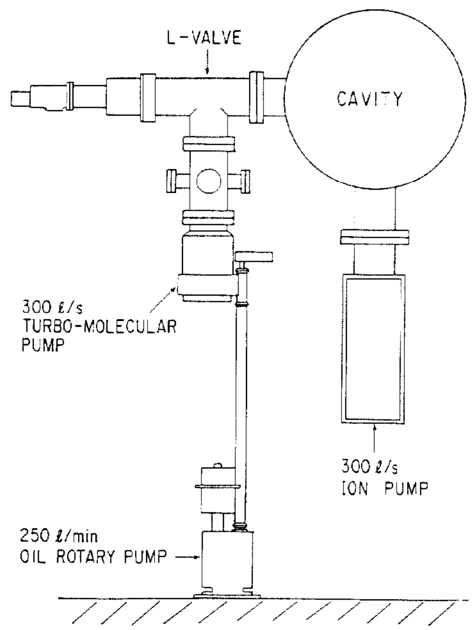
32 APS units which had been baked at 140°C for 10 days and conditioned up to 200 kW per 9 accelerating cells were installed into the 4 straight sections around the Fuji and Tsukuba experimental areas. To achieve a maintenance and pumping procedures independently of the other parts of an accelerator, each RF section is separated by the two metal valves on its both ends. The pressure in each section was typically on the order of 10^{-8} Torr for an input power of 200 kW per 9 accelerating cells. During four-month operation in the TRISTAN main ring the base pressure reached down to the order of 10^{-9} Torr without the RF power. The pressure at an RF input power of 200 kW per 9-cell with a stored current of 1 mA also decreased from 5×10^{-8} Torr to 1×10^{-8} Torr.

Acknowledgement

The authors would like to thank Prof. T. Nishikawa and Prof. J. Tanaka for their valuable suggestions. They also wish to acknowledge the continued interest of Prof. G. Horikoshi and Prof. Y. Kimura.

References

1) K. Akai et al.: KEK preprint 86-54, Sep. 1986.
2) H. Mizuno: TRISAN Design Note TN-85-008, KEK.
3) H. Ishimaru et al.: 10th International Vacuum Congress, Baltimore, Oct. 26, 1986.



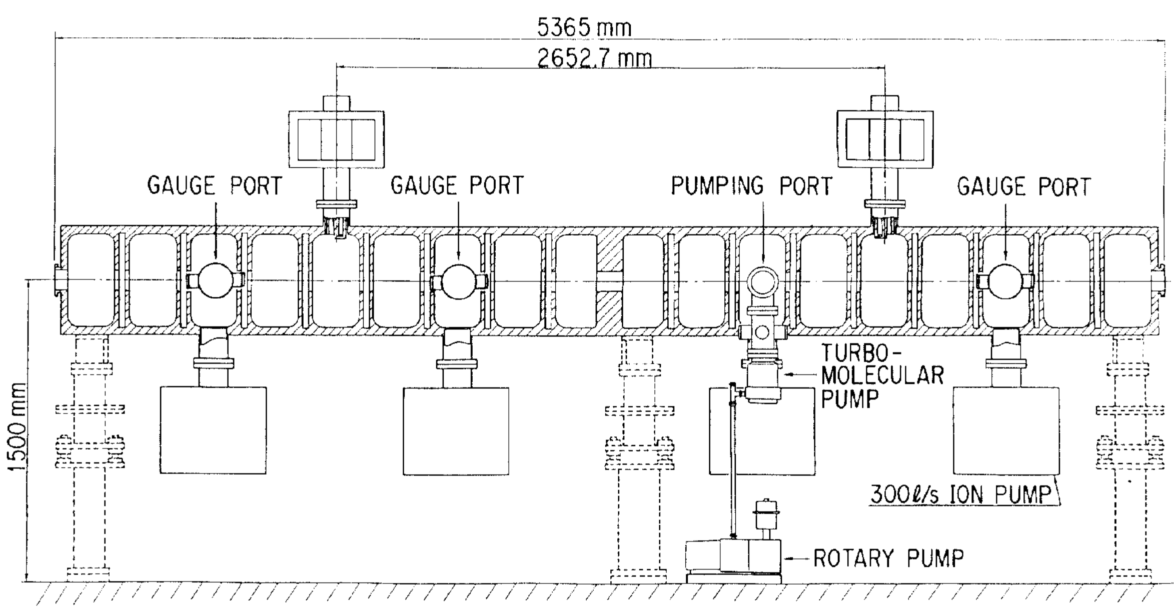


Fig. 5 The 18-cell APS unit with RF vacuum system in the TRISTAN main ring.