# Vacuum System for HIMAC Synchrotrons

M. Kanazawa, M. Sudou, K. Sato, M. Kumada, A. Itano, E. Takada, K. Noda,
National Institute of Radiological Sciences
4-9-1 Anagawa, Inage-ku, Chiba-shi 263, JAPAN

N. Suetake, Y. Yoshiwara, H. Itoh, T. Miyaoka, and Y. Morii.
Toshiba Corporation, 1-1-6 Uchisaiwai-cho, Chiyoda-ku, Tokyo 100, JAPAN

## Abstract

HIMAC synchrotrons are now under construction, which require vacuum chambers of large aperture and high vacuum of about $10^{-9}$torr. Wide thin wall vacuum chamber of 0.3mm thickness reinforced with ribs has been developed as the chamber at dipole magnet. We have just now started to evacuate the lower ring. The obtained average value was about $5\times10^{-8}$torr with turbo-molecular and sputter ion pumps, and $1.1\times10^{-9}$ torr after baking.

## I. Introduction

A heavy-ion accelerator, HIMAC (Heavy Ion Medical Accelerator in Chiba)[1] is now under construction at National Institute of Radiological Sciences (NIRS), Japan. In this synchrotron, fully stripped ions from He to Ar must be accelerated from the injection energy of 6MeV/nucleon to the maximum energy of 800MeV/nucleon within 1.0 second. Due to this low injection energy of heavy ions, cross sections of electron capture and coulomb scatting are large. To prevent beam loss with these reactions, required vacuum pressure is as low as $1\times10^{-9}$torr. To meet this requirement, we have constructed a vacuum pumping system with turbo molecular, sputter ion, and Ti getter pumps, and also a baking system with maximum temperature of 200°C to reduce the out-gassing rate from the chambers.

To increase the beam current by ten times in the synchrotron, the multiturn beam injection scheme is adopted. Hence, horizontal and vertical acceptances of the rings are 260π and 26π mm mrad, respectively. Slow beam extraction with third order resonance is used in HIMAC, and the further horizontal space is necessary for last three turn in this extraction process. Considering these requirements, the apertures at dipole magnet are ±105mm and ±25mm for horizontal and vertical sizes, respectively. If we make the wide dipole chamber with the thick plate of stainless steel, the thickness of about 4mm will be necessary, and ramping dipole field will be distorted with eddy current in the chamber. To avoid this distortion, we have developed the thin wall chamber reinforced with ribs. With this chamber we could also reduce the magnet gap to 66mm, and also its out-gassing rate was very low.

## II. Vacuum chambers

Aperture of the vacuum chambers has been determined to accept the injected beam with large emittance and has sufficient space for last three turns of the slow beam extraction. The Conflat flange of ICF306 is used to join the vacuum chambers. Material of SUS316L has been selected for the beam duct to minimize field disturbances. However, the large chambers of the inflector and the electric deflectors for the extraction were constructed with SUS304 and the metal O-ring because of no magnetic field around them and its largeness, respectively. There are several types of chambers depending on the value of the ramping speed of the magnetic field.

### A. Ceramic chamber

This type of chamber is used in the fast bump magnet that has ramping time of about 200μ second. Inner surface is coated with titanium metal of about 5 μm thickness to assure smooth flow of beam image current. The measured resistance was less than 1.0Ω and this value is consistent with thickness of the titanium layer. This fact indicates good electric contact between the kovar metal and the Ti coating.

### B. dipole chamber

To suppress field distortion of the dipole magnet due to eddy current, thin wall vacuum chamber of 0.3mm thickness reinforced with ribs has been developed. The chamber that is set with same curvature with the dipole magnet is shown in the figure 1a and the shape of the cross section is shown in the figure 1b.

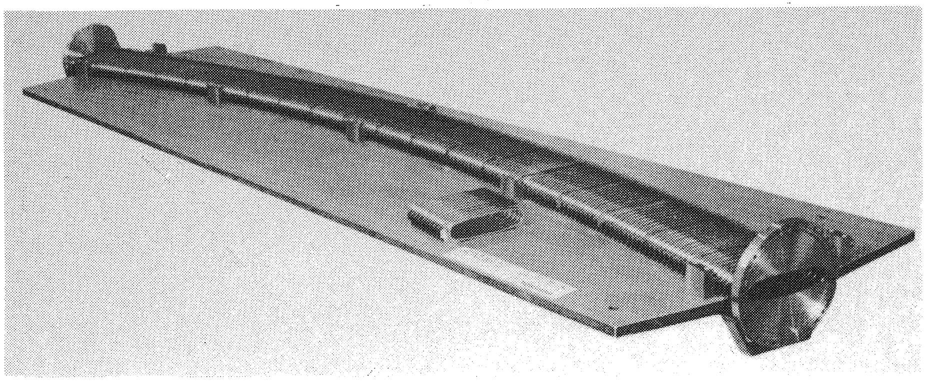

Figure 1a. One section of vacuum chamber set on a steel plate with the same curvature as the bending magnet.

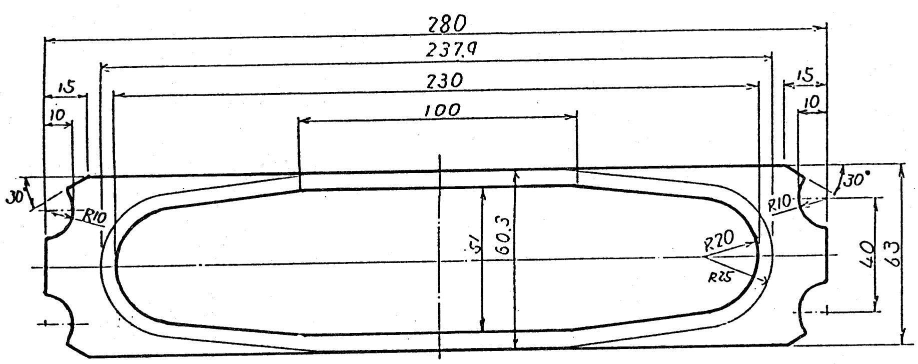


Figure 1b. Cross section of the dipole chamber.

The gap between the magnet pole and the rib is 1.5mm. Heating directly with the current of 270A in its chamber, we could bake this chamber up to 200°C in the test, and the measured out-gassing rate was $4\times10^{-14}$ torr l/sec cm$^2$ at $3\times10^{-8}$ torr with build up method after the baking.

C. Bellows chamber

Bellows chamber with race trace shape is used at the bump magnets that must be excited within 50m second to make bump orbit for the slow beam extraction just after the acceleration end.

III. Pumping system

As shown in the figure 2, the vacuum pumping system for one ring consists of 8 turbo-molecular pump (TMP) of 300 l/sec, 22 sputter ion pumps (SIP) of 400 l/sec, and 24 titanium getter pumps (TGP) of 800 l/sec. Pirani and cold cathode ionization gauges are used to monitor the vacuum pressure. The ring is divided into three sections that can be isolated with metal gate valves, and each section has a panel to control vacuum system in its section. To control and monitor easily with very few operators, the vacuum pressure and status of the pumps can be monitored in the control room with the computer graphics, and the vacuum pumps can be controlled from the control room; on-off of TMP and SIP, Ti-flash in TGP. To protect the high voltage devices of the inflector and the deflectors for the extraction, the power supplies are turned off automatically with vacuum deterioration (>$10^{-7}$ torr). If the ring pressure become higher than $10^{-5}$ torr, a neighboring pneumatic gate valve in the beam transport line is closed. In the case of higher pressure than $10^{-4}$, a gate valve of TMP is shut.

IV. Baking

To decrease the out-gassing rate, we have designed a baking system with the temperature of about 200°C. Three sets of baking control system control each one third of the ring. Four dipole chambers are connected in series and power supply of 350A and 50V maximum is used. The chambers that have same shape in one section are baked with the sheath heaters connected in series. Typical temperature pattern is as follows; Increment to 200°C with 16 hours, keeping with constant temperature about 100 hours, and decrement to normal temperature with 16 hours. Before baking the ring, obtained average pressure was $6\times10^{-8}$ torr after four days pump down by using the TMP's and the SIP's. After finished the baking, the obtained value was $1.1\times10^{-9}$ torr without TGP's, that was the satisfactory value to accelerate the required ion species in HIMAC synchrotron.

V. Acknowledgements

The authors are grateful to Dr. A. Mizobuchi and Mr. K. Chida for their advices concerning the system design.

VI. References

[1] Y. Hirao et al., "Heavy Ion Synchrotron for Medical Use," Nucl. Phys. A538, 541c(1992)
Y. Hirao et al., "Heavy Ion Medical Accelerator in Chiba, "NIRS-M-89, HIMAC-001, 1(1992)

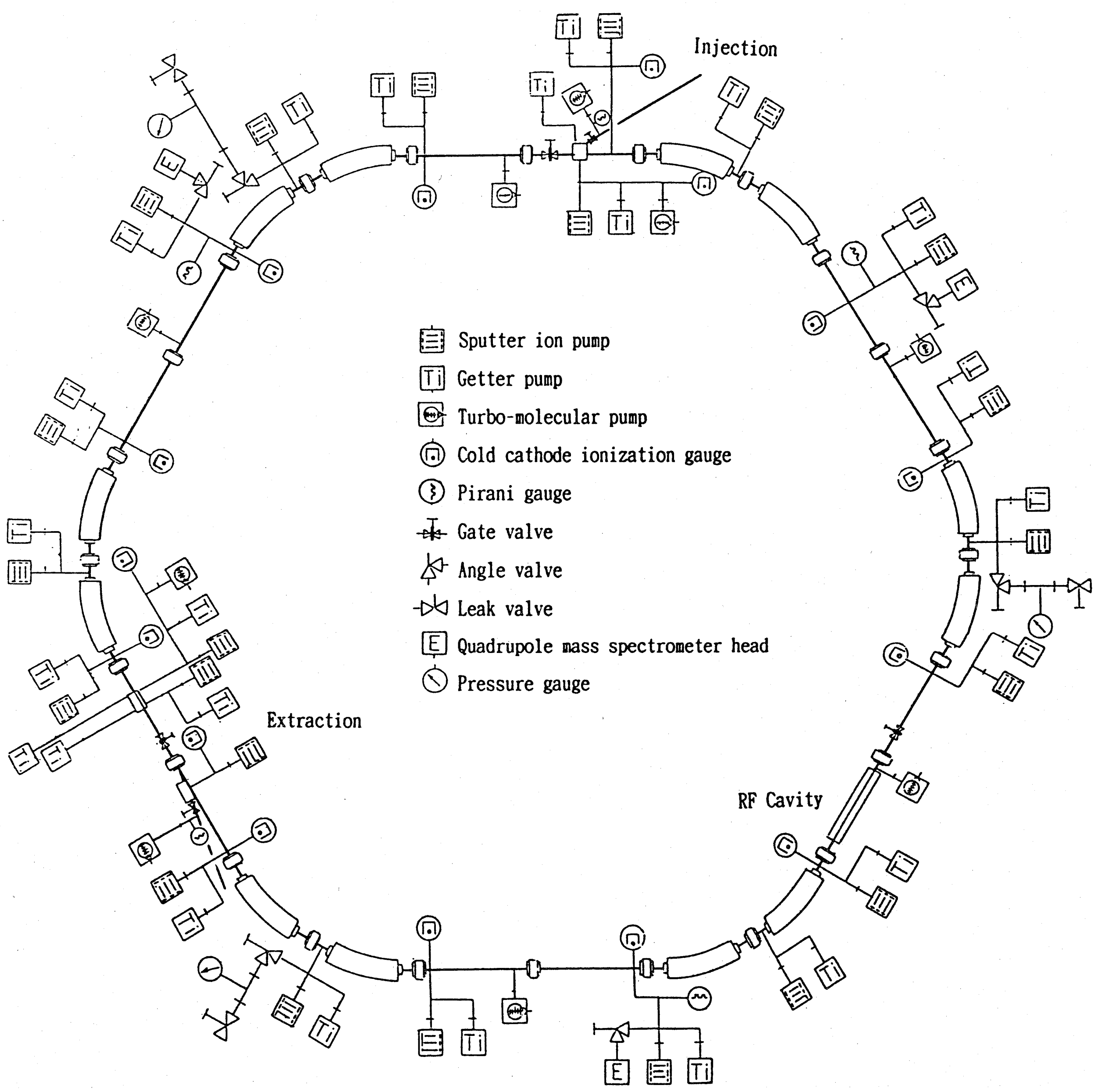


Figure 2. Layout of the vacuum system of HIMAC synchrotron.