

# VACUUM SYSTEM OF THE RCNP RING CYCLOTRON

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## ABSTRACT

Manufacturing and vacuum testing for the RCNP six-sector ring cyclotron is under way. The vacuum chamber of the cyclotron consists of twelve separate chambers connected by pneumatic expansion seals. The reliability of the seals was verified with the model studies. The system is evacuated by distributed cryopumps down to  $1 \times 10^{-7}$  Torr. Some of the RF cavity chambers and vacuum components have already been delivered to the site.

## INTRODUCTION

The ring cyclotron is a  $K=400$  energy quadrupler of the present AVF cyclotron.<sup>1)</sup> Beams extracted from the AVF cyclotron are transported through one of the beam lines of the present facility and injected into the ring cyclotron. The injection and extraction radii of the ring cyclotron are 2.0 m and 4.0 m, respectively.

The main components of the vacuum chamber of the six-separate sector cyclotron consist of 12 separate sections; these are 6 magnet chambers, 3 acceleration RF cavities, a flat-topping RF cavity chamber and 2 valley chambers.

These chambers are connected each other at their interfaces by pneumatic expansion seals which are requested to seal at different levels of magnet and RF cavity chambers.

The structure of the expansion seal is that two race-track shaped doughnut flanges are linked with a pair of bellows. These bellows are welded inside and outside edges of the doughnut flanges to form a closed vessel. The vessel is inflated by compressed air to seal connections and shrunk by evacuating it.

Though a large amount of out-gas would come from the pole faces and from the trim coil insulators, separation of these regions from acceleration space by vacuum tight membrane, which has been adopted by many cyclotron designers, is not realized due to narrow magnet gap and mechanical simplicity. Fig. 1 shows the plan view of the ring cyclotron.

The estimated out-gas load after 20 hours of evacuation is around  $2 \times 10^{-2} \text{ Torr} \cdot \text{l} / \text{sec}$  due mainly to the trim coil insulators. The whole assembling after installing internals and evacuation of the system is scheduled to be at middle of 1990 after magnetic field measurements in the site.

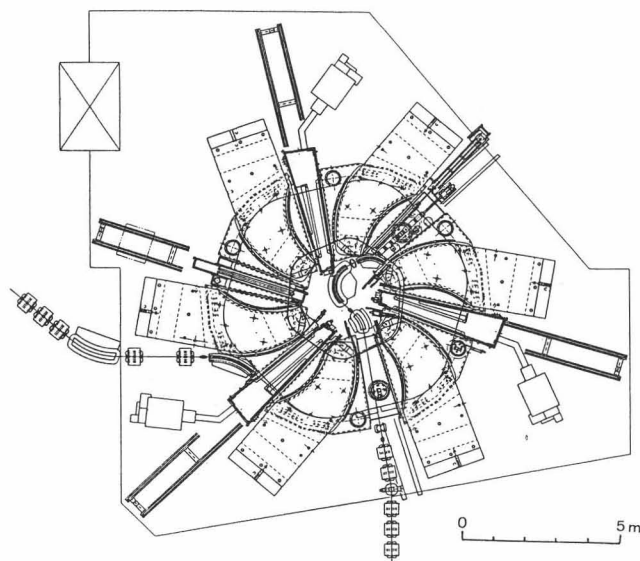


Fig. 1. Plan view of the ring cyclotron.

## VACUUM CHAMBERS AND CONNECTION

The magnet chamber is demountable structure by a lift of the upper yoke<sup>2)</sup>. The trapezoidal stainless steel plates which are welded directly to the side faces of the magnet pole as upper and bottom surfaces of the chamber tie up a monolithic side wall with elastmer gaskets. 36-pairs of trim coils, sandwiching poly-imide sheets, are fixed with screws to the pole faces. The surfaces of the copper trim coils are insulated by plasma sprayed ceramic coat (0.15 mm thick) and/or by poly-imide sheets. These are possibly the main source of the out-gas inside the cyclotron chamber.

These are exposed directly to the beam acceleration space. For the mechanical simplicity, the manufacturing design has not equipped the vacuum tight membrane to separate the pole face region. The feedthroughs of the trim coil current

leads are made of copper hollow conductors sealed by double O-rings with insulator flanges.

The RF cavity and the flat-topping cavity are single gap, variable frequency  $H_{101}$  mode resonators<sup>3)</sup>. These chambers are made of stainless steel plates by welding structure lined with water cooled copper plates. The resonant frequency is changed by rotating a pair of capacity plates for RF cavity whereas by sliding a pair of tuning panels. The copper skin of the tuning plates are sustained by aluminium and/or stainless frameworks. The side walls of the RF cavity chamber cannot withstand atmospheric pressure under evacuation, so these are supported by suspending on the rigid magnet chambers as shown in Fig. 2.

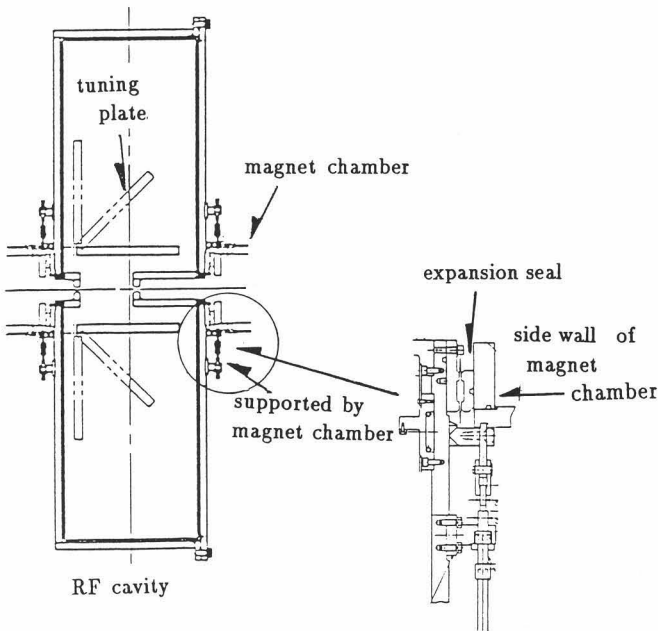


Fig. 2. Cross-sectional view of RF cavity connected with pneumatic expansion seal and suspended on the magnet chambers.

Main equipments of the injection and extraction elements such as magnetic and electrostatic channels, beam diagnostic devices are installed in the two valley chambers made of stainless steel. The magnetic channel coils are also insulated by alumina ceramic coat.

The beam injection line at center region of the cyclotron is connected directly to two valley chambers.

The seal material used is, in principle, elastmer gaskets whereas those in beam lines are metal seals considering radiation damage. The main characteristics of the vacuum chamber is listed in Table 1.

Table 1

Characteristics of the vacuum chamber  
12 separate chambers  
connected with pneumatic expansion seals

Diameter	inside outside	~ 3 m ~ 10 m
Height	Cavity section Valley section Magnet section	~ 3 m ~ 0.6 m ~ 0.4 m
Volume		~ 50 m <sup>3</sup>
Surface Area	Metals: Fe, SUS, Al, Cu, etc. inside vacuum Ceramic coat for Trim coils Poly-imide sheets Polymer, Elastmer gaskets, etc.	~ 1,000 m <sup>2</sup> ~ 120 m <sup>2</sup> ~ 180 m <sup>2</sup> ~ 4 m <sup>2</sup>
Feedthrough	Trim coils, cooling water pipes, beam diagnoses, etc.	~ 1,500

The cavity and valley chambers are to be withdrawn backwards along rails from the stationary position for the maintenance of the cavity and also for the installation of the injection channels and of the beam diagnostic devices in the central region.

In the restricted space around the connecting sections between chambers where the feedthroughs of the trim coil leads stand together in large numbers, working conditions are terrible. A sealing method between the vacuum chambers by a pneumatic expansion seal has been designed<sup>4)</sup>. The expansion seal is expected to absorb the acceptable dimensional tolerance; misalignment and deformation of each chamber under evacuation process. This is also expected to simplify the easy connecting and disconnecting works of the chambers.

#### PNEUMATIC EXPANSION SEAL

Two race-track shaped doughnut flanges (25 mm thick each) made of stainless steel are linked with a pair of single bellows to form a closed vessel. The bellows are made of 0.8 mm thick, 40 mm wide stainless steel sheets. The roots of the bellows were welded to the inside and outside edges of the seal flanges carefully avoiding thermal strain.

A feature of the designed expansion seal is to be able to connect two chambers with different level gasket positions



and free from the permanent strain of the seal surfaces by using the thick seal flanges. The essence of the design of the expansion seal is to verify the uniform compression of gasket along corners with required expansion stroke (6 mm) and the reliability for the repeated use.

A seal flange is fixed to the cavity or valley chamber flange with bolts whereas the another flange is movable smoothly to compress the seal gasket on the magnet chamber by expansion of bellow mechanism.

A prototype of the seal has been manufactured and vacuum tested. Fig. 3 shows the expansion seal attached to an evacuation bench.

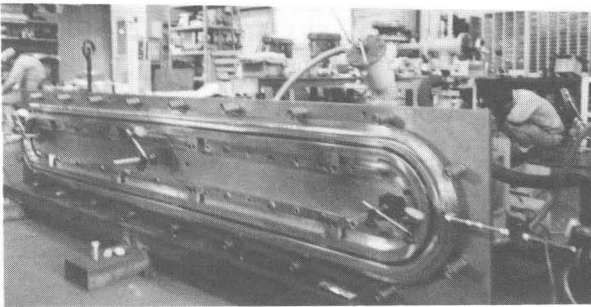


Fig. 3 Pneumatic expansion seal.

With the aid of guide bars not to be slanted by flange weight, the displacement of the movable flange is essentially

parallel to the fixed one both at straight and semi-circular sections. This verifies the uniform compression of the gasket. The flange is moved back by purge and evacuating the vessel. The average displacement of the movable flange is around 10 mm per  $1 \text{ kg/cm}^2$  pneumatic pressure though the hysteresis movements caused by non-elastic strain of the bellows sheets are observed.

The reproducibility of the seal performance was confirmed applying the pneumatic pressure of around  $1 \text{ kg/cm}^2$ .

## EVACUATION SYSTEM

The major source of out-gas inside the chambers is poly-imide sheets as well as ceramic coated surfaces of trim coils and magnetic channels. The out-gas rate measured by samples after 20 hours evacuation comes up to a few  $10^{-9} \text{ Torr} \cdot \text{l/sec} \cdot \text{cm}^2$ . Taking into consideration listed in Table 1, the total gas load amounts to  $2 \times 10^{-2} \text{ Torr} \cdot \text{l/sec}$ . The evacuation system, as shown in Fig. 4, is composed of three stages. Emphasis is put on the pumping down time of the intermediate pressure region as short as possible by distributing the diffusion pumps at each magnet chamber.

A roughing system, composed of rotary, mechanical roots, turbo-molecular pump evacuates the system down to  $10^{-4} \text{ Torr}$  in around 40 min, then the diffusion pumps with freon cooled chevron baffles works at intermediate pressure region. Six 20 inch cryopumps ( $10,000 \text{ l/sec}$  each for  $\text{N}_2$ ) are

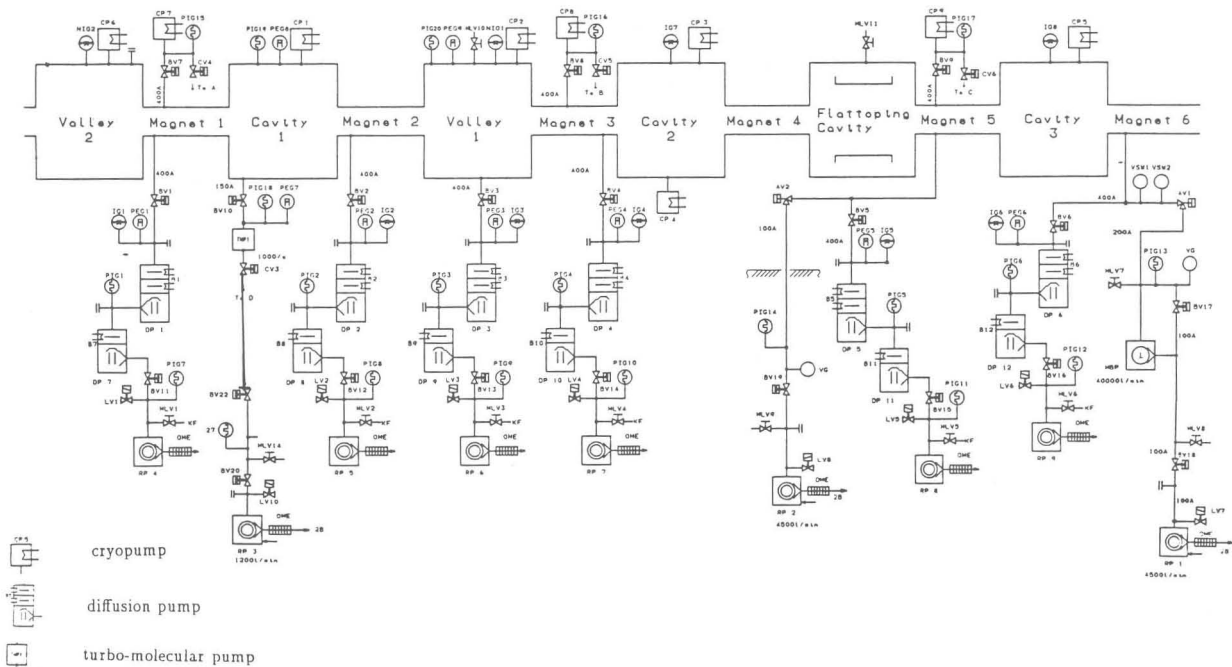


Fig. 4. Blockdiagram of the evacuation system.

mounted on RF cavities and valley chambers whereas three 16 inch (6,500  $\mu$  /sec each) are distributed at alternative magnet chambers. Cool down time of the cryopumps matches with the pumping down time of intermediate pressure. The estimated pumping down time from atmosphere to the operating pressure of acceleration for protons and alpha particles ( a few  $10^{-7} Torr$ ) is several hours whereas around 10 hours ( $\sim 1 \times 10^{-7} Torr$ ) for light ions.

#### PRESENT STATUS

Three of the six magnet chambers have been manufactured. After usual chemical cleaning, leak tests have been finished prior to installation of trim coils and other internals. After mounting trim coils, evacuation test has been made for these chambers. The out-gas rate measured is within the limit of estimation ( $1.1 \times 10^{-3}$  and  $2.6 \times 10^{-4} Torr \mu$  /sec with and

without trim coils, respectively),

Construction and assembling tuning panels of the RF cavity and flat-topping cavity is essentially completed. Evacuation tests have been cleared and some of the cavities have already been delivered to the site.

As for the valley chambers and remainder of the magnet chambers, the manufacturing is now in progress. These will be delivered by the end of this year.

#### REFERENCES

1. H. Ikegami, in these proceedings.
2. K. Hosono et al., *ibid.*
3. T. Saito et al., *ibid.*
4. A. Shimizu et al., in Proc. of 11th International Conf. on Cyclotrons and their Appl. Tokyo (1986) 207.