AN ALUMINIUM RF ACCELERATION CHAMBER FOR THE RING CYCLOTRON

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ABSTRACT

An RF acceleration chamber for the RCNP ring cyclotron was constructed and successfully excited. A square of 5 m × 4 m variable frequency acceleration chamber is made of monolithic of pure aluminium plate. The stiffness to withstand an atmospheric pressure is sustained by rib array of aluminium alloy.

Leak tight manufacturing and low outgassing made it possible to evacuate and overcome the electron multipactoring with a small vacuum pump. The installation of a large cryopump is under progress.

INTRODUCTION

An intermediate energy particle accelerator complex has been designed as a new facility at RCNP[1]. As for the construction and power excitation of an RF cavity is described elsewhere[2].

The cavity, placed between the powerful electromagnets, should be of magnetic neutrality. The cavity, wherein particles are accelerated, whereby the vacuum chamber is composed, should be made of materials suited to the following characteristics;

low magnetic susceptibility,
resistance to neutron radiation damage,
fast decay time of the induced radioactivity,
high conductivity of electricity and heat,
mechanical stiffness to withstand an atmospheric pressure,
low outgassing rate from vacuum surface,

The candidates for the cavity materials studied other than aluminium were the copper clad onto stainless steel and copper clad onto high manganese steel, but these were excluded mainly by the long decay time of radioactivities and poor machinability and relatively high material cost.

The choice of aluminium as cavity materials has advantage such as low specific weight, resistance to corrosion, and good machinability and weldicity with economical construction cost apart from the above mentioned characteristics.

The construction of a large vacuum chamber offeres aluminium a significant field of application and industrialization. Fig. 1 shows a schematic drawing of the ring cyclotron.

The cavity has horizontal central slits through which to let the particles pass. The sealing at the slits with magnet chamber is made by elastmer gaskets using a pneumatic expansion seal to absorb the mechanical distortion by the evacuation of the large cavity.

The range of the variable frequency (20 ∿ 33 MHz) is tuned with the rotatable tuner plate mounted on the stock cantilevered on the midplane flange. The copper skin of the stock and the tuner plate is sustained by stainless steel and aluminium structures.

To prevent collisions of accelerated particles with residual molecules, and also to overcome electron multipactoring at RF excitations, the cavity should be evacuated down to 10^{-7} Torr region.

The dimensions and the surface area of the cavity are listed in Table 1.

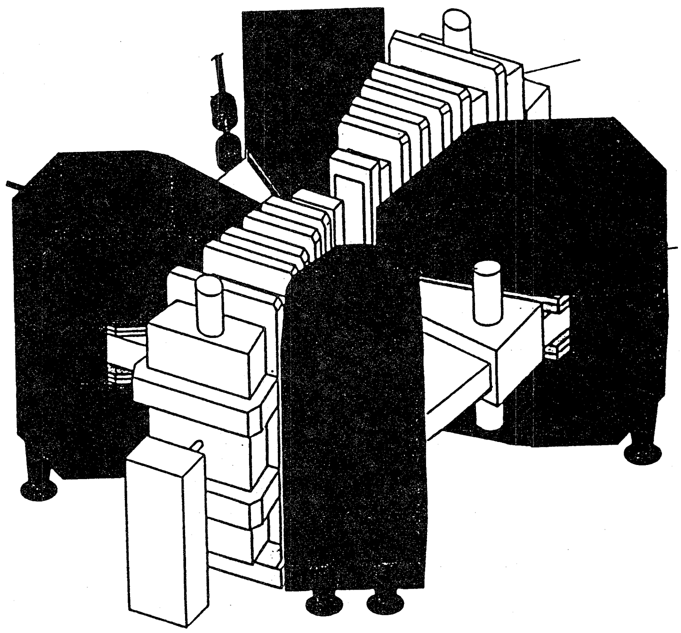


Fig. 1. Schematic drawing of the ring cyclotron.

Table 1

Cavity dimensions and surface area under vacuum

Length		5 m
Height		4 m
Width		0.4 ∿ 2.2 m
Volume		25 m^3
Surface Area		
Cavity chamber		
	Aluminium (A1070)	75 m^2
	Elastmer gasket	50 m × 2 mm
Tuning plate and stock		
	Copper	50 m^2
	Stainless steel	15 m^2
Feedthrough cooling pipe		
	Polyamid	30 m × 5 cm
Total weight		25 Ton

CONSTRUCTION OF THE CAVITY CHAMBER

Prior to the construction of the large cavity chamber, a small chamber ($0.6 \times 0.6 \times 0.6$ m^3) was made to test the welding technique of 50 mm thick aluminium plates, polishing and cleaning processes of the surfaces. Also the check technique of the defect of the welding seams has been studied using the ultrasonic and X-ray inspections.

The outgassing rate of the pure aluminium plate was measured using the test chamber to be around 5×10^{-6} Torr·ℓ/m^2·sec without any special chemical treatments of surface and baking.

As the cavity chamber, pure aluminium plates (A1070) were used because of the good electric and thermal conductivities and anti-corrosion advantages. The cavity is reinforced by box type ribs made of anti-corrosion aluminium alloy (A5052) directly welded to the cavity wall, to withstand an atmospheric pressure of 200 metric tons. The welding was made by several layers of MIG methods using an automated machine though the inner corner of the chamber was welded manually. Several flanges and suction ports were also made of A5052 alloy and double seams were used for critical sections to check the helium tightness.

After inspections of the welding defects using the ultrasonic and X-ray methods, the mechanical distortions of the large cavity due to welding stresses were reformed by pressings. Finally, the cavity flange were machined and grooved by milling machine to get the dimension accuracy.

Fig. 2 shows a photograph of the cavity. The drawing of the cavity is shwon elsewhere[2]. The inner surfaces of the cavity exposed to the vacuum were polished with 250 mesh buff, degreased and rinsed with a neutral detergent.

Preliminary evacuation test of the cavity prior to installing the tuner plate was made using a 10 inch diffusion pump. Helium leak tests proved the total leak was well below 7×10^{-5} Torr·ℓ/sec and a few defects were rewelded. The achieved pressure was below 1×10^{-6} Torr and degassing rate of the cavity after 20 hours evacuation was estimated to be about 7×10^{-6} Torr·ℓ/m^2·sec.

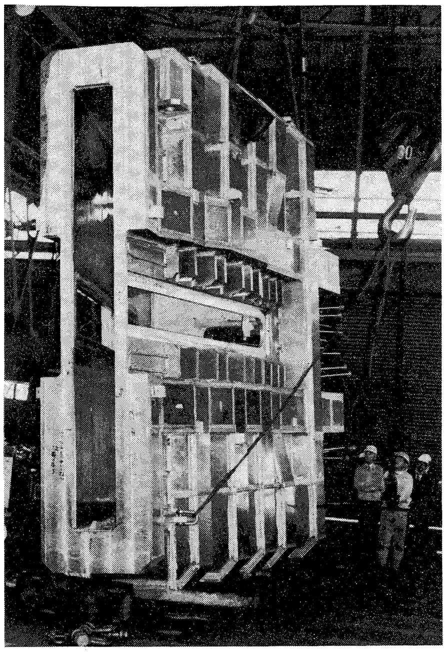


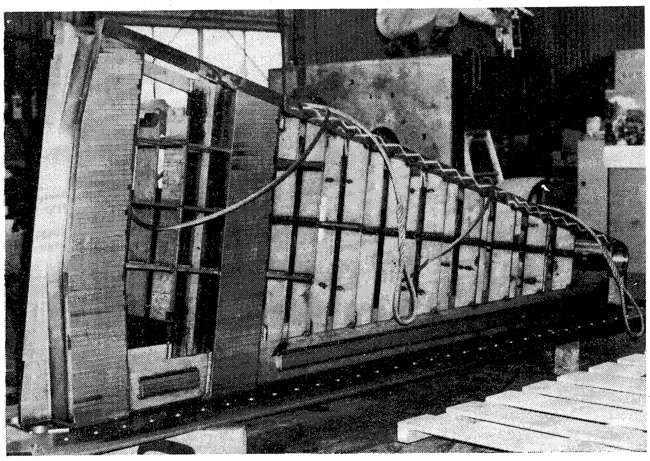
Fig. 2. Photograph of the aluminium chamber.

INSTALLATION OF THE TUNER PLATE

The tuner plate to change the resonant frequency mounted on the stock rotates around a rotating shaft. The skins of these structures which are sustained with screws by stainless steel framework as shown in Fig. 3 and acceleration gap electrodes are made of oxigen free copper. Water cooling pipes are soldered to these copper skins in the interior of the framework. The cooling pipes and the driving powers of the tuner plate are fed through the rotating shaft of the tuner plate.

For the flexibility of the tubing for the remountable skin copper plates and also for the limited space of the rotating shaft, polyamid tubes instead of metal bellow tubes are used for the feedthrough sections. Total length of about 30 m of the 15 mm diameter of the polyamid tube is a considerable outgassing source of the tuner plate especially on the RF excitations.

The assembled tuner plate was installed in the cavity chamber through the front window of the chamber as shown in Fig. 4.



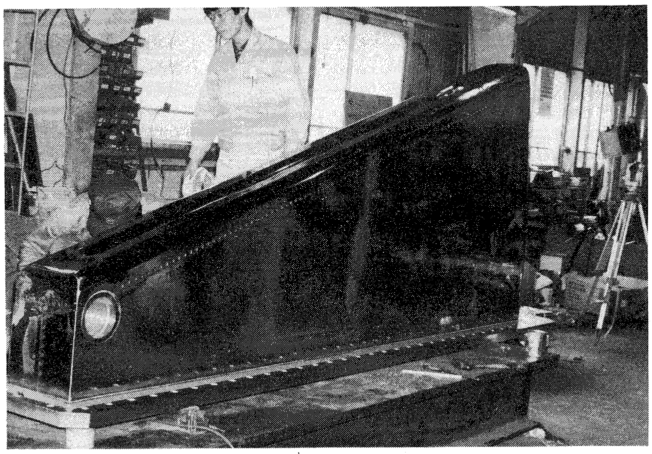


Fig. 3. Photograph of the stock of the tuner plate.
upper: Stainless steel framework.
lower: Covered with the copper skin.

EVACUATION OF THE CAHMBER

The cavity chamber of 25 m^3 was evacuated by a roughing pump system of 6,000 ℓ/min. Kenney and 25,000 ℓ/min. mechanical booster pump. About 50 min. of pumping down time makes the chamber down to 10^{-3} Torr region. The distortion of the chamber wall due to atmospheric pressure was measured at several points. The maximum displacement at midplane slit flange was 1.75 mm which remains the designed tensile force of around 2 kg/cm^2 for the pure aluminium chamber wall.

As an intermediate pressure region evacuation, a 10 inch diffusion pump system with cold trap has been equipped at the rear port of the chamber. The pumping down curves at cavity chamber and at pump head showed that a huge condensable gas load equilibriated at 2×10^{-5} Torr inside the chamber though 10^{-7} Torr region at the pump head. The mass analysis of the residual gasses and the gas chromatograph analysis of the condensed compounds on the cold trap revealed that the degrease of the tuner plate was incomplete. So the tuner plate was disassembled, then the framework and tuner plate, especially the interior side of the framework, were recleaned with flourine solvent.

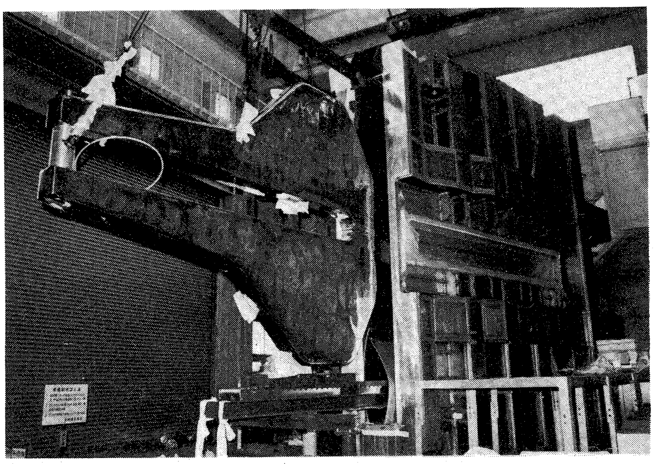


Fig. 4. Rotatable tuner plate being installed into the cavity chamber.

A 30 cm diameter LN_2 cold trap was mounted at the upper suction port where a large cryopump is to be equipped. Together with the diffusion pump, this is effective to trap condensable gasses. Though the outgassing rate is still sensitive to the ambient temperature, the typical gas loads of the condensable and incondensable components are 2×10^{-3} and 1×10^{-4} Torr·ℓ/sec, respectively, from build up measurements after 20 hours evacuation. The achieved cavity pressure with this pumping system is 1.2×10^{-6} Torr at 3 m distance from the pump suction.

The RF power test of the cavity was made at 22.5, 25.2 and 30.5 MHz.[2] During the aging of the multipactoring, the outgassing rate grew 3 ∿ 5 times of that of the off power state. Overcoming the multipactoring, the cavity was successfully excited still above 200 kV with around 3×10^{-6} Torr.

The installation and cooldown test of a 22 inch cryogenic pump (9,000 ℓ/sec for air) is under progress.

REFERENCES

1. I. Miura et al., RCNP Ring Cyclotron. (in these proceedings)
2. T. Saito et al., An Aluminium RF Cavity for the Ring Cyclotron Project. (in these proceedings)