PNEUMATIC EXPANSION SEAL OF THE SEPARATE SECTOR CYCLOTRON VACUUM CHAMBER

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Summary

A pneumatic expansion seal which connects and seals the interface of the separated vacuum chambers of a ring cyclotron has been designed. The model tests verified the feasibility of the seal performance for the repeated use.

Introduction

An intermediate-energy ring cyclotron has been designed as a cyclotron cascade project at RCNP[1].

The vacuum chamber of the six-separate sector cyclotron consists of 12 separate sections, these are 6 magnet chambers, 3 RF cavity chambers, a flat topping RF cavity chamber and 2 valley chambers. These chambers are sealed 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 shape doughnut flanges which compress the elastomer gaskets are linked with a pair of bellows welded inside and outside edges of the flanges to form a closed vessel. The vessel is inflated by compressed air and shrinked by evacuating it. The design goal of the expansion stroke is 6mm for a 3m long expansion seal. A small scale model of the system is designed, manufactured and tested to verify the seal characterstics and the mechanical performance.

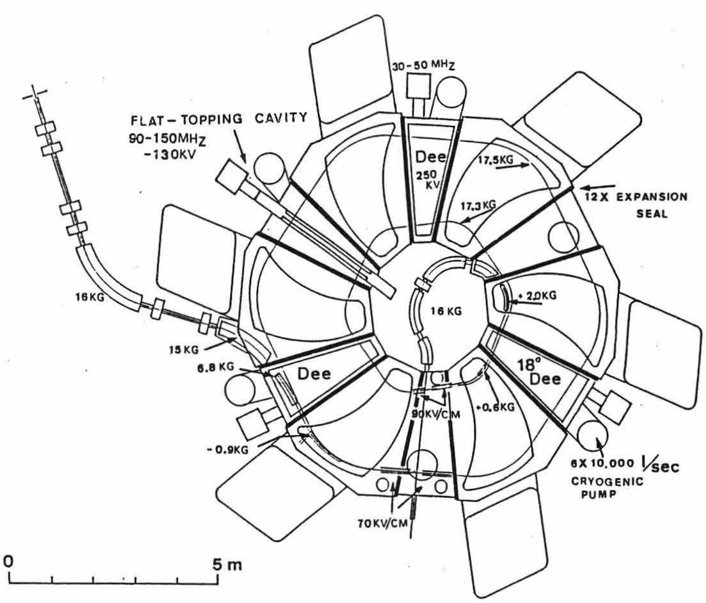

Fig. 1. Plan view of the RCNP ring cyclotron project.

Vacuum Chamber

The magnet chamber is demountable structure by a lift of the upper yoke. The trapezoidal stainless steel plates which are welded directly to the magnet poles tie up a side wall with elastmer gaskets. 35 pairs of trim coils are fixed to the pole faces. The trim coils are insulated by ceramic coating and/or by polymer sheets which are possibly the main source of the out-gas inside the cyclotron chamber.

The feedthroughs for the trim coil current leads stand together in large numbers along the chamber interfaces.

The RF cavity has a delta type 1/2 λ mode acceleration electrode whereas the flat topping cavity is a single gap H_{101} mode resonator[2]. These chambers are made of copper clad stainless steel. A plan view of the ring cyclotron is shown in Fig. 1 and the main characteristics of the vacuum chamber is listed in Table 1. The estimated out-gas load after 20 hours of evacuation is around 2×10^{-2} Torr•ℓ/sec.

Table 1

Main characteristics of the vacuum chamber

12 separate chambers
connected with pneumatic expansion seals

Diameter	inside	3 m
	outside	10 m
Height	Cavity section	4 m
	Valley section	0.5 m
Volume		80 m^3
Surface Area inside vacuum	Metals: Fe, SUS, Al, Cu etc.	1000 m^2
	Insulation Sheet for Trim Coils	200 m^2
	Polymer, Ceramic, elastmer etc.	3 m^2
Feedthrough	Trim coil, cooling water etc.	500 pairs

The RF cavity chamber is to be withdrawn backwards 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 working conditions is terrible, a sealing method between the vacuum chambers by a pneumatic expansion seal is considered. The expansion seal is expected to absorb the reasonable dimensional tolelance and deformation of each chamber under evacuation process. This is also expected to simplify the easy connecting and disconnecting works of the chambers.

The magnet and RF cavity design requires the seal gasket positions at different levels. The cross-sectional view of the connecting section between the magnet and RF cavity chambers sealed with a designed pneumatic expansion seal is shown in Fig. 2.

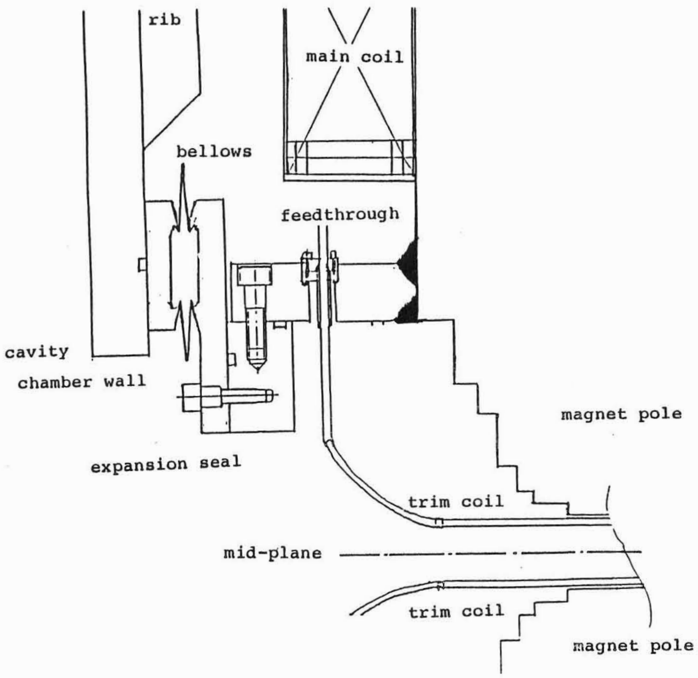

Fig. 2. Cross-sectional view of the pneumatic expansion seal between the magnet and RF cavity chambers.

A seal flange is fixed to the magnet chamber flange with bolts whereas the another flange is movable smoothly to compress the seal gasket on the RF cavity chamber by expansion bellows mechanism.

Pneumatic Expansion Seal

The required aperture of the full scale expansion seal is around 2.6m long and 0.3m high. The essence of the design of an expansion seal is to verify the uniform compression of gasket along corners with required expansion stroke and the reliability for the repeated use. A scale model of 1.2m long has been designed and manufactured.

Two race-track shape doughnut flanges (25mm thick each) made of stainless steel are linked with a pair of single bellows to form a closed vessel. The bellows are made of 0.8mm thick, 40mm 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 special 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.

Figure 3 shows the drawing of the scale model and Fig. 4 is a photograph of the manufactured expansion seal.

Test Results

One of the seal flange was fixed to a chamber wall with bolts prior to the inflation of the bellows. Displacement of the movable flange was measured along the surface positions introducing the compressed air through an air inlet hole to the closed vessel.

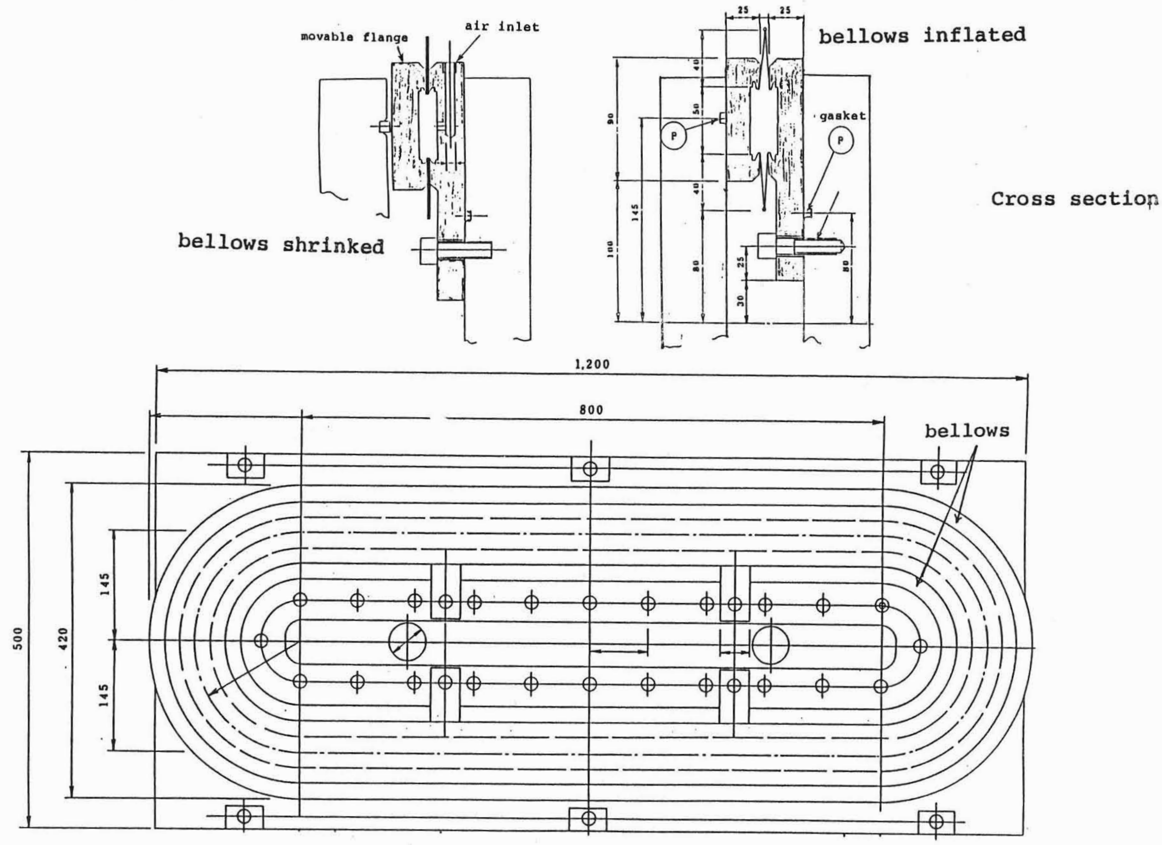

Fig. 3. Scale model of the pneumatic expansion seal.

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 position dependence of the displacement of the flange inflating the bellows up to 0.8 kg/cm^2 is shown in Fig. 5. The results show the average expansion rate is around 10mm per 1 kg/cm^2 pneumatic pressure though the hysterisis movements caused by non-elastic strain of the bellows sheets are observed in the model.

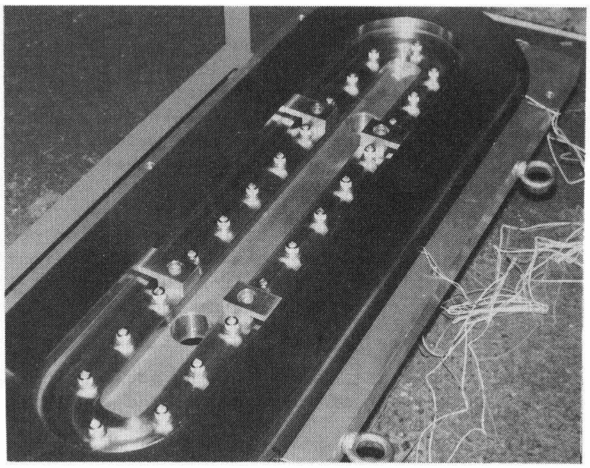

Fig. 4. Photograph of the expansion seal.

The distributions of the strains (radial and azimuthal) of the bellows sheet were measured by strain gauges. Radially, the compression strain of $(3{\sim}4)\times10^{-3}$ is observed under 8mm expansion stroke near welded edges.

The seal performance of the model was tested using a evacuation bench. The repeated tests confirmed the reproducibility of the perfect seal in the expansion stroke of 8mm applying around 1 kg/cm^2 pneumatic pressure. The seal tests under the unparallel stroke conditions were also performed. Unparallel stroke upto 3mm for the 1.2m long model expansion seal is practically feasible.

References

1. I. Miura et al., "Peoposal for Cyclotron Cascade Project" in these Proceedings.
2. T. Saito et al., "RF System of RCNP Ring Cyclotron Project" ibid.

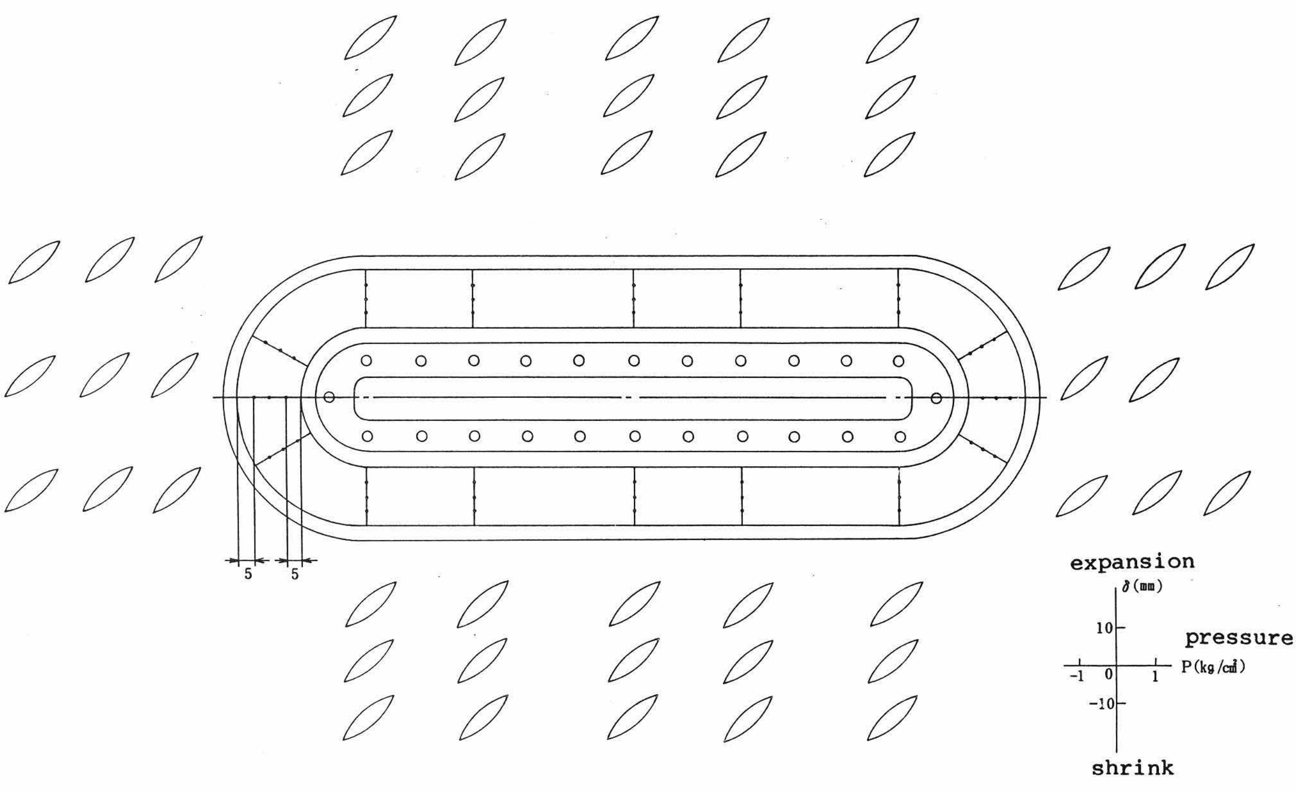

Fig. 5. Hysteresis displacement of the movable flange vs. pneumatic pressure (-0.5 ~ +0.8 kg/cm^2) of the expansion seal.