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DESIGN OF THE SECTOR MAGNET FOR THE RCNP RING-CYCLOTRON

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ABSTRACT

A Separated-Sector Cyclotron (Ring-Cyclotron) has been designed as a post accelerator for the RCNP-AVF cyclotron. The general design specifications of the sector magnet are outlined in this paper.

SIX SPIRAL-SECTOR GEOMETRY

We have designed the sector magnet under the following conditions. (1) The injection radius is 200 cm because we will use the existing AVF cyclotron as the injector, which has an extraction radius of 100 cm. In order to accelerate protons to 400 MeV, protons of 65 MeV, are injected into the ring cyclotron. (2) In the acceleration, the vertical betatron frequencies (ν_z) for the various ions and energies should be always larger than 1.0. (3) The maximum magnetic flux density of the sector is set to 17.5 kG and the magnetic gap width is 60 mm, in order to reduce the total weight of the magnet.

Table 1 Design parameters of the spiral-sector magnet

Number of sector magnet	6
Sector angle	22°~27.5°
Gap width	60 mm
Height of magnet	5.26 m
Overall diameter	14.4 m
Total weight	~2100 tons
Injection radius	2 m
Extraction radius	4 m
Maximum magnetic field	17.5 kG
Maximum ampere turns	1.4×10^5 A·T
Maximum current	950 A
Maximum power	440 kW
Number of trim coils	36 pairs×6
Maximum current	500 A
Total trim coil power	~350 kW

The six spiral-sector geometry has been adopted on the basis of the above conditions. We calculated the field maps of the various spiral sector magnets in order to get the desired field profiles and the desired orbit properties. Fig. 1 shows the calculated radial and vertical focusing frequencies and the isochronous fields for the maximum energies for various ions. Fig. 2 shows the equilibrium orbits. The final parameters of the sector magnet have been determined from the analyses of the magnetic properties and the orbit calculations. Table 1 lists the design parameters of the spiral-sector magnet. The maximum magnetomotive force is estimated to be 1.4×10^5 ampere-turns for the maximum field of 17.5 kG. The maximum power consumption of the main coils is estimated to be 440 kW. Each sector magnet is about 5.5 m in length and 5.26 m in height. The weight is about 350 tons. The shape and geometrical size of the sector magnet are shown in Fig. 3.

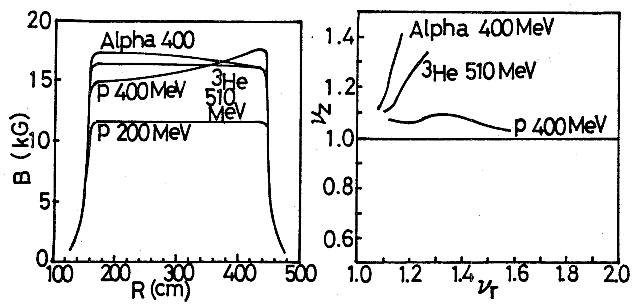

Fig. 1. Calculated radial and vertical focusing frequencies and isochronous fields for the maximum energies for various ions.

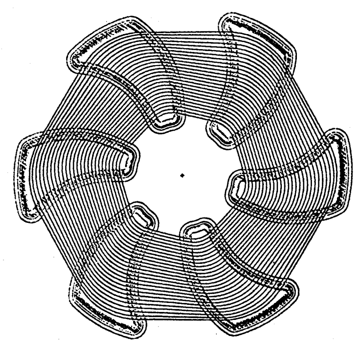

Fig. 2. Equilibrium orbits.

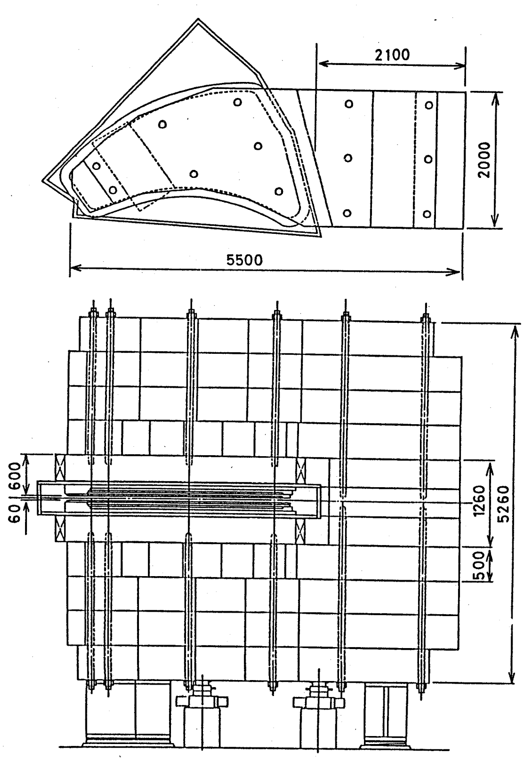

Fig. 3. Shape and geometrical size of the sector magnet.

YOKE AND POLE

The upper and lower yokes will be divided into four pieces, respectively. Each piece of the yokes is 500 mm in thickness and will be made of low carbon (~0.02%) rolled iron. The pole pieces will be made of low carbon (~0.005%) forged iron. The radial pole edges are shaped stepwise, which is nearly equal to a Rogowski's curve. The ratio of the cross-sectional area of the yoke to the area of the pole base is about 1.14. Fig. 4 shows the shape and geometrical size of the pole. The sector angle is 22°~27.5°. A vacuum chamber made of SUS is welded at the side faces of poles.

COILS

For one pole, the main coil and the coil which makes compensation for th magnetic field excited by the main coils will consist of 80 turns and 20 turns of hollow copper conductors, respectively. The sizes of hollow conductors are shown in Fig. 5. We can control the magnetic field of 500 Gauss at the maximum by the compensation coils. The hollow conductors insulated by glassfiber tapes will be reinforced with epoxy resin. Fig. 5 shows the cross-sectional view of the coils. The maximum current densities of the conductors are 2.7 A/mm^2 for the main coil and 1.6 A/mm^2 for the compensation coil.

We have calculated the effective fields of tril coils by the code "TRIM" in order to determine the trim coil configuration and the required currents. Using the calculated effective fields, we have made computer optimization to reproduce isochronous fields for various ions and energies. The trim coils which are mounted onto the pole faces are 36 pairs. Two pairs among them are also used for harmonic coils. They have a shape of hard-edge pattern of the equilibrium orbit and are made by copper-plates of 10 mm in thickness. We use three kinds of width, which are 40 mm, 60 mm and 80 mm. A hollow-conductor is welded into each copper-plate for current lead and cooling. The configuration of the trim coil and the cross section are shown in Fig. 6. Each trim coil is coated with alumina-ceramics for insulation and is fixed on the pole face by SUS-Fe welded bolts.

We have arranged to measure the magnetic fields preliminarily in the Spring, 1989. The detailed design of the field measuring system is now in progress.

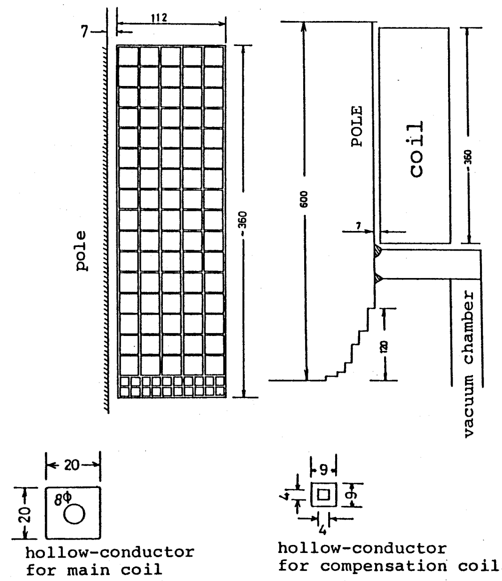

Fig. 5. Cross-sectional view of the main and compensation coils.

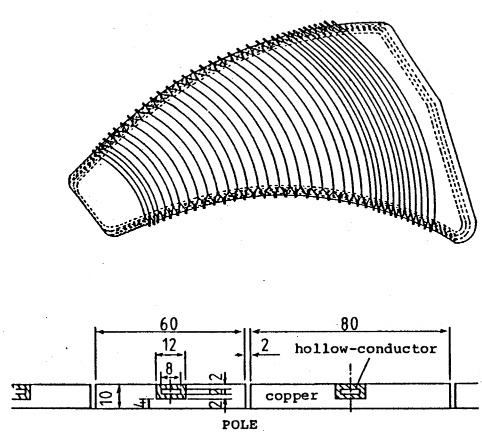

Fig. 6. Configuration and cross section of trim coils.

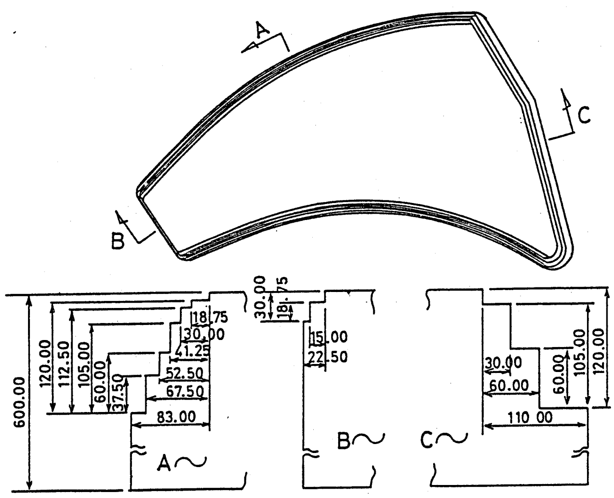

Fig. 4. Shape and geometrical size of the pole.