MAGNETIC SYSTEM OF THE RCNP RING-CYCLOTRON

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ABSTRACT

A Separated Sector Cyclotron (Ring Cyclotron) has been designed as a post accelerator for the existing AVF cyclotron and is being constructed at RCNP. The main magnet system of the ring-cyclotron consists of six spiral sector magnets. Final design characteristics of the sector magnet are outlined in this report.

INTRODUCTION

The sector magnets have been designed under the following condition. (1) The injection radius of the ring- cyclotron is 200cm, because the existing AVF cyclotron of the extraction radius of 100cm is used as the injector. (2) In order to accelerate protons up to 400 MeV, about 65 MeV protons are injected into the ring-cyclotron. (3) In the acceleration, the vertical betatron frequencies (ν_z) for various ions and energies are always larger than 1.0. (4) The maximum magnetic field is set to 17.5 kG and the magnetic gap width is 60mm, in order to reduce the total weight of the magnet.

We calculated the field maps of the various sector magnets in order to obtain the desired field profiles and the desired orbit properties. The six spiral-sector geometry[1] has been adopted for the satisfaction of the above conditions. Fig. 1 shows the calculated radial and vertical betatron frequencies (ν_r and ν_z) and the isochronous fields for maximum energies of various ions.

POLE AND YOKE

The final parameters of the spiral-sector magnet are listed in Table. 1. The shape and the geometrical size of the magnet are shown in Fig. 2. The weight of one sector magnet

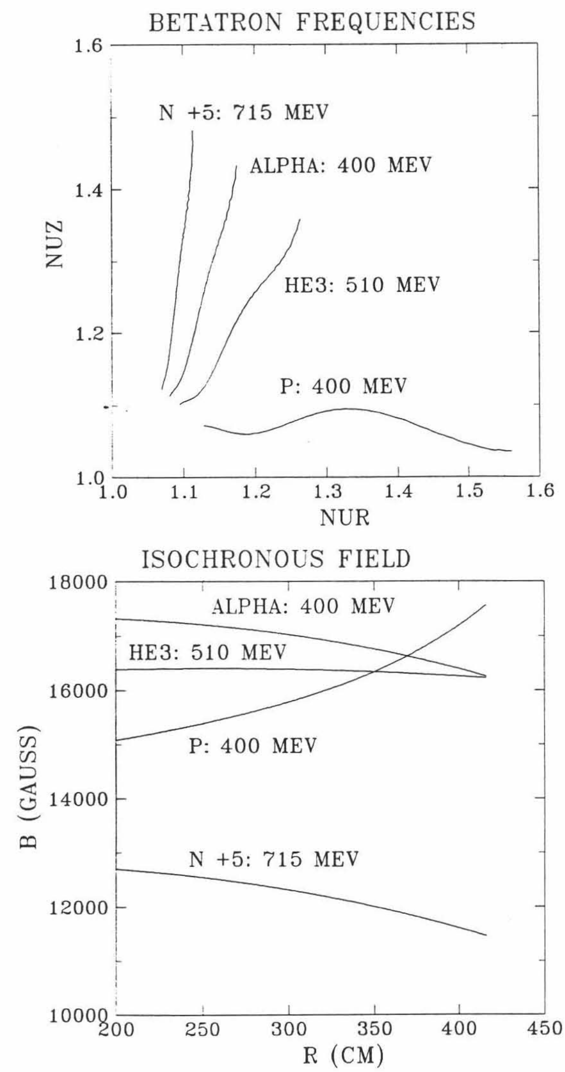

*Fig.*1 Calculated radial and vertical betatron frequencies and isochronous fields for the maximum energies of various ions.

is about 360 tons.

The radial pole edges are shapes stepwise, which is nearly equal to a Rogowski's curve. The yoke is divided into 11 slabs with maximum thickness of 500 mm. The ratio of the cross-sectional area of the yoke to that of the pole base is 1.14. Very homogeneous forged ion with carbon content less than 0.004% for the poles and rolled iron with carbon content less than 0.002% for the yokes have been produced by Sumitomo Metal Industries Ltd.. Fig. 3 is a photograph of a yoke slab for the first magnet. An example of the specification of the steel is listed in Table 2.

A vacuum chamber made by SUS (μ <1.01) is welded at the side faces of the pole. Fig. 4 shows the detailed cross sectional view of the pole edge section.

MAIN AND AUXILIARY COILS

The maximum magneto-motive force is estimated to be about 1.4×10^5 ampere-turns to obtain the maximum field strength of 17.5 kG. The main coil and the auxiliary coil consists of 80 turns and 20 turns of copper hollow conductors, respectively. We can control the magnetic field of 500 Gauss at the maximum by the auxiliary coil. The sizes of the hollow conductors are shown in Fig. 5. Fig. 5 also shows a photograph of the main coil. The hollow conductors insulated by glassfiber tapes are reinforced with epoxy resin. The maximum current densities of the conductors are 2.7 A/mm^2 for mail coil and 1.6 A/mm^2 for the auxiliary coil. The coils are located outside of the vacuum chamber. The maximum current of the main coil is 900A and the maximum power is 440 kW.

TRIM COILS

We have calculated the effective fields of trim 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 shapes of hard-edge pattern of the equilibrium orbit and are made by copper-plates of 8mm in thickness. A hollow conductor is welded into each copper-plate for current lead and cooling. Each trim coil is coated with alumina-ceramics (Al_2O_3) for insulation and is fixed on the pole face by SUS-Fe welded bolts to reduce the magnetic perturbation due to

Table 1
Final design parameters of the spiral-sector magnet

Number of sector magnets	6
Sector angle	22° ~27.5°
Gap width	60 mm
Height of magnet	5.26 m
Overall diameter	14.4 m
Total weight	~2200 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	900 A
Maximum power	440 kW
Number of trim coils	36 pairs×6
Maximum current	500 A
Total trim coil power	~350 kW

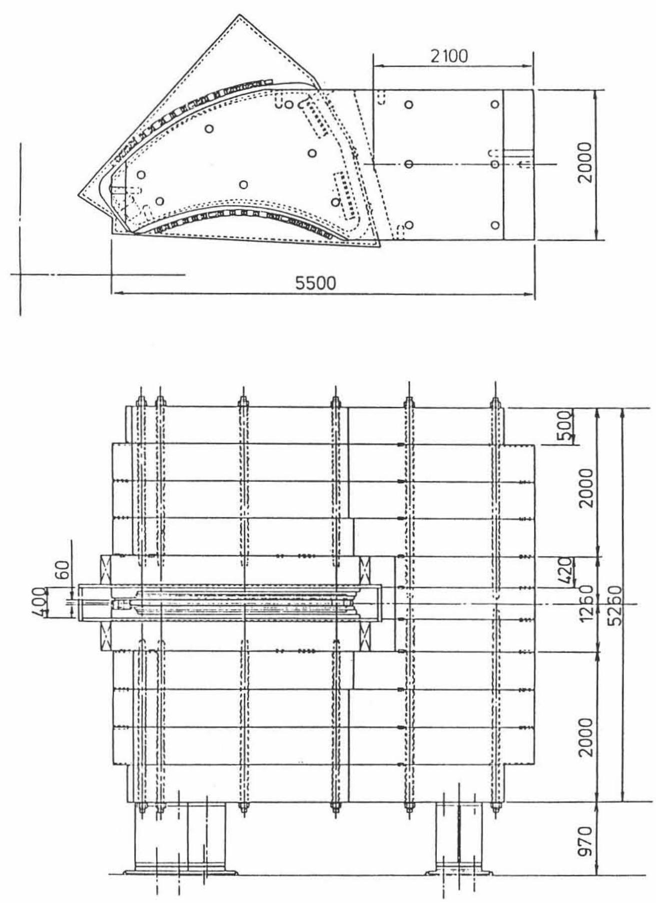

*Fig.*2 Shape and geometrical size of the sector magnet.

bolt holes. The configuration of the trim coils and the cross section are shown in Fig. 6. Power supplies of forty-six are used for the trim coils and the harmonic coils. These poewr supplies are housed in 8-cubicles. The total maximum power is estimated to be about 350 kW. Fig. 7 shows a photograph of trim coils.

The final design of a measuring equipment of the field maps is completed. Twenty Hall generators arranged radially are used for the measurement. The measuring system and all power suplies are controlled by a computer (VAX). We can measure filed maps with the azimuthal interval of 0.4° step and with the radial interval of 5mm step over the whole region.

Fabrication of the sector magnets and the measuring equipment is progressing at Sumitomo Heavy Industries Ltd. (SHI). Preliminary field measurment in order to finalize pole shape is started using two sector magnets at the work-shop of SHI, in June, 1989.

Installation of the magnet system at RCNP will started in December, 1989.

REFERENCE

1) K. Hosono, I. Miura, Y. Misaki and M. Kibayashi; Proc. 11th Conf. on Cyclotron and their Appli. (Tokyo 1986), p.296.

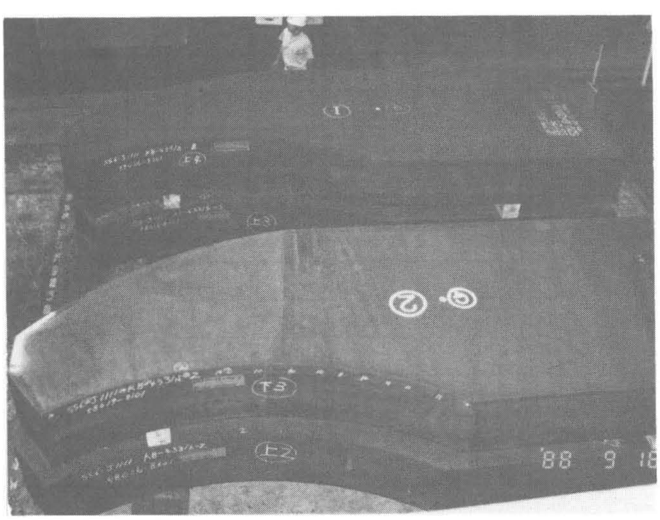

*Fig.*3 Photograph of yoke slab (500 mm thickness) for the sector magnet.

Table 2
Chemical Compositions of the low carbon steel
(weight percent)

	C	Al	Si	Mn	P	S	Cu
Pole	0.004	0.039	0.04	0.10	0.003	0.005	0.02
Yoke	0.002	0.029	0.02	0.10	0.003	0.003	0.02

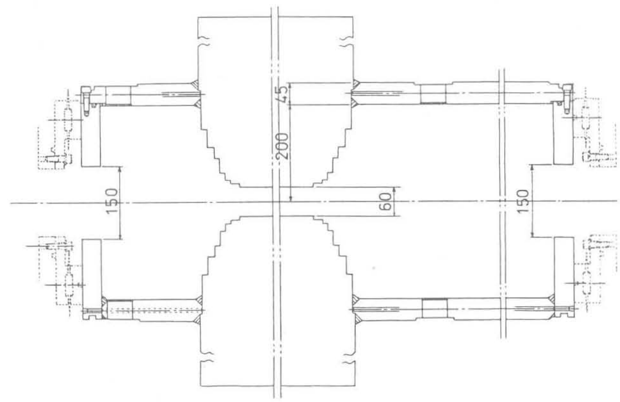

*Fig.*4 Cross sectional view of the pole edge section.

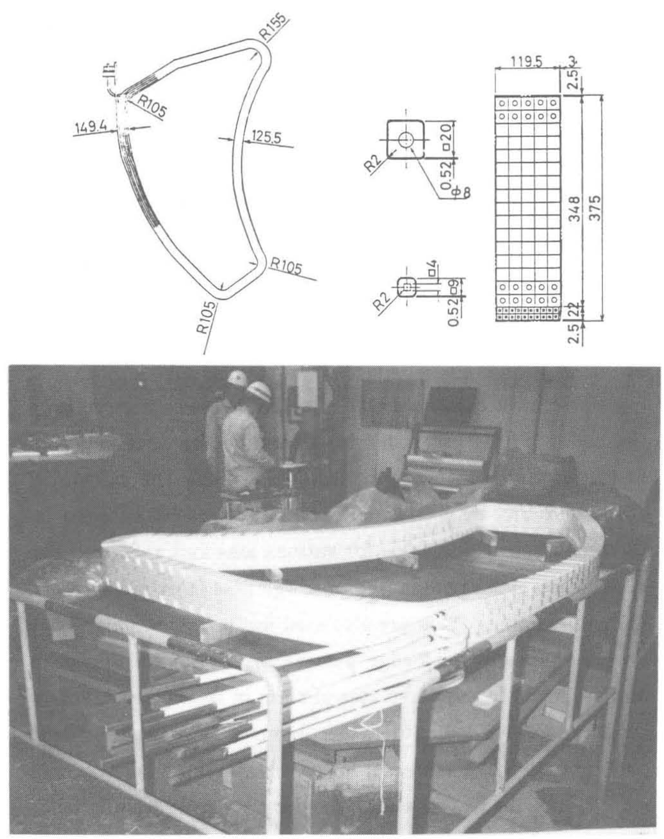

*Fig.*5 Main and auxiliary coils, and photograph of the main coil.

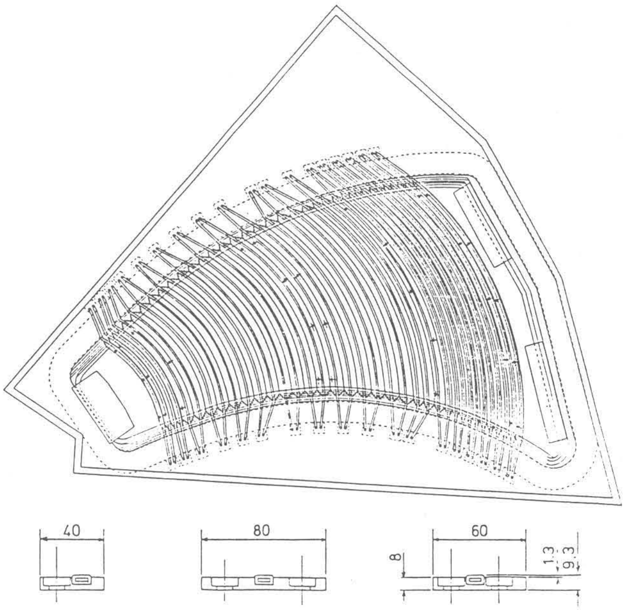

*Fig.*6 Configuration and cross section of the trim coils.

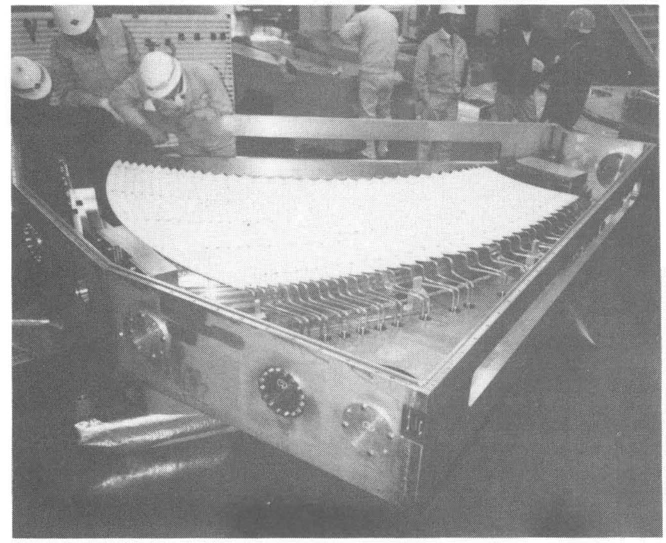

*Fig.*7 Photograph of trim coils.