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MAGNETIC FIELD DESIGN AND MEASUREMENT FOR THE KURCHATOV INSTITUTE CYCLOTRON

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The conversion of the 150 cm cyclotron was made in order to increase the energy of particles, to decrease the energy spread to 0.2% and the beam emittance to 10 mrad × mm. The use of the bunching system[1] in this case should make very short (1.5 nsec) intensive neutron pulses for time-of-flight experiments.

The design of a magnetic field was based on a one-fifth scale model. Measuring techniques employing Hall plates with two temperature regulating systems and the digital voltmeter with a computer provides a precision of about 0.03%.

The magnetic field data can be used to predict characteristics of particle motion in the cyclotron. Calculations of these characteristics can be done by numerical integration with the BESM-6 computer. The magnetic structure of our cyclotron is shown in Fig. 1. Table 1 lists the main parameters of this magnetic structure.

Table 1

Main parameters of the magnetic structure

pole-face diameter	150 cm
AVF sectors	3
spiral, max.	50°
gap, min.	20 cm
gap, max.	34 cm
average field at R_{ext}	7-17 kG
circular coil, pairs	8
harmonic coil, pairs	8
median coil, pairs	2
max A-turns at all coils	130'000 at
cooled by	$H^2 0$

The advantages of the magnetic structure are:

1. All elements of the magnetic structure can be assembled in the vacuum chamber outside the magnetic gap. This is convenient, especially for the assembly of the magnetic field measuring system.

2. The special form of sectors (Fig. 1) gives a weak effect of saturation within a range 7-17 kG. Figure 2 shows $F = (\overline{B^2} - (\bar{B})^2)/(\bar{B})^2 = F(R)$ and $\tan\gamma = f(R)$ for various magnetic inductions.

3. Although concentric coils can produce a magnetic-field bump in the centre of the cyclotron, we shall not use it for axial focusing of particles. For this purpose we shall use slit-diaphragms on the Dees which provide an axial focusing[2] for radii up to 200 mm. These slit-diaphragms form also orbits of particles if

$$U_D = \text{const} \times \frac{E_K}{ze},$$

where U_D is the Dee voltage, E_K the kinetic energy of a particle at the extraction radius and $\bar{z}e$ the particle charge.

4. We paid special attention to achieving an isochronous average field in a range of 530-630 mm for the use of bunching with deflection[1]. In this region the real field differs from the isochronous one by less than 10 G. The final correction of the average field will be realized with the concentric coils using signals of 8 pick-ups to be placed inside the Dees.

5. For protons and He_3^{2+} ions, the maximum energy in isochronous field is limited due to axial focusing ($\nu_z \geq 0.1$) and will be E_p = 27 MeV and E_{He_3} = 66 MeV. In order to increase the proton energy from 27 to 37 MeV and He_3^{2+}-ion energy from 66 to 75 MeV, the acceleration will be accomplished in a non-isochronous average magnetic field. In the latter case, the maximum energy of these ions will be limited due to phase shift.

6. The increase in the proton energy up to 37 MeV requires a Dee frequency of about 20 MHz. In this case, a non-uniform Dee voltage arises along the radii. Hence, the centres of the orbit shift from the centre of the magnetic field. This may be compensated by the first harmonic of the magnetic field. The amplitude of the first harmonic is

$$B_1 = \frac{6.2 \times 10^{-4}\, ze\, U_D f^2 L_D \cos\phi}{\bar{B}} \times \frac{1}{R},$$

where $4\, ze\, U_D \cos\phi$ is the energy gain per revolution two Dees), f is the Dee frequency, R is the radius, L_D is the Dee length and $\bar{B}$ is the average magnetic field.

In our case, B_1 = 40 G at R = 0.05 m and $B_1 \sim 1/R$. For this purpose, nine pairs of harmonic coils are used.

7. The extraction system consists of two deflectors with a non-uniform electric field, a focusing magnetic channel and a steering magnet. Table 2 lists the maximum energies of different particles.

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Table 2

Maximum energies of particles

Particle	p	d	^{3}He	^{4}He	^{6}Li	^{7}Li	^{9}Be	heavy ions
E_{max} (MeV)	37	30	75	60	90	78	60	60 $\frac{z^2}{A}$

REFERENCES

1) I.D. Breslavtsev et al. Pribori i technika experimenta. N 4, p. 26, 1972 (in Russian).

2) N.I. Venikov et al. Atomnaja energia. II, p. 247, 1961 (in Russian).

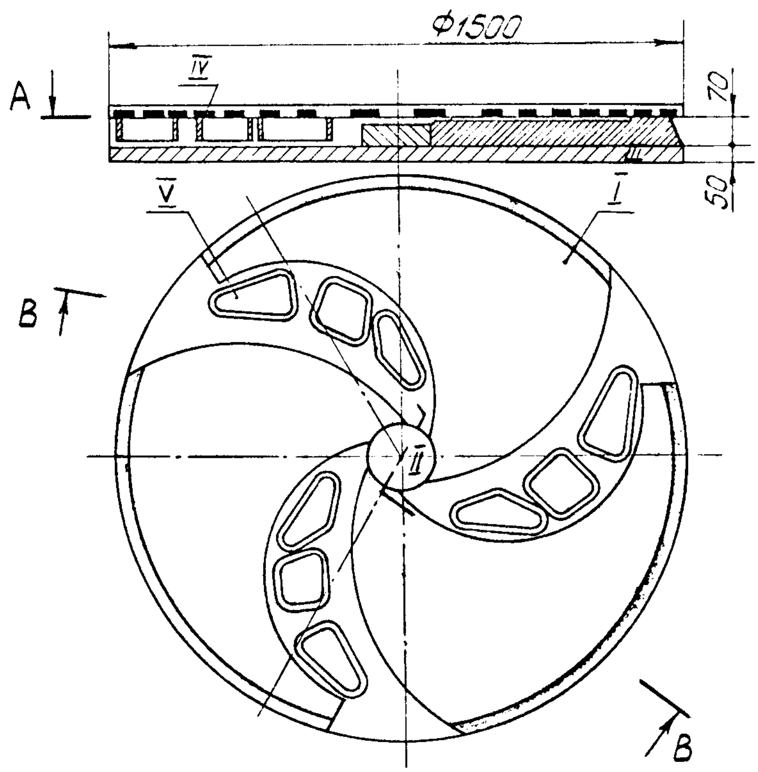

Fig. 1

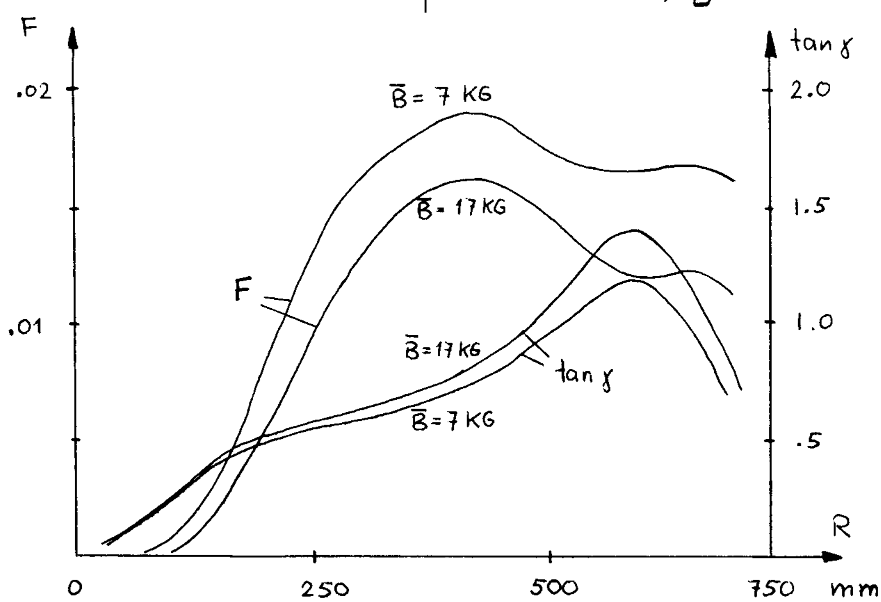

Fig. 2