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CONVERSION OF KAZAKHSTAN CYCLOTRON TO A VARIABLE ENERGY ISOCHRONOUS CYCLOTRON

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A 150-cm type cyclotron for investigations in nuclear physics and for production of radioactive isotopes was designed by the Efremov's Institute of Electro-Physical Apparatus and by Kurchatov's Atomic Energy Institute. The cyclotron was designed to accelerate protons, deuterons, alpha particles, and multicharged ions. The layout of main equipment is shown in Fig.1.

The main design feature of the cyclotron magnet system is the direct attachment of the accelerator chamber lids to the magnet poles. In this way all mechanical loads induced by magnet forces and atmosphere pressure have an effect on the magnet yoke only, and not on the chamber. This fixed position of the lids in the magnet gap provides for constancy of the magnetic field profile; when the accelerator chamber is disassembled no additional correction is needed. Any correction of the magnetic field is realized in the ordinary way. The extraction radius of the cyclotron is 66. 5 cm; the fall off of the magnetic field at this radius is 2. 5%.

The accelerator chamber consists of two parts, which may be removed separately from the magnet gap. Vacuum sealing of the lids is secured with the rubber gasket.

A variable frequency conventional oscillator with a nominal power capability about 300 kW is used to feed the two-dee resonance system. The amplitude of accelerating dee-to-dee voltage may be raised to 250 kV. The wavelength of the resonator is changed from 20 to 35 m by varying the inductance of the dee stem. This is done by moving the shorting fingers on the resonance lines without breaking the vacuum sealing. The quality of the resonator is about 6000. The vertical dimension of the dee is 10. 3 cm; the aperture is 7 cm. The central dee geometry and ion source are standard.

The accelerated ions are deflected by an electrostatic deflector with hyperbolic electrodes. The deflection potential is about 65 kV; extraction efficiency is about 50%. Four magnet quadrupole doublets and two bending magnets are used to focus the extracted beam to the remote target at a distance of 24 meters. This system deflects the beam through an angle of 100° (the beam twice changes its direction through an angle of 50°). Ion losses during transportation of the beam from the deflector to the target are practically absent; the pipe diameter is 13. 3 cm. The beam transporting system has an intermediate focus that makes it possible to decrease the energy spread of the beam by diaphragming the beam at this point. Seven slots in the shielding wall of the experiment hall permit investigations with fast neutrons by the drift method (the basic length is 25 m).

The energy of accelerated particles in this cyclotron may be raised to 20 MeV for protons and to 24 MeV for deuterons. The beam current on the remote target is about 100 μA, the dimensions being 1 by 2 cm.

There is remote control of all the adjusting and measuring devices of the cyclotron installation under high radiation level.

The layout of the cyclotron installation is shown in Fig. 2. This cyclotron is to be converted to a variable energy sector cyclotron in the very near future, the conversion to be made in two stages. In the first stage, the vacuum tank and resonance line will be unchanged. Two lids with three low spiral sectors per lid will be fabricated anew. The spiral angle is chosen to be 20° at the outer radius. The sectors are plane. The distance between sectors 21. 6 cm, and between valleys 39 cm.

When the excitation of the magnetic is changed to a new level, the magnetic field profile will be trimmed with nine pairs of circular coils placed on the inner surfaces of upper and lower lids, symmetrical to the medial plane. The trimming coil currents are found by the least-square method. Variations of the flutter are produced with three pairs of coils located in valley (one coil in every valley) at large radii. Six pairs of harmonic coils located in valleys (two coils in each valley) are intended to correct the first harmonic of the magnetic field at small and large radii.

Magnet measurements for determining the necessary magnetic fields were made on the 1:3 model magnet, shown in Fig. 3. Two disks are used as accelerator chamber lids. Sector plates fastened to the disks are of two types: strait sectors and removable spiral adding plates. By replacing the removable adding plates one changes the spiral angle of the sectors and finds the necessary shape of the sectors.

The magnetic field induction was measured by means of a Hall generator with a constant current supply. The output voltage from the Hall generator was measured with a potentiometer. The mechanical device allowed the Hall plate to be placed at any point desired.

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For varying the ion energy the magnetic field must be changed over a wide range. Thus, model magnet measurements were made at ten levels of magnetic field, from nine to seventeen kilogauss.

The magnetic field was measured at azimuthal intervals of 3° and at 24 radii. Average magnetic field and the amplitudes and phases of harmonics were calculated with a computer. The curves of dependance of the average magnetic field in units of central field (H) on the radius for the different H_o are shown in Fig. 4. It was assumed that the magnetic field without the trimming currents must be isochronous at 12 kilogauss.

The curves for amplitudes of third, sixth, and ninth harmonics and the phase of third harmonic for the case of acceleration protons to the energy of 30 MeV are shown in Fig. 5.

Preliminary consideration of the magnetic field measurement shows that the frequency of the radial oscillations is about 1. 01 - 1. 02 and axial oscillation is about 0. 1 - 0. 3.

In the first stage the maximum energy ions will be 30-35 MeV protons, 30 MeV for deuterons. The higher proton energy is limited by the shortest wave length of the resonator and oscillator.

It is planned to manufacture a new single-dee 180° resonator. The frequency range of the radiofrequency oscillator will be changed also. All these changes will permit to increase the proton energy up to 50 MeV.

The external beam-tranport system will remain unchanged.

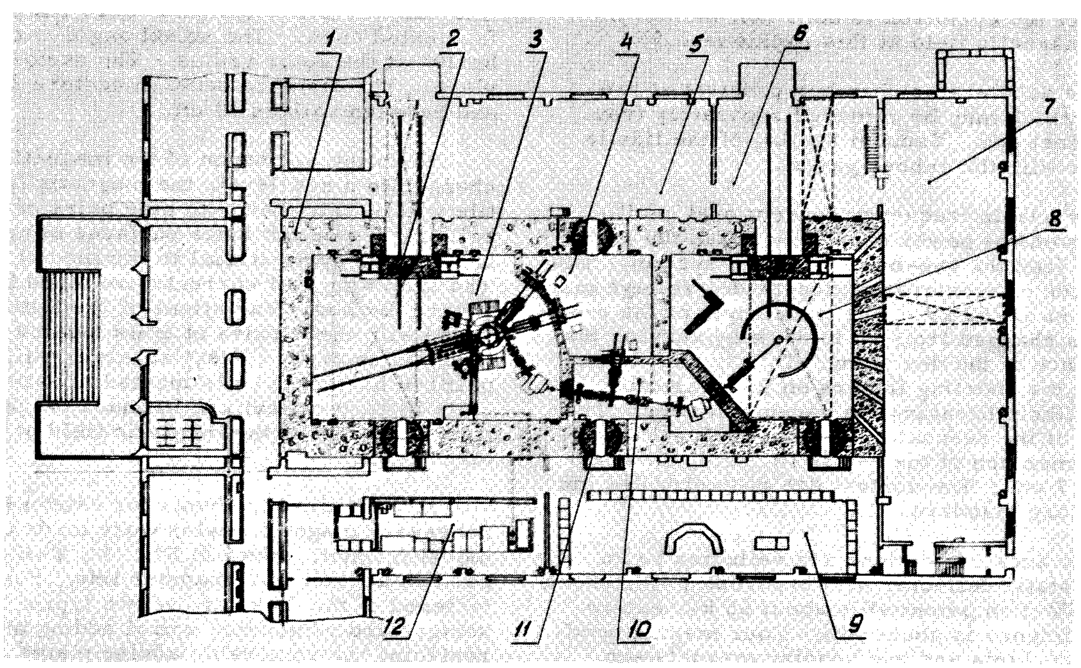

Fig. 1. The 1.5-Meter Cyclotron Installation at Alma-Ata. 1 main concrete shielding wall, 2 motor-driven gate, 3 cyclotron hall, 4 target manipulation room, 5 work shop hall, 6 shop space, 7 neutron experiment hall, 8 experiment hall, 9 main control room, 10 intermediate focus room, 11 motor-driven turntable gate, 12 rf oscillator.

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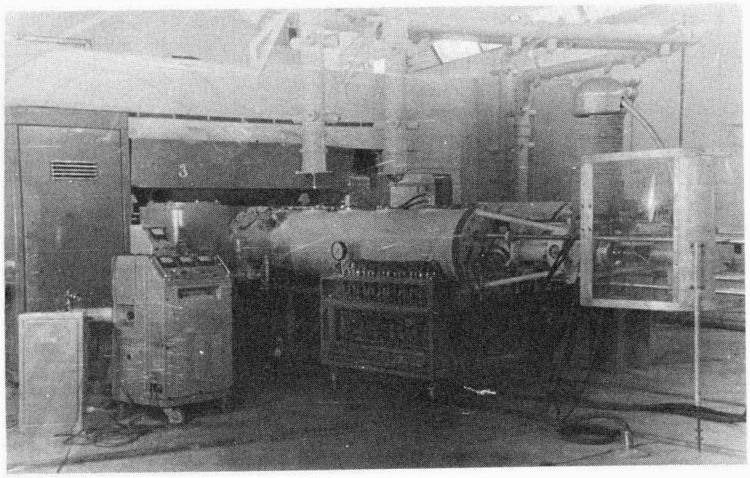

Fig. 2. The Kazakhstan 1.5-Meter Cyclotron installation.

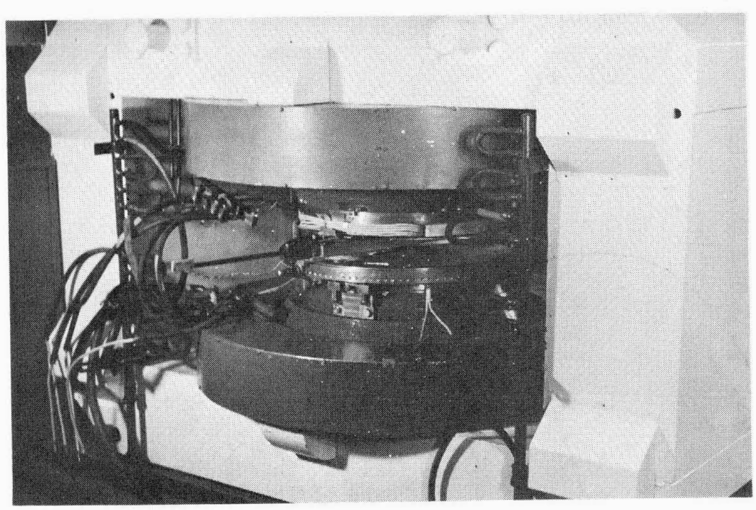

Fig. 3. The 1:3 Model Magnet. The authors are grateful to R. A. Mesherov, who performed part of the magnet measurements.

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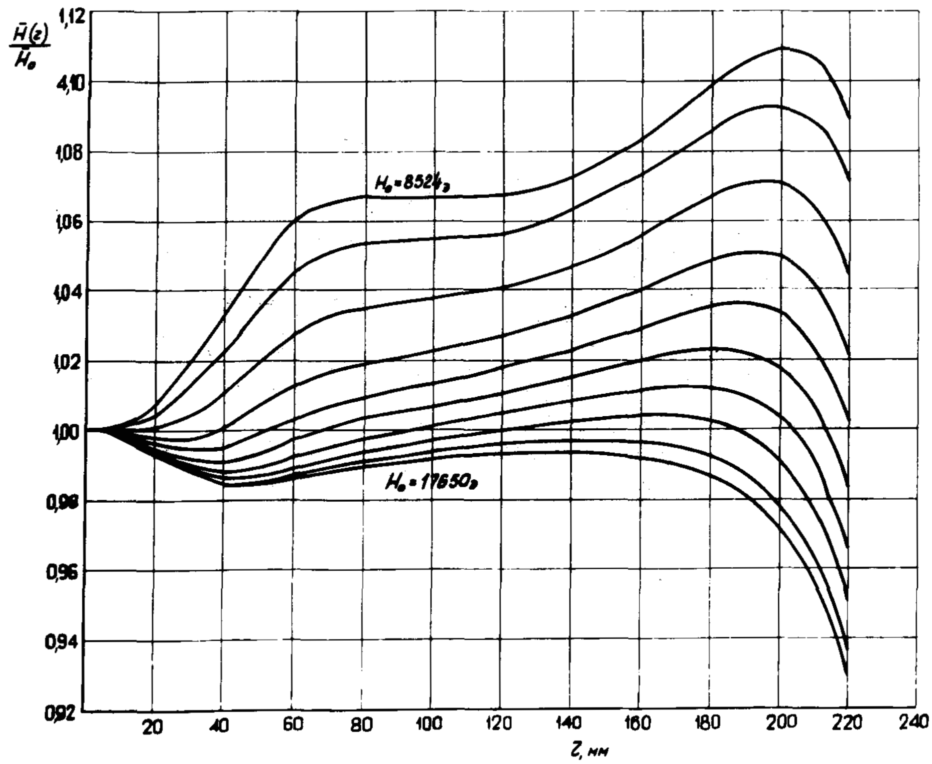

Fig. 4. Magnetic Field vs Radius, from 8.53 to 17.65 kG.

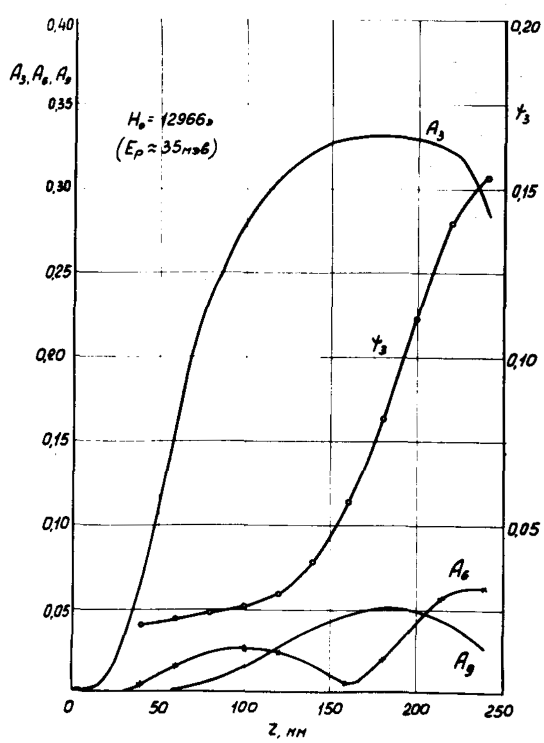

Fig. 5. Third, Sixth, and Ninth Harmonics, and Phase of Third Harmonic.

