STATUS OF A COMPACT H^- CYCLOTRON AT THE KURCHATOV INSTITUTE OF ATOMIC ENERGY

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ABSTRACT

A compact isochronous cyclotron MPC-10[1] is currently being constructed at the Kurchatov Institute. The main parameters and status of all systems of MPC-10 are discussed.

1. INTRODUCTION

The MPC-10 is compact isochronous cyclotron intended for operating as a component part of a positron emission tomography research center and will be used for producing ultrashort-lived radionuclides ^{11}C, ^{13}N, ^{15}O, and ^{18}F. The main parameters of the cyclotron are given in Table 1.

Table 1 - Main cyclotron parameters

1. Beam		
Type of ion	- accelerated	H^-
	- extracted	H^+
Maximum energy	- guaranteed	10 MeV
	- expected	12 MeV
Intensity		50 μA
Number of extracted beams		2
2. Magnetic system		
Pole diameter		80 cm
Number of sectors		3
Average field		1.55 T
Coil power consumption		33 kW
Weight	- iron	17.5 tons
	- copper	1.5 tons
3. RF system		
Number of dees		2
Dee angle		90 deg
Harmonic mode		1
Dee voltage		40 kV
Operating frequency (fixed)		23.5 MHz
Dissipated power		17 kW
4. Ion source		
Type of source		"Cold cathode", internal, Penning, of thermionic mode
Insertion		radial
Arc power		1 kW
Gas flow		5 - 10 ccm
5. External dimensions		2.5*2*1.5 m*m*m

Cyclotron parameters selection are dictated by the requirement to provide the negative ions acceleration and also by a compromise between the requirements on magnetic and RF systems and the power of their power supply systems, taking into account the requirements on vacuum and reduction in weiht and dimensions. Accelerated ions are extracted by stripping electrons at 1mm thick graphite stripper.

The possibility of accelerating D^- ions is also under investigation. It is suggested that D^- ions will accelerate till the energy value totals ~6Mev at the second accelerating voltage harmonic.

2. MAGNETIC SYSTEM

The cyclotron magnetic system[2] consists of a yoke, poles, exciting coil and a structure shaping an isochronous magnetic field (Fig.1 and Fig.2).

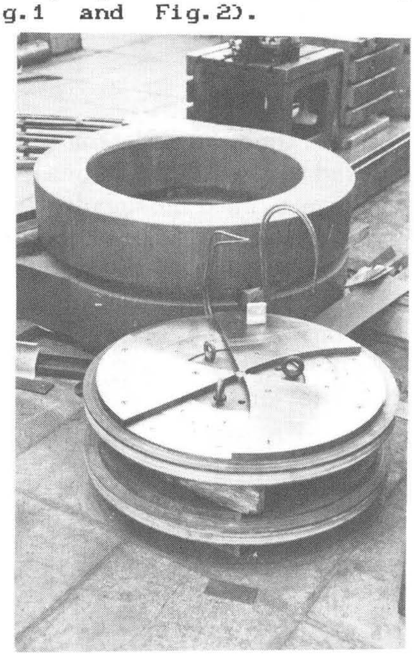

Fig. 1. Magnet structure and main coils.

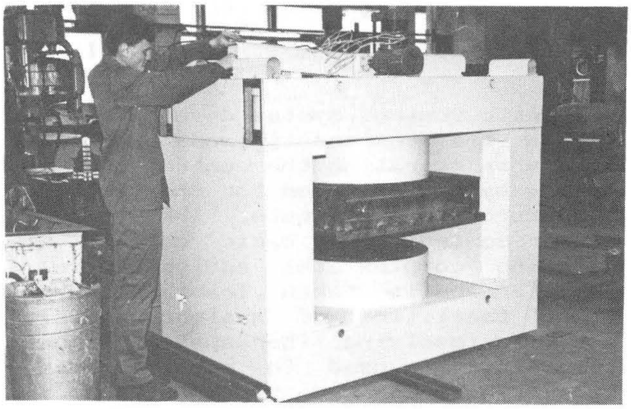

Fig. 2. Yoke and poles of MPC-10 magnetic system.

The magnet structure geometry was found by applying a technique which combined experimental studies on a magnet mock-up made on a 1:4.57 scale and computer simulation according to a code computing 3-D magnetic fields in a uniform magnetization approximation. Gaps in the structure hill and valley are 80 and 126 mm respectively, a sector angle increases with the radius from 60^o to 75^o. This provides the possibility to form a magnetic field at the level of 1.55 T capable of accelerating both H^- and D^- ions with acceptable phase shifts, and also provides a flutter required for vertical focusing.

At present the most parts of magnetic system are produced. An automated magnetic field-measuring system intended for a final field shaping directly at the cyclotron magnet is constructed too.

The power supply for a magnet main coil provides the current up to 400 A at the stability of 10^{-4} and at the voltage of 100 V. The power supply is installed in the production area and tested for dummy load (Fig.3).

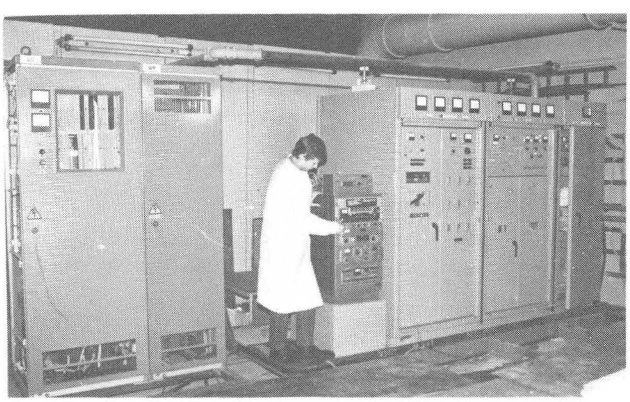

Fig. 3. Magnet main coil power supply (on the left) and RF oscillator (on the right).

3. RF SYSTEM

A resonance circuit[2)] is a two-conductor quarter-wave line ($\rho \sim$ 100 Ohm) in a common rectangular chamber loaded with capacity of 90^o dees (C ~ 140 pF) at its end. An operating frequency is 23.5 MHz. The commercial transmitter PKM-20 (power of up to 25 kW) will be used as an RF oscillator. At present the oscillator is installed in the production area and adjusted for dummy load (Fig.3). Frequency tuning within 1.5MHz is provided which is achieved by changing the dee area. There are trimmer capacitors for tuning (the tuning range is 0.5 to 0.6 MHz), an inductive loop and capacitor for coupling to an RF oscillator, a facility for controlling a dee position involving TV monitoring of a shift of laser beam reflected by mirror fixed on a dee.

The equipment includes also a master oscillator; facilities of resonator frequency stabilization based on a phase detector and transistor transformer with pulse modulation for trimmers drive control; a facility for accelerating voltage amplitude stabilization; synchronizer for pulsed modulation of RF voltage during while; in the process of tuning and training, providing also the protection under breakdown.

4. ION SOURCE

An internal ion source of PIG-type with cathode self-warming and radial insertion has been chosen for the MPC-cyclotron. The design of this source has been developed and optimized for intensity at the test bench. At present the work aimed at increasing ion current and the source lifetime is beeing conducted.

The ion source, providing the possibility to change ion acceleration regimes (from H^- to D^-) in the minimal time-period without violating the vacuum, is beeing developed. At the same time the research work aimed at the determination of central area optimal geometry, which will make it possible to combine the above-mentioned acceleration regimes, is conducted.

5. VACUUM SYSTEM

The cyclotron vacuum chamber[2)] consists of a body and two covers, produced of stainless steel. The chamber is gasketed with rubber seals in its grooves. The copper clad is fixed to the inner chamber surfase by diffuse welding and cooled by the water sirculating in the tubes sutuated between the clad and the body. The chamber is pumped hard by means of two diffuse pumps with a pumping velocity over hydrogen of ~10^4 l/s. The fine vacuum of $8 \cdot 10^{-7}$ torr was obtained after the elimination of vacuum leaks during the chamber test (Fig. 4).

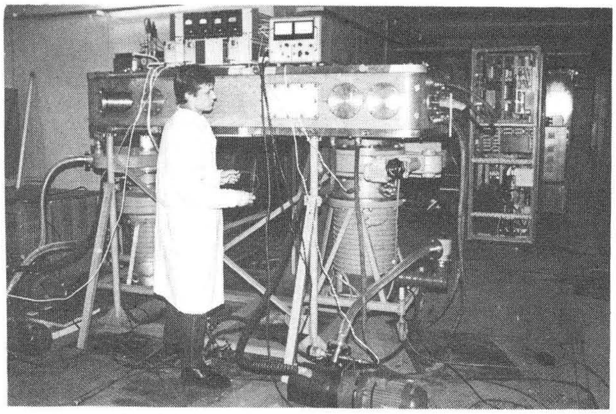

Fig. 4. Vacuum tests of the cyclotron chamber.

6. BEAM DIAGNOSTIC

The system of integral and differential probes, Faraday cups, luminescence screens with TV recording of an optical image of a cross-section is provided for monitoring the intensity and position of both internal and extracted beam. An ionization detector of a beam cross-section is provided for monitoring the beam intensity and size during target irradiation. The accuracy of current measurement is ~10% at the intensity in excess of 1 mA, a spatial resolution in each coordinate is ~1 mm.

7. CONTROL AUTOMATION AND CYCLOTRON PARAMETERS MONITORING

Automatic Control System development is based on the components and experience gained when operating the control and monitoring system intended for the cyclotron at the Kurchatov Institute. IBM PC/AT is used for control. As a basic control and monitoring complex the equipment in a CAMAC standard is taken. Transmission-reception facilities of analogue and discrete data involving fiber-optics communication lines are used to achieve connections between CAMAC-units with objects, control and monitoring. Application of these data communication facilities simplifies cable mounting, provides electric isolation of control units from objects under control, enhance noise immunity, simplifies the composition of CAMAC equipment.

The hard- and software are adjusted and tested while operating separate cyclotron functional systems.

8. REFERENCES

1) C.D. Burbeza et al., "Status of a compact cyclotron for PET at IAE", in Proc. 2 th International Meeting on Cyclotrons and Their Applications, L9-89-708, Dubna, 1989, pp.107-114.

2). N.S. Artemov et al., "Designs of magnetic and resonance systems for a special medical cyclotron MPC-10". IAE-5004/14, Moscow, 1990 (in Russian).