# INITIAL OPERATION OF CIAE MEDICALLY USED CYCLOTRON

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*Abstract*

A 30 MeV compact cyclotron, CYCIAE 30 devoted to medical radioactive isotope production was built in CIAE and put into operation in Dec. 1994. It was originally designed by IBA, Belgium[1] . Some major modifications of the design have been taken. In order to improve the performance of the machine, the magnet redesign and adjustment have to be taken. All equipment: RF, power supplies, vacuum and water cooling system, except ion source and strippers, are made in China. The initial operation of the machine was reported.

## I. GENERAL DESIGN FEATURES

CIAE medical cyclotron is a fixed-field, fixed-frequency isochronous cyclotron accelerating $H^-$ ions beam up to a maximum energy of 30 MeV and extracted beam intensity of more than 350 uA and low power consumption less than 100 kW. The machine is shown in Fig.1.

The design of the machine was reported elsewhere[2,3,4].

This project with most of equipment made in China has been proved fully successful in last two year operation. Now 7 different isotopes are supplied to many hospitals. Parts of them are exported, like $^{57}Co$ and so on.

## II. THE MAGNET SYSTEM

The magnet of cyclotron is a key part for the machine, since it should provide a good quality field to ensure high intensity beam to be accelerated to final energy.

The magnet mapping results shown the field is quite close to the theoretical isochronous field based on the error of RF shift and first field harmonic. The measurement results are shown in Fig 2 and 3. The maximum RF phase shifts are less than $+-10^o$ and first harmonic field is around 5 gauss in the accelerating area. High quality isochronous field keeps the particle accelerated to the extracted energy stably.

The working isochronous field can be achieved using electrical power 7 kW only.

In addition, switching magnets, quadrupoles, steering magnets and corresponding power supplies are fabricated based on our own design. Their quality is same or better than the requested theoretically.

Fig. 1 CIAE Medical Cyclotron --- CYCIAE 30

## III. RF ACCELERATING SYSTEM

The RF accelerating system is made in Chinese manufacturer. The system in shown in Fig 4. The accelerating electrodes, the "dees" are supported by stems inserted in the valleys.

The dees are made of solid copper and are conduction cooled. This considerably reduces the risk of water-leakage inside the machine and thus the contamination risks.

The two $30^o$ dees operate on the 4th harmonic mode with respect to the particle revolution frequency. To prevent any phase mismatch and to simplify the RF system, they are connected at the center below the median plane to leave room for the inflector.

The R.F. cavities are entirely located in the valleys. The R.F. power needed to obtain 50 kV of dee voltage is approximately 5.5 kW per cavity. In addition, up to 15 kW of R.F. power are used for beam acceleration.

A single R.F. amplifier delivering 25 kW of power at 65.5 MHz is installed in the median plane and is capacitively coupled to the cavity. The variable load due

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to the beam behaves as a variable load resistor on the final tube. So the amplifier always operates at peak efficiency.

Zero-bias, grounded-grid triodes are used for the final 25 kW amplifier and 2 kW driver amplifier. This design gives the system absolute stability and eliminates the grid and screen grid power consumption. The R.F. system tested at the working frequency before the beam commissioning. The result shows that Dee circuit coincides well with the results of magnetic mapping.

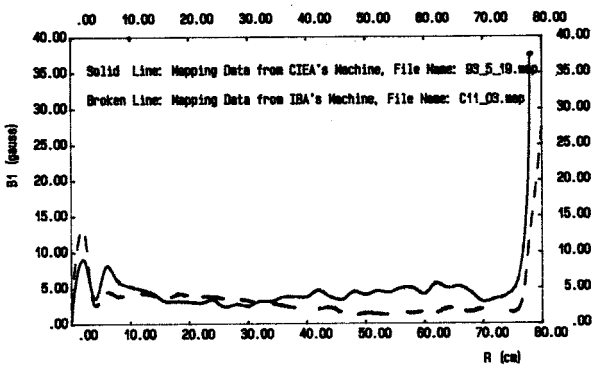


Fig. 2 Amplitude of First Harmonic

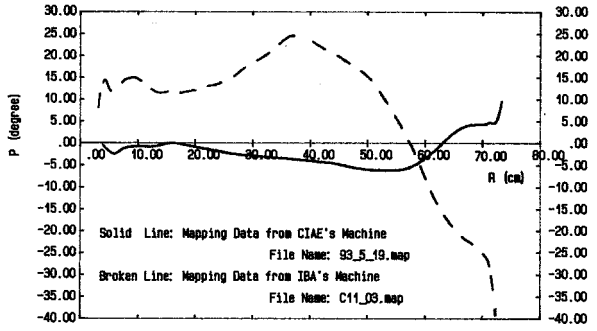


Fig. 3 Comparison of The Total Phase Shift

## IV. VACUUM AND WATER COOLING SYSTEM

The vacuum chamber of CYCIAE 30 cyclotron is a cylinder made of aluminum alloy, sealed onto the magnet yoke by "O" rings. Some openings on the vessel for beam exit, stripper entry, R.F. feed etc. are isolated from ambient atmosphere by air-lock system and "O" rings.

Three types of pumps are used in the cyclotron. Roughing is performed by forepumps from 1000 mbar down to $10^{-2}$ mbar. High vacuum is maintained by two oil diffusion pumps (3000l/s) from $10^{-2}$ mbar down to $10^{-6}$ mbar and by two cryogenic pumps (1500l/s) to improve vacuum around $10^{-7}$ mbar adequate for extracting beam above 350 uA. Cryopumps could also increase the pump-down speed in the cyclotron.

Demineralized water is used for machine cooling through manifold with stainless steel ball valves, flow controllers, distributing the water to all cooling circuits.

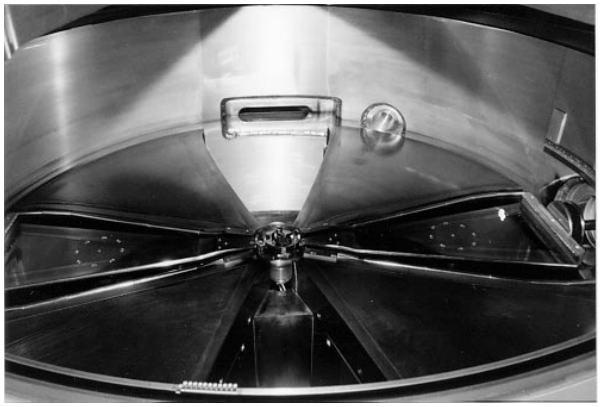

Fig. 4 The RF System

Fig. 5 The Control Room of CYCIAE 30

Temperature, resistivity and flow amount of water are used as control interlocks to guarantee the safety of the equipment.

All the vacuum and cooling systems have been proved for the machine operating properly.

## V. CONTROL SYSTEM

The cyclotron and related equipment is controlled by a SIMATIC S5-135U programmable controller because of its reliability and its versatility. It also offers the possibility to expand and interconnect with other programmable devices. Fig 5 shows the control room of CYCIAE 30.

Normal operation of the cyclotron is entirely automatic, from cyclotron start-up to targetry and chemistry, requiring no operator during routine production. Color monitor displays graphically the operations.

A spill proof keyboard and two "virtual" knobs that can be used for preset the cyclotron parameters. To meet the control requirements, PLC is used. More convenient and reliable system is for most of operators.

## VI. TWO YEAR OPERATION

After the beam commissioning the machine was put into operation in Dec. 1994. The isotope production started as routine work according to the hospital requirement. The medical use isotopes are produced regularly. During the

operation, no operators are needed usually since the system work very stable.

Now 7 medical use short neutron isotopes have been produced for the market home and abroad. The operation proved the machine is excellent.

## REFERENCES


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