DESIGN STATUS OF THE MEDICAL CYCLOTRON FACILITY

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1. Introduction

A dedicated cyclotron facility for the production of radio-isotopes to be used in nuclear medicines, is being designed and built. The facility will be housed in a hospital in Bombay and will be provided with both the options of having internal and external target irradiations. The machine is designed to deliver proton beams of 30MeV having maximum internal and external beam currents of 100 μA and 50 μA respectively. Other than protons, beams of deuterons and alphas of suitable energies will also be made available. The design studies of the machine were undertaken about an year ago. The design work for most of the systems has been completed. At a later stage, there is a plan to convert the machine to a variable energy multiparticle one and also extend its capabilities. Enough flexibilities in the design are being provided to cater to this requirements. The facility when completed will offer almost all the short lived radio-isotopes for this purpose. Figure 1 shows the isometric view of this cyclotron. In the following sections brief descriptions of the designs of various systems is given.

2. Magnet System

The magnet system employs a three sector geometry with a minimum gap of 16cm. being dictated by the geometrical constraints. The sectors are designed for H=2, where H is ratio of the gap of the valley to the hills. Using the confirmal transformations[1], an analytical approach[2] has been devised for this purpose. As per this approach, the field distribution for square edge poles can

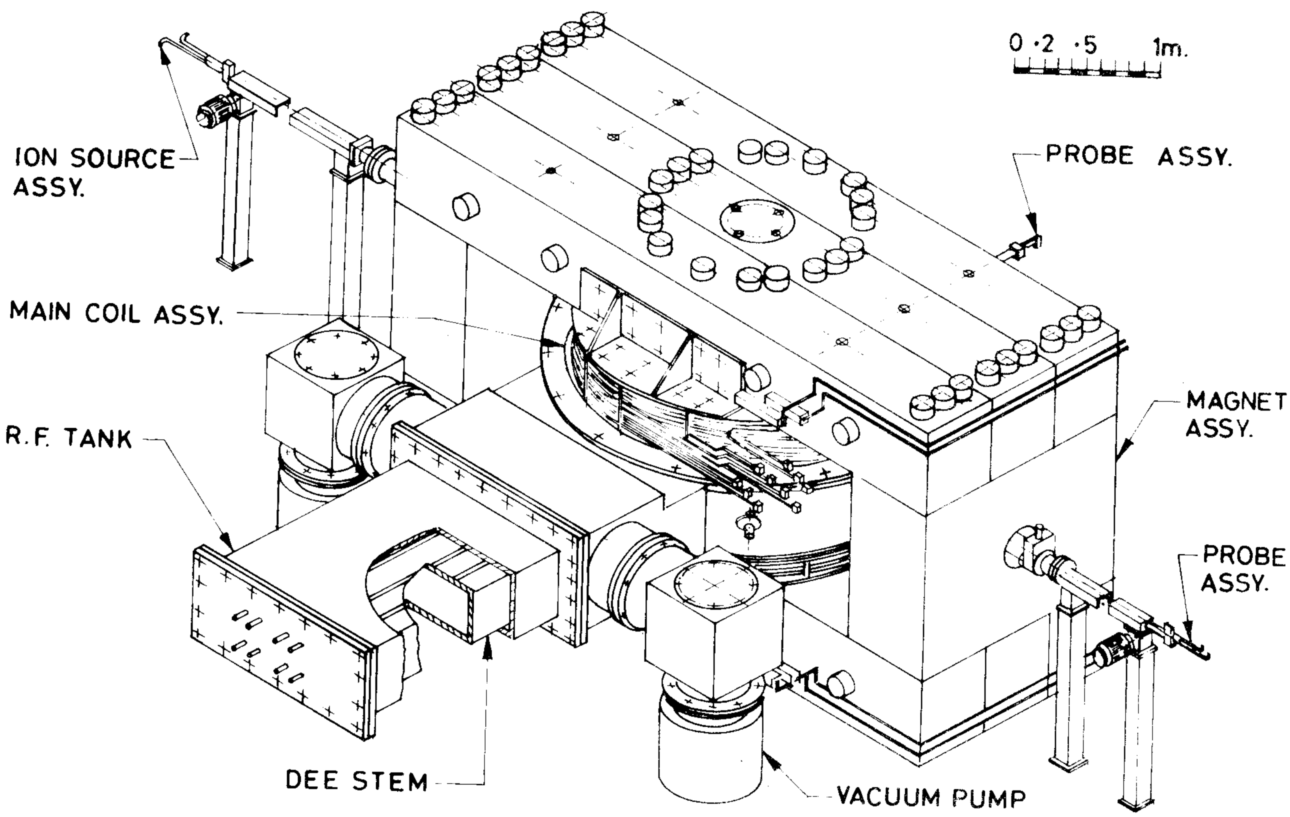

Fig.1: View of the Medical Cyclotron.

be written as

$$B_z(r,\theta) = -B_0\left[\cos\left(\frac{1}{3}\cos^{-1}\tanh\left(\frac{\pi r\theta}{g}\right)+2\pi/3\right)\right]\cdot f(r)$$

where Bo is the max. hill field, g the gap between sectors and f(r) accounts for outer edge fringing of the field. By using the above expression, $\langle B \rangle$, flutter, ν_z, ν_r, sector width etc. can be calculated for the given input conditions. The isochronous field profile and the suitable spiral angle ξ_0 is taken as the input. The value of ξ_0 has been chosen in such a way that ν_z lies between 0.2 to 0.3 in the whole of isochronous region. The final shape of the sectors has been obtained through optimization so that the proper field distribution for 7.5 MeV deuteron (15 MeV alpha) and as well as 30 MeV proton beams can be attained by putting minimum load on the trim coils. Computations show that six no. of trim coils can take care of the field deviations from isochronism. Figure 2, shows the plan view of the magnet assembly. The max. diameter of the pole piece, sector width and spiral angle are 150cm., 59° and 38° respectively. The max. magnetic field between the sectors for 30 MeV proton beam is 18.5 kG. The total magnet assembly consists of about 12 parts, in total weighing about 90 tones. All the parts of the magnet will be made from forged steel having maximum carbon content of $\simeq$0.1%. The main coil consist

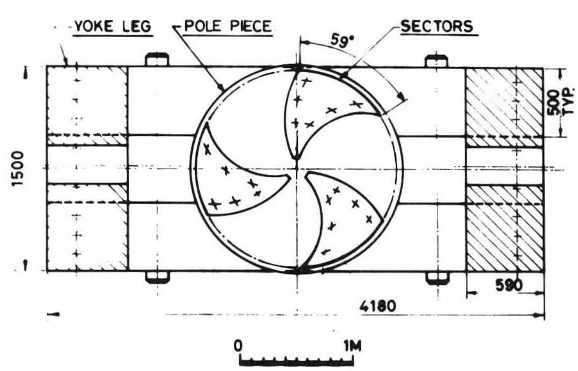

Fig.2: Plan view of the magnet.

of 12 pancakes made of ETP copper. The total power for the magnet is $\simeq$ 100kW. The six trim coils will be made from 6mm square conductor and are positioned with a spacing of constant Δr^2. Three sets of valley coils are provided for the purpose of centring and extracting the beam. The maximum power of the trim & valley coils is well under 10 kW. In figure 3, is shown the configuration of trim and valley coils.

3. Central Region

Since in the initial phase, the

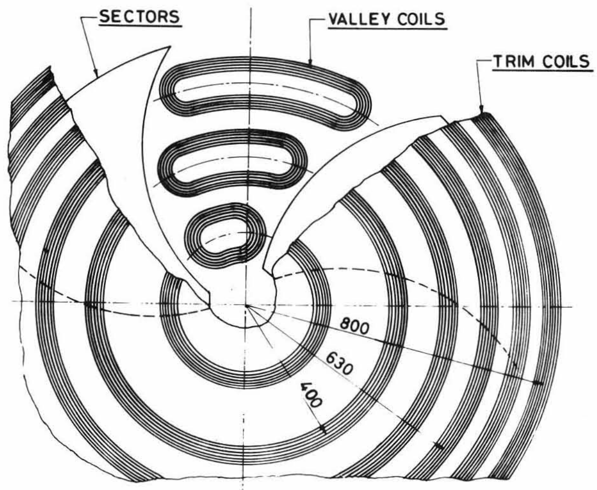

Fig.3: Trim & Valley Coils

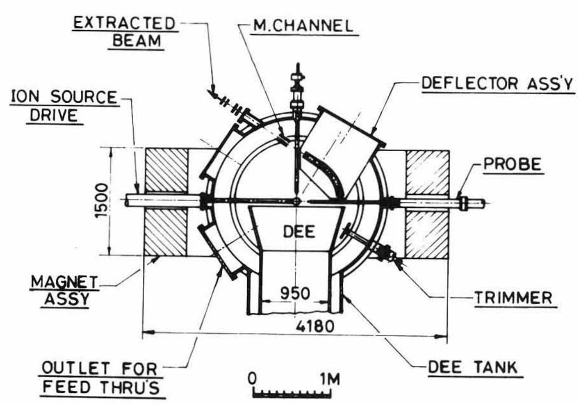

Fig.4: Plan showing the various systems of the facility.

machine will work as a fixed energy machine, the central region is not provided with any flexibility of movements. The ion source and the puller are fixed having a limited amount of slit rotation (90°) of the ion-source. The ion source is inserted radially through one of the yoke leg of the magnet as is shown in figure 4. This makes the design of the central plug much simpler because one does not have to worry too much about the compensation of the undesired field harmonics which are associated with the axial insertion. The geometry of the central plug will just provide the suitable field profile to meet the requirement of axial focussing in the region. The design studies for the central plug, puller and the ion source location are in progress. In figure 5 is shown the enlarged view of this region giving the electric field distribution for one of the possible geometry, for a 45kV on the dee. Two probes are provided for the beam diagnosis. One of these probes will also serve as internal target irradiation probe.

4. R.F. System

The R.F. system consists of a single dee of 180° with driven Master Oscillator Power Amplifier (MOPA) system.

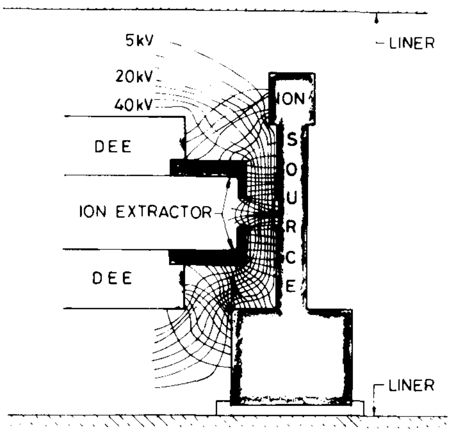

Fig.5: Electric field distribution in the vertical plane in the central region.

The dee and dee stem acts as a quarter wave resonator ($\lambda/4$) circuit, developing 45kV (ground to peak) at the dee, at a frequency of 21 MHz. The design details of the mechanical parts are shown in figure 6. A 2.5cm gap has been provided for beam acceleration and dee to liner gap has been fixed at 3.2cm. The capacitance between the dee to the linear is approx. 300 pf. The rectangular structure of the dee stem is mainly dicatated by mechanical considerations. By taking into account the "Q" of the circuit and in turn losses of R.F. structure; beam loading, efficiency of power transfer etc., the total R.F. power requirement has been estimated to be 70kW. The MOPA system is divided in three parts; the final amplifier, the driver amplifier and the frequency source. The final amplifier is being designed around a power tetrode (CQZ-50) M/s. BEL (India), capable of delivering 100kW upto 30 MHz. The driver is a wide band amplifter giving $\simeq$ 1kW to the grid of the final amplifier. Comercially available frequency synthesizer will serve as a frequency source. The fine tuning will be achieved by using a phase comparator and a servo amplifier coupled to a trimmer capacitor. The detailed circuit developments are under way.

5. Vacuum System

A pressure of $\simeq$ 1 x 10^{-5} torr is required to be maintained in the dee and the R.F. tank of the cyclotron. The dee tank is made of non-magnetic stainless steel whereas the RF structure is composed, mainly of OFHC copper. The entire system comprises of a volume of $\simeq 4.5m^3$ with a total surface are

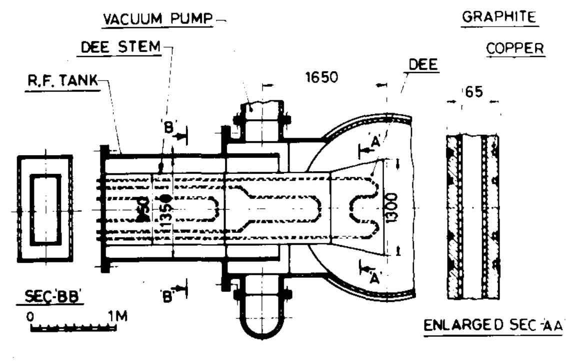

Fig.6: Details of the R.F. System.

of $\simeq 72m^2$. The outgassing rate for whole structure is estimated to be 9 x 10^{-3} torr lit./sec (10 hrs of pumping). The pumping system is based on the standard diffusion-rotary pump combination. Two pumping modules each having an effective pumping speed of 3500 l/sec. are used. Each unit consists of a 500 mm. diffusion pump having a pumping speed 12000 l/sec., backed by 3000 l/min. rotery pump. The two angle valves one for each system serve as the isolation valves between the chamber and the pumps. Roughing of the system is carried out independently with a roots pump of 6000 l/min. capacity. Estimates show that it will be possible to get a working pressure of $\simeq$ 5 x 10^{-6} torr inside the cyclotron.

6. Computer Controls

The entire operation of the machine will be controlled through a small computer.

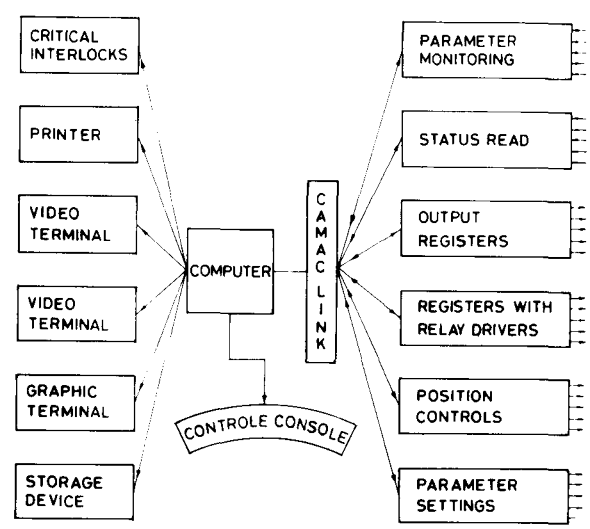

Fig.7: Schematic of the Computer Controls.

Some of the major functions, for the computer controls will involve:

a) reading, adjusting and setting of the parameters of each system,
b) continuous monitoring of the important parameters, like mag. field, dee voltage, frequency, ion source and beam current etc.,
c) the indication of the critical interlocks,
d) graphic display,
e) proper and adequate storage devices.

A system based on an IBM/PC X T through a CAMAC link is being evolved. Figure 7 gives the block diagram of this system.

7. Conclusions

Except for the central plug, Beam extraction and beam transport systems, the design work of the remaining systems has been more or less completed. The plans for the building for housing this facility are underway. The services required for operating the machine; demineralized water, electrical sub-station, air conditioning, cooling water services etc., are being planned.

8. Acknowledgement

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References

1. H. Neu and H. Werner, Nucl. Instr. & Meth. 10(1961) 333.
2. Zaffar Ahmed and R.C. Sethi, in these proceedings.