THE SUPERCONDUCTING CYCLOTRON PROJECT K500 AT CALCUTTA CYCLOTRON CENTRE

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A superconducting cyclotron to accelerate different ions up to 80 MeV/A is under construction at Calcutta. The project is now in its second year of construction. The design is similar to the K500 superconducting cyclotrons at the National Superconducting Cyclotron Laboratory, MSU and Cyclotron Institute, Texas A&M University. Work is proceeding on various systems with an effort to develop and build them within the country as far as possible. A cryogenic facility is fast being developed at the Centre and the liquid helium plant is already on order. Negotiations are going on with a public sector company to develop the coil winding facility. The radiofrequency resonator system will be fabricated at Bhabha Atomic Research Centre, Bombay, a sister organization of our Centre. Most of the electronics will be developed in-house. Negotiations are also going on for the fabrication of the magnet frame. Magnetic field simulation studies have been carried out. It is proposed to use the helium gas recovered by the Centre from hot springs located about 250 km from Calcutta. The project is scheduled for completion by the year 2001.

1. Introduction

The Cyclotron Centre at Calcutta is operating a K=130 room temperature cyclotron (VEC). An ECR source is soon going to be connected to this machine to accelerate heavy ion beams which are at present available to the nuclear physics community of the country, primarily, from 14UD pelletrons at Bombay and Delhi. The VEC with ECR source will have an edge over the heavy ion beam energy at least for the light and medium mass ions. Beams with energy about 5 -30 MeV/A for medium and light mass ions will be available.

The nuclear physicists propose to continue the heavy ion research at still higher energies in the first decade of the next century and this led to initiation of the superconducting cyclotron project. Beams of 80 MeV/A for the fully stripped light ions and ~10 MeV/A for very heavy ions will be available. Although, nuclear physics research is the main motivation for building this machine, research in other areas of basic and applied sciences has also been planned. Special emphasis will be laid on evolving a radioactive ion beam facility. A facility for treatment of ocular melanoma has also been planned. Development of superconducting magnet and allied technologies is another motivation for construction of this machine. Funding for the construction has been approved by the Government. This cyclotron will be modelled after the K500 superconducting cyclotrons at MSU[1] and Texas A&M University[2], and will be more close to the latter.

Major specifications of the cyclotron are as follows:

K_{bend}	: 520	;	K_{focus}	:	160
B_{max}	: 5.8 T	;	B_{min}	:	4.3 T
$\langle B \rangle_{max}$	: 4.9 T	;	R_{extr}	:	67 cm
$N_{sectors}$	: 3	;	ξ	:	120°
N_{dees}	: 3, 53°	;	h	:	1, 2
$f_{radiofreq}$	: 9-28 MHz	;	V_{max}	:	80kV

Status of different systems of the cyclotron and ongoing activities is described in the following sections.

2. Status of the Cyclotron Systems

2.1 Superconducting coil and cryogenics

Winding of the superconducting coil will be done in-house to develop the expertise. The sophisticated coil winding set up will be fabricated by a public sector enterprise experienced in carrying out large precision jobs. A contract will soon be finalized. Laboratory for housing this set up along with other facilities is presently under construction. A half scale model coil will be wound to test the set up and to get a feel of the mechanical problems which may arise during winding of the actual coil.

The superconducting cable is similar to the type used for the Texas A&M University cyclotron. The copper substrate has a 5 mm x 2.8 mm rectangular cross section. NbTi filaments are embedded along the wider face of the substrate in a narrow U shaped channel. Our current plan is to fabricate the cable, consisting of 500 filaments of 40 microns size, at the Bhabha Atomic Research Centre. Short lengths of cable have already been fabricated and are undergoing tests.

Design details of the cryostat have been frozen and vendor development is currently going on. Fabrication of cryostat involves complex and skillful techniques. The vessel material is special SS 316 stainless steel for the liquid helium tank and low carbon steel grade AISI 1010 or 1020 for the coil tank. Coil volume and liquid helium volume are 800 litres and 300 litres, respectively. Cryogenic transfer lines will be fabricated in-house.

A liquid helium plant with the production rate of 70 l/h, with liquid nitrogen precooling, has been ordered. In the refrigeration mode its capacity is 200 watts. It will be possible to tap helium gas at 20°K for cryopumping of the cyclotron chamber. The plant is likely to be commissioned by the end of 1996.

A cryogenic laboratory is fast coming up at the Centre. Various tests during development of the cable and winding of the coil will be conducted at this laboratory. Joining of the cable and test of the joint is a critical issue. It is planned to operate this laboratory, eventually, on an industrial scale. A one fifth scale model of the magnet coil will be fabricated using the actual conductor for the measurement of various magnet and coil properties. A small liquid helium plant and cryostat will soon be available on site for these tests.

2.2 Magnet frame

The magnet is a pill box type structure and the frame weighs about 100 tons. It consists, primarily, of five parts, namely, lower pole cap, lower return path ring, centre return path ring, upper return path ring and upper pole cap. The steel composition is as follows:

C	:	0.25% (max)
Mn	:	0.50% (max)
P	:	0.04% (max)
S	:	0.05% (max)
Si	:	0.20% (max)
Fe	:	rest

All the parts will be made from forged steel except the pole tips which will be manufactured using rolled plates. All the necessary fabrication, quality assurance, test and check out procedures have been worked out. Negotiations are going on with the companies, primarily in India, for steel forgings and machining.

2.3 RF System

The system will use Eimac150000 as the high power tube. Maximum RF power delivered at 80 kV dee voltage is about 240 kW. Three dees are fed separately from three chains of amplifiers maintaining a 120° phase difference of between the successive dees. This gives the advantage of h=1 mode of operation. Design studies have been completed and several components are on order. A number of complex electronic units and components will also be developed in-house utilizing the available expert manpower. A full scale amplifier will be fabricated for model studies.

The resonators are large and complicated OFHC copper structures. There are three dees, one in each valley. Power is fed to the resonators at the dees through coupling capacitors which in turn get the power from amplifiers via transmission lines. Tall dee stems run vertically, all the way from top and bottom of the magnet. Frequency tuning is accomplished by changing the position of the movable shorting end. Fabrication of the resonator system involves sophisticated techniques. We have established the feasibility of this job being done at the Bhabha Atomic Research Centre, Bombay - essentially, an in-house facility allowing strict quality control.

2.4 Ion Source, injection and extraction

Current plans are to develop a 14 GHz room-temperature ECR source for heavy ions. A 6.4 GHz source is already operational at our Centre for the present cyclotron. Heavy ions from the 14 GHz source will be axially injected into the superconducting cyclotron from the top. Design work on the long external and axial injection lines, as per our building layout, has just been initiated. The extraction systems consisting of electrostatic and magnetic channels like the Texas A&M University cyclotron, will be constructed in the laboratory.

2.5 Power supplies

The cyclotron requires 20 highly stable magnet supplies - 2 for the main magnet (0.001% stability) and 18 for the trim coils (0.003% stability). There are 10 RF system power supplies with very fast crowbar protection provided on the anode and screen grid supplies. Design studies on most of these power supplies have been completed. Some prototypes are being fabricated. In view of the sophistication, it is realized that major parts of the power supplies will have to be fabricated in-house. In some cases, however, more complex and precision parts will be developed in-house and added to the commercially procured units.

2.6 Controls

An open ended computer control system is preferred by our experts in order to accommodate future upgrades and requirements. Proprietary solutions will be avoided in view of fast changing trend of the micro electronic technology. UNIX workstations with sophisticated network protocol and strong graphic support is prescribed for operator consoles. The middle level control is proposed to be based on PC/ATs running RT UNIX. Several options are available for the equipment level control.

2.7 Magnetic field simulations and measurements

Magnetic field contributions due to iron and superconducting coils, both having cylindrical symmetry, were calculated using the two dimensional code POISSON. The almost fully saturated pole tips are replaced by equivalent surface currents and Biot-Savart law is applied to obtain vertical component of the magnetic field due to a current element. Integration over all the sector surfaces and making corrections for the holes for inserting dee stems and other such insertions yields fairly accurate field distribution due to the pole tips.

We plan to carry out detailed magnetic field mapping. Entire set up for these measurements will be designed and developed in-house, as far as possible.

2.8 Building

Civil engineering design of the new building, which will house the cyclotron and associated services, has been finalized. It is now under evaluation by the Atomic Energy Regulatory Board for radiological and other safety considerations. Shielding thicknesses and ventilation rates have been obtained as a result of elaborate calculations, from radiological safety point of view, using ALICE-91 and other codes. These quantities are determined by the production of neutrons in areas of significant loss e.g. deflector in the cyclotron vault, beam dumps etc. Permissible radiation exposures required 3.5 m thick concrete walls for the vault (50 pnA of 500 MeV ^{7}Li beam) and 1.5 m thick walls for the experimental areas. The radiation safety requirements are far more stringent now and our Centre is located in a populated area. The cyclotron will be located on the ground level. Our effort has been to meet the radiation safety standards in the most cost effective manner.

In the first phase it is planned to have three experimental areas - two for nuclear physics and other research experiments and one for the eye treatment. Provision has been made to extend the beam lines to add more areas. It will also be possible, if required in future, to bring the beam back into the beam rooms of the existing cyclotron. It may be mentioned here that we are operating here under severe land constraint.

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References

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