STATUS OF THE CALCUTTA K500 SUPERCONDUCTING CYCLOTRON PROJECT

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Abstract

The superconducting cyclotron under construction at this Centre has K_{bend}=520 and K_{foc}=160. Several parts of the main magnet frame have already been machined. They are undergoing inspection tests at the vendor's site. Trial windings on a full-scale dummy bobbin are going on to perfect the techniques using an elaborate superconducting coil winding set up at VECC. Fabrication of the RF resonators is also going on. The He liquefier/refrigerator has been installed. Among the other major systems, the cryostat and cryogenic transfer lines are in the process of finalization for awarding the contracts. Several other sophisticated components/parts are being fabricated at VECC or, in some cases, by the industry. Construction of the building and support services is going on full swing. The experimentalists are planning for large scale experimental facilities and are in the process of obtaining funds for the same.

1 INTRODUCTION

The K=130 room temperature cyclotron (VEC), operating at this Centre for the past two decades for light ions, has recently started accelerating light heavy ion beams from a 6.4 GHz ECR source[1]. A 14 GHz source supplied by M/s PANTECHNIK has also been commissioned to produce the solid ions for injection into VEC. The injection from the new source will be done towards the end of 2001. Thus, a low to medium energy heavy ion facility will soon be available to the experimentalists at Kolkata (formerly Calcutta). In order to extend the scope of research with heavy ion beams at VECC, we decided in the early 90s to construct a superconducting cyclotron. Design of the K500 cyclotrons operating at the NSCL, East Lansing[2] and the Cyclotron Institute, College Station[3] was adopted. It will be the largest nuclear physics facility available in India during the next one decade or more. Eventually, one or both the ECR sources will be moved to the superconducting cyclotron laboratory in the same campus. The VEC will then operate as the primary beam source for a low energy Radioactive Ion Beam (RIB) facility which is also under construction.

Construction of the superconducting cyclotron[4] has been going on steadily but with a bit slower than desired pace. This is due to the complexity in fabrication of several components and the reluctance of the industry to take up such jobs. Further delays were introduced by difficulty in availability of certain crucial items. Situation has, however, improved recently. We hope to start the commissioning trials around the end of 2004. Figure 1 shows layout of the accelerator and the beam lines.

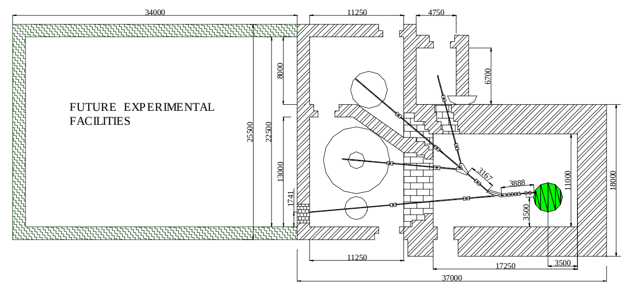

Figure 1 : Beam line layout for the K500 superconducting cyclotron under construction at Kolkata.

2 STATUS OF THE CYCLOTRON SYSTEMS

2.1 Main Magnet Frame

All parts of the frame are made of low carbon steel forgings. Rigorous chemical and ultrasonic test were carried out on the forgings before the machining. All except one i.e. the upper pole cap forgings were accepted

Figure 2 : Pole tips assembled on the pole base for inspection at the fabrication site.

in the first instance. A large cylindrical forging for the upper pole cap, weighing about 60 tonnes, was rejected because an unacceptably large void/inclusion was noticed at its edge during the ultrasonic tests. Magnetic field analysis showed that this defect would give rise to a first harmonic with amplitude ~1.6 gauss at the extraction radius. This is assuming that the thickness of the void/inclusion is ~3 mm which is the resolution of the ultrasonic equipment. A new forging was, eventually, made with acceptable quality. Most of the parts of the frame have been machined within acceptable tolerance

Figure 3 : Machining of the central return path ring for the main magnet frame

utilising a number of jigs and fixtures specially made for the purpose. Drilling of numerous holes is posing considerable problem, as the material is very soft. Figure 2 shows the pole tip family components assembled on the pole base for dimensional checks. Figure 3 shows the machining operation on the central return path ring.

2.2 Superconducting Coil

The elaborate set up for winding the superconducting coil is now being used to wind a dummy coil on a full scale

Figure 4 : Superconducting coil winding setup at VECC.

dummy bobbin to get a feel of the actual job as well as to train the team. Several layers are being wound using the NEMA G-10CR spacers that will be used for the actual coil. This set up, shown in figure 4, has been fabricated and installed by a private firm as per our requirements. It consists of several stations for various operations and checks during winding. The entire set up will be completely debugged by the time actual winding starts in the early 2002. At this time the manufacturer will have supplied the SS bobbin that will, eventually, become part of the cryostat. Reference 2 gives more details of the superconducting coil winding process. A 1/5th scale superconducting coil is planned to be wound with minor modifications in the set up. This coil will be tested in a test facility involving an SMD20 dewar from M/s Oxford Instruments. This facility is coming up fast and will also be used to characterise the superconducting cable.

2.3 Cryostat

This part of the superconducting cyclotron is, possibly, the most intricate and complex in construction due to its

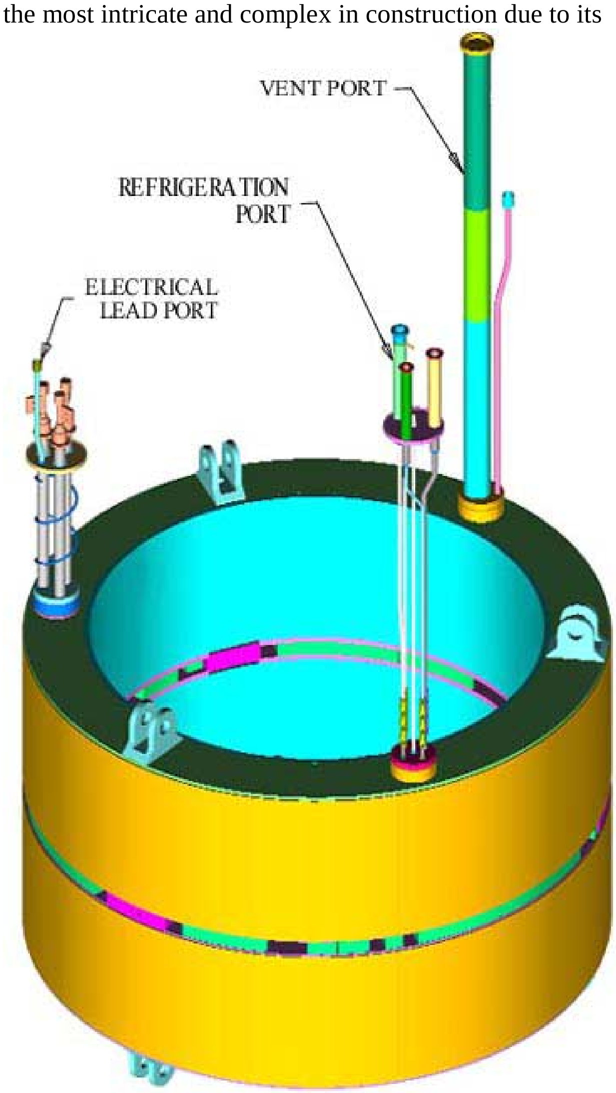

Figure : 5 Computer generated bobbin assembly.

'combined function' role. It not only houses the coil at 4.5K but also provides positioning/driving access for several extraction and diagnostic components inside the acceleration chamber. It is enclosed by the main magnet frame. We have been facing several problems in getting it fabricated. Most fabricators are, in the first instance, reluctant to take up the job being one of its kinds. It is also quite difficult to assess the job for a quote. The fabrication and assembly has to be done interactively with the coil winding. All these factors and our procedures have considerably delayed placement of the fabrication contract. The manufacturer will do the final assembly in the vault after the coil winding has been completed. In the mean time, we have been simulating the entire assembly on computer to check accuracy of the drawings and work out the sequence of operations. Heat load calculations for the entire assembly have been done[5].

2.4 Cryogenic Transfer Lines and Plants

Layout and specifications for the cryogenic delivery system have been finalized as per the design of our building. We have started negotiations with the possible

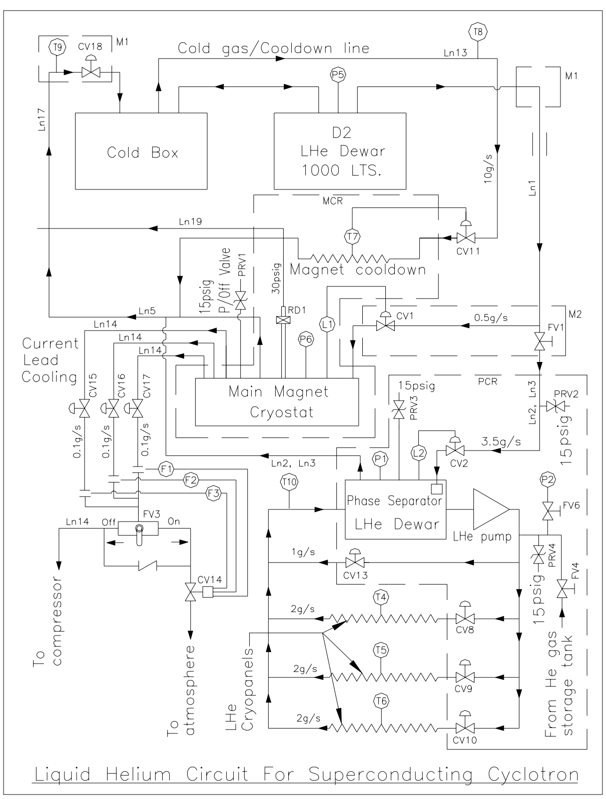

Figure 6 : Flow diagram of LHe Delivery System.

vendors for fabrication and installation. Apart from supplying LHe to the cryostat, a major function of the transfer lines is to cool the cryopanels to evacuate the acceleration chamber to high vacuum. The cryogens must be pumped up from below the cyclotron to the cryopanels through the RF resonators. Figure 6 shows the flow diagram of the LHe delivery system. Both LN2 jacketed as well as vacuum jacketed transfer lines will be used in the system.

The HELIAL 50 liquefier has been installed last year on a temporary site in the campus. It has been operating quite well. The liquefaction capacity with LN2 cooling is 100 l/h while without LN2 cooling it is 50 l/h. Refrigeration capacity with LN2 cooling is about 200 W at 4.5K. A 1000 litre dewar has been provided as buffer. The plant will be moved to its permanent site near the cyclotron when the building is ready in early 2002.

2.5 Radiofrequency System

The RF system has frequency range 9 to 27 MHz and the maximum dee voltage is expected to be 100 kV. Several parts of the RF resonators are being fabricated. The Central Workshops of BARC, Mumbai (formerly Bombay) have taken up the job with our collaboration. Like the cryostat, we have faced problems with the vendors in view of sophisticated techniques involved in the fabrication. Moreover, the material for fabrication is OFHC copper for most of the parts. Computer modelling of the dee shell and dee shell former was done. Scaled down prototypes were fabricated to learn and perfect the techniques involved.

Eimac 4CW 150000E tetrode will be used for each of the 3 amplification stages. A number of relevant circuits are being fabricated in house. Several PCBs for the low power electronic circuits are being designed and developed. Figure 7 shows the dummy assembly of an RF phase detector circuit.

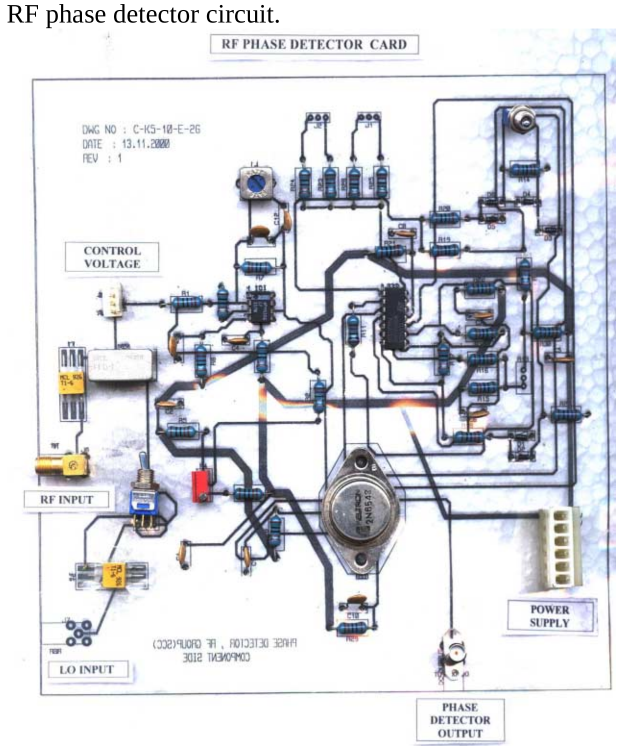

Figure 7: Dummy assembly of the RF Phase detector.

2.6 *Trim Coils*

Intricate jigs and fixtures have been fabricated for winding the trim coils. There are 13 sets of trim coils wound around the pole tips. OFHC copper conductor with 6.35 mm square cross section and central hole for water cooling will be used. Several coils have been wound.

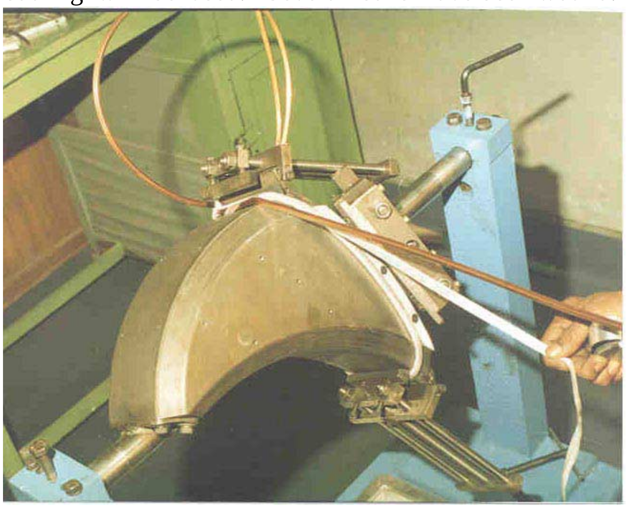

Figure 8 : Trim coil winding set up.

The coils will be epoxy impregnated. Figure 8 shows a part of the trim coil winding set up.

2.7 *Magnetic Field Measurements*

A magnetic field measurement set up based on the ones used at College Station and East Lansing is being fabricated by a vendor. However, the data acquisition and control software as well as instrumentation are being developed at VECC.

2.8 *ECR Sources*

In addition to the PANTECHNIK's 14 GHz ECR source, an indigenously designed source is being constructed. This source will also operate at 14 GHz microwave frequency. Some parts of this source are already under fabrication. The axial mirror peak field on the injection side is 12 kG and on extraction side it is 10.75 kG. A 'halbach' type sextupole geometry with 11.24 kG field at the inside plasma wall will be used. Figure 9 shows the diagram of this source.

2.9 *Power Supplies*

Two 20V, 1000A power supplies for energising the α and β superconducting coils will soon be supplied by M/s DANFYSIK. They come along with the dump resistors and associated electronics. We shall also develop the standby power supplies at VECC. Several other power supplies such as those for the trim coils, RF system, extraction system, beam line magnets, ECR and injection line magnets etc. are being fabricated, largely, in house. This is a large activity involving fairly large amount of manpower. We have excellent expertise in this area. Elaborate fabrication and testing facilities are being set up.

2.10 *Computer Control & Beam Diagnostics*

The overall control mode has been planned to be open-loop control of accelerator operations and intelligent beam property regulation through various diagnostic devices. The NT & Linux work stations at console, Ethernet LAN for connectivity, Pentium PCs with Windows NT/CE and VXworks for front end and CAN, RS485, RS422, GPIB, Add-on modules for device interfacing are favoured at present. A number of single and multi-tasking application systems have been developed. They are being tried out with the existing cyclotron. Some developmental work in the area of capacitive as well as scintillation detector phase probes and image digitization has been carried out.

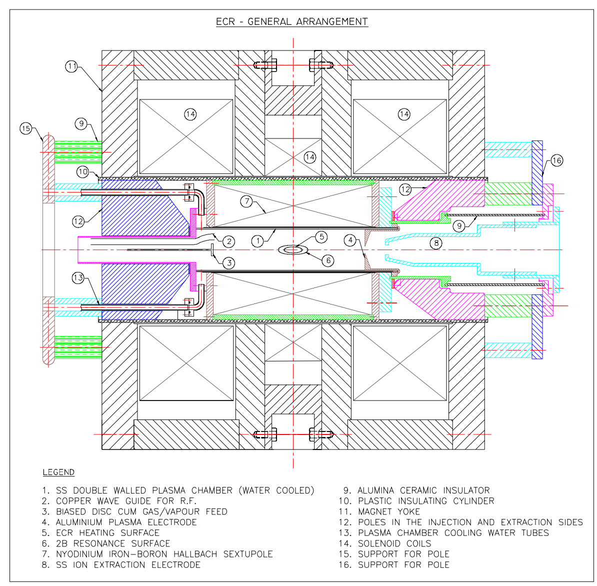

Figure 9 : Line diagram of the 14.6 GHz ECR source under construction .

2.11 *Beam Lines and Experimental Facilities*

Layout of the first 3 experimental caves that are presently under construction is shown in the figure 1. Configuration of the beam lines as shown in this figure is now final. Preliminary design calculations on the beam steering and phase space matching systems, immediately after extraction, have been carried out. Ion optics of the rest of the beam transport system utilises the two bending magnets to reduce the dispersion coefficients to a certain extent. The optics beyond the second magnet is telescopic in nature.

The experimental facilities that are being planned for these experimental caves include a large multipurpose scattering chamber, a 4π charged particle array, high energy γ-detector array, discrete γ-detector array etc. The undeflected beam line will take the beam to a large hall to be constructed soon for housing the facilities such as projectile fragment separator etc. Several national groups are working on finalisation of the first phase of experimental facilities.

The construction of the elaborate underground part of the building has been completed. Significant fraction of the part above the ground has also been constructed. We expect to occupy the building, along with limited services, for accelerator activities in the first quarter of 2002.

3 PROJECT SCHEDULE

We are expecting that the parts of the main magnet frame will be delivered to us by October this year after making a trial assembly of the frame for inspection at the manufacturer's site. The bobbin is likely to be available for the superconducting coil winding at VECC by April 2002. The coil winding may take about six months to be completed. The assembly of cryostat in the vault of the superconducting cyclotron building will begin towards the end of 2002. In the mean time, installation of the LHe plant and associated systems will be going on at its permanent site. The cryogenic delivery system will also be installed during this period. We expect to energise the main magnet sometime during the first quarter of 2003 and complete the magnetic field measurements by the end of 2003. Assembly of the rest of the cyclotron systems will be carried out during 2004 to begin the commissioning trials towards the end of that year.

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