STATUS OF THE K500 SUPERCONDUCTING CYCLOTRON PROJECT AT KOLKATA

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Abstract

The 100 tonne main magnet of the cyclotron has been successfully energized without a single quench. Detailed magnetic field measurements were completed using a fast and fully automatic mapper system. Based on the measurements, shimming of the magnet iron was done to bring down the first harmonic below acceptable level near the cyclotron center and in the extraction region. Prior to that, several teething but interesting problems were successfully overcome during cool down and energization of the main coils. The magnet was operated satisfactorily for over one year. Currently, assembly of various other systems is going with an aim to tune out the first beam in early part of 2008. We have gone through very difficult but useful experience during the assembly of the complex RF resonator structures and in providing sufficient cooling for the cryo-panels. Work is also going on for installation of the injection line, extraction system, computer control etc. In this paper, brief details of various activities will be presented.

INTRODUCTION

The cyclotron magnet cool-down was started at the beginning of 2005 and it was operated satisfactorily for almost one year till 2006 [1]. During this period magnetic field measurements and correction of the imperfections were carried out in detail. In middle of 2006, the coil was warmed up to assemble other systems of the machine, like RF resonators, cryo-panels, injection and extraction beam line, etc. Figure 1 shows the main magnet assembly.

Figure 1: Main magnet assembly.

COMMISSIONING OF MAIN MAGNET

A 200W (at 4.5K) helium refrigerator/liquefier and the transfer lines connecting the cold box and nitrogen delivery system to the cryostat had already been installed. A turbo-molecular pump, backed by scroll pump, was used to maintain ~10^{-6} mbar pressure in the cryostat outer vacuum chamber (OVC). Two 1000A, 20V power supplies with 10-ppm stability for the main coil along with dump resistors and control software were used to energize the magnet.

Magnet Cool-down

At first the moisture level in the cryostat was reduced below 10 ppm by repetitive evacuation and purging with pure helium gas and heating the coil with 5A current. Then cold helium gas was delivered directly from cold box until cryostat temperature comes down close to 5K. Subsequently, liquid helium (LHe) filling started. The temperature at four different places of the coil was monitored online as a check to keep their maximum difference within 50K. Initially, liquid nitrogen (LN) cooling to the radiation shield was not available. Still the cryostat could be filled up within 21 days (figure 2), with a 3 days halt due to vacuum degradation (12^{th} -15^{th} day). It was due to some leaks on the current lead bellows, which were fixed. During cooling, the radial support link forces were adjusted to keep the forces within safe limit.

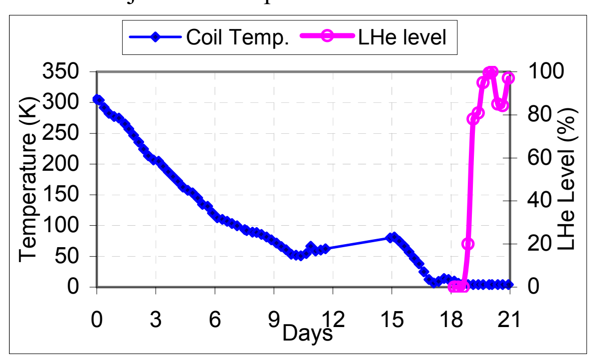

Figure 2: Coil temperature and liquid helium level in the cryostat during the cool down period.

Magnet Ramp-up

A stable liquid helium level in the cryostat was ensured before energizing the magnet. Due to very high inductance at low currents, the ramp up rate was restricted to 2 A/min till 50A and 10 A/min for higher currents. During abnormal situations, the power supplies were put off and the coil energy dissipated through dump resistors.

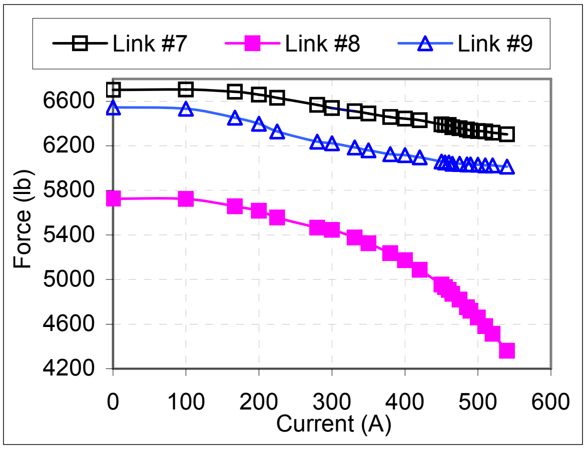

Figure 3: Radial support link forces vs. current.

The force on the coil was monitored by strain gauges on radial support links. The coil was moved to a position where its axis was closest to the magnetic axis of symmetry. At this position, the forces on the radial support links were decreasing monotonically with current due to magnetic hoop stress as shown in figure 3.

Magnetic Field Measurement Results

The magnetic field has been measured with a search coil and NMR set up, with linear and angular positioning accuracy of 10 μm and 0.5 arc-seconds, respectively. Three iron shims were placed on each of the pole tips, near radius equal to 12 cm, 17 cm and 35 cm respectively, to smooth out the dips (~80G) in iron-average field, as shown in figure 4.

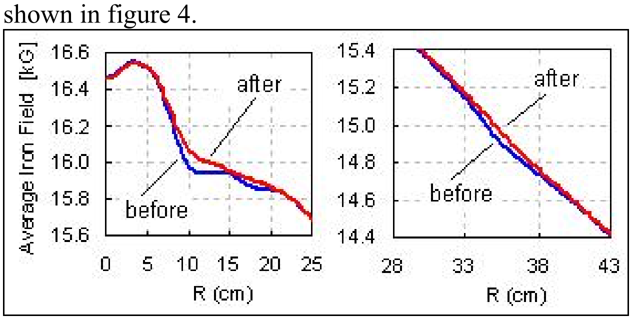

Figure 4: Average field profile of iron, before and after addition of shims at 3 radial positions on each pole tip.

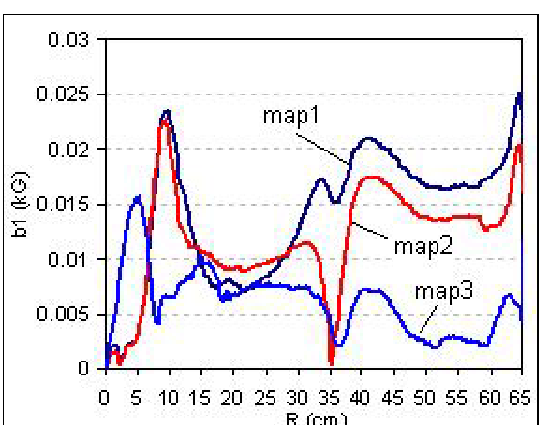

Figure 5: Minimization of 1st harmonic field.

The most important issue was to minimize the first harmonic component in the field in the central and extraction regions. As shown in the figure 5, primary measurements (map 1) showed large first harmonic (>20G) at the edges of pole tips. Near the centre, this was due to assembly error of small hill extension components. From 35cm onwards, the large first harmonic was contributed by one of the outer pieces of pole-tips. Readjusting them reduced the first harmonic by some amount (map 2). Finally first harmonic was brought down less that 6G at extraction by iron shimming (map3).

RF AND OTHER SYSTEMS

Trim-coils

There are 13 epoxy potted trim coils wound on each pole tip as shown in figure 6. There are 78 trim-coil feed-thrus and several vacuum fittings on the back of the pole caps, that were thoroughly leak tested, after installing RF liners on the pole tip sectors wound with trim coils. Figure 7 shows the median plane liner and dees installed in position over the pole tips and trim-coils.

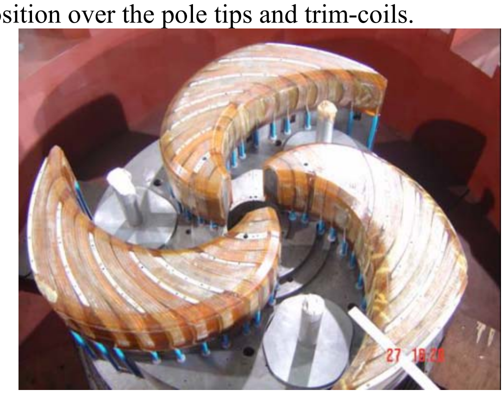

Figure 6: Trim coils placed on the pole tip.

Figure 7: Liner and dees installed on lower pole tip.

RF System

Three RF amplifiers are installed at site and tested. Q-value measurements show satisfactory performance. Various other sub-systems of the RF electrical system including dedicated controls and power supplies have been installed and tested.

Assemblies of the three lower cavities are over. Rigorous trials were taken on making solder and braze joints in close proximity at the end of inner conductor assemblies. The joints were hydro-tested at 16 kg/cm^2 pressure and helium leak rate found was below 5x10^{-9} std cc/sec. At one end of this 5.5 m long structure, dees are mounted and machining was done to maintain parallelism between the faces of the inner conductor spinning base flange and dee joint flange within ± 0.13 mm. Figure 8 shows various components below the magnet frame.

The inner conductors were installed with the cryogenic transfer lines for cryo-panels located inside the three lower dees. Work on installation of the sliding short drive systems is in progress and installation of the upper resonator cavities will start soon.

Figure 8: One of three lower outer conductor spinning assemblies below pole base of the cyclotron magnet.

Cryogenic Delivery System for Cryo-panels

Installation and testing of the cryogenic system for cryopanels has been done. At liquid nitrogen temperature, vacuum at the cold head was observed to be 4x10^{-6} mbar. Further cooling down with liquid helium, the temperature of cold head was maintained below 20 K, with a heater energized to 12 watts placed at cold head.

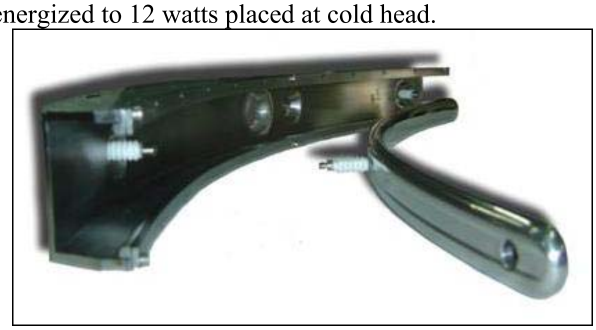

Figure 9: Electrostatic deflector.

Electrostatic Deflector

A deflector test stand had already been setup. The deflector system (figure 9) has been tested there satisfactorily with more than 50 kV over 6 mm gap and less than 100 nA dark current, over several weeks.

Control System

The control system of Superconducting Cyclotron follows a two-layer architecture. A number of PCs/ Workstations, acting as control console reside on a Gigabit Ethernet optical fibre LAN. The front-end computers (FECs), running Windows XP/ Linux, communicate over serial links (RS 232/ 422/ 485) to device controllers and instruments.

Injection and Extraction Beam lines

The ECR ion source has been installed in the high bay of the superconducting cyclotron building. Most of the components of the injection beam line are installed. Figure 10 shows the injection scheme with two ECR ion sources. Layout of the external beam lines is shown in figure 11.

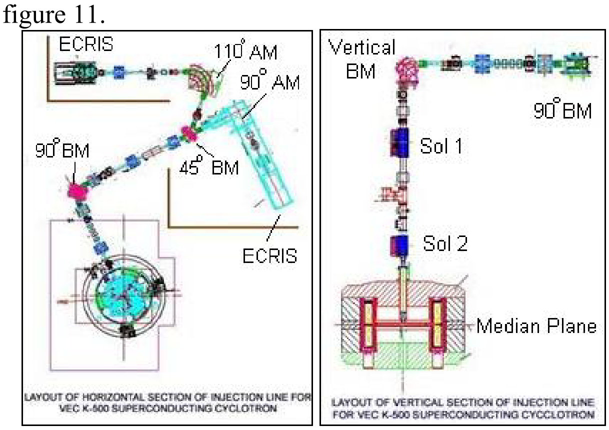

Figure 10: Schematic top and elevation view of injection beamlines with two ECR sources.

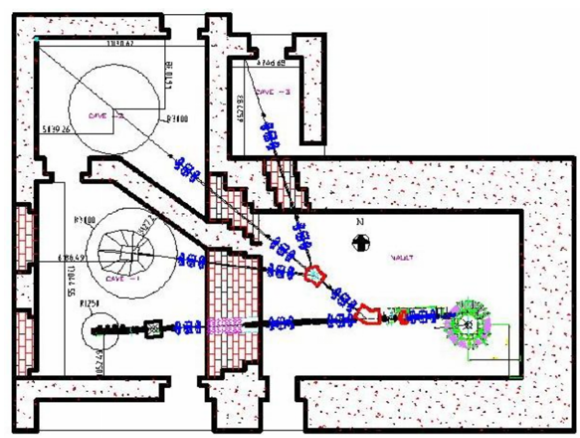

Figure 11: Schematic of extraction beam lines.

CONCLUSION

The most important component of the cyclotron i.e. superconducting magnet has already been commissioned. Other systems are currently being assembled. The cyclotron is expected to accelerate beam in early 2008.

ACKNOWLEDGEMENT

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REFERENCES

[1] Rakesh K.Bhandari, "Status of the VECC Superconducting Cyclotron Project", APAC2007, RRCAT, Indore, India.