K130 Cyclotron

K130 cyclotron magnet

The H-shaped electromagnet is the largest and the heaviest component of the Variable Energy Cyclotron at Kolkata. It weighs approximately 262 ton. Its overall dimensions are 610 cm long, 224 cm wide and 290 cm height. The yokes consist of 5 slabs 610 cm X 89 cm X 45 cm, each slab weighs about 20 ton and two trapezoidal legs weighing about 17.5 ton each. Each of the two yokes is attached to a cylindrical pole piece 224 cm in diameter together with 3 spiral shaped pole tips placed 120° apart.

The magnet coils uses ETP copper conductor of square cross section 2.9 cm x 2.9 cm with 1.9 cm diameter hole in the centre for coolant flow. The conductor was wound in pancakes of two layers, each layer having ten turns with I.D. 228.3 cm and O.D. 288 cm. Ten such pancakes were used, five each for upper & lower assemblies. The coil has 200 turns and capable of producing 600,000 ampere turns. The total weight of copper in the conductor is approximately 9 tonnes.

The cyclotron has trim and valley coils. Each of the trim coils having 2 to 4 concentric turns were symmetrically placed both in upper and lower pole faces. Valley coils introduce field harmonics in a controlled way. There are five sets of such coils, each set having three pairs located at the top and bottom pole faces of the three valley gaps. Valley coils are made of round hollow copper conductors. 64 leads, 34 from 17 trim coils and 30 from 5 valley coils, come out of both top and bottom copper plates holding the trim and valley coils to be connected to the cooling water channels and the power supplies.

The magnet along with the coils was installed at Kolkata in April 1975 and is in operation.

Fig. 1 : K130 Cyclotron Magnet
The radio frequency (RF) system of the K-130 Cyclotron mainly consists of the Dee, the Dee stem, the fixed and moving panels, all enclosed in a vacuum tight enclosure called the resonator tank and Dee tank. They form the variable frequency quarter wave resonator of the RF System. The moving panels tune the RF system in the range 5.5 MHz to 16.5 MHz by changing the inductance of the Dee stem and develop a maximum of 70 kV at the Dee. The measured Q factor of the resonator is about 3000. The total losses including skin losses, beam power, transmission line, losses at joints, etc. at 16.5 MHz is about 250 KW.

The mechanical features of the various components are described below:

Dee: The Dee is made of 20 mm thick copper plates. Rectangular grooves, on the plates, house copper cooling channels. Two such plates are assembled over K-Monel Yokes to provide a rectangular aperture of 38 mm x 18.5 mm at the edge of the Dee. The Dee is attached to the Dee stem by K-Monel clamping bars. Silver plated copper foil is used to connect the Dee with the Dee stem at the joints.

Dee Stem: The Dee stem is fabricated from 1.6 mm thick copper sheet, mounted on a stainless steel structural framework. It is rectangular shaped of dimension 2765 mm x 1300 mm x 203 mm. Copper cooling tubes are brazed on the skin to provide water-cooling.

Fixed and Moving Panels: There are eight water cooled panels of dimension 2830 mm x 900 mm, two are fixed and the remaining are moving. The moving panels are located on either side of the Dee stem, three on each side.

Dee Cart: The Dee cart is attached at the back of the resonator tank. It holds the Dee-Dee stem assembly cantilevered inside the resonator tank through an anchorage and adjusting mechanism.

Trimmer capacitor: The Trimmer capacitor is a parallel plate type capacitor having major two assemblies, Trimmer Rotor attached to Resonator Tank wall and Trimmer Stator attached to Dee Stem. They are water cooled at the periphery of the plates. The Trimmer capacitor fine tunes the RF frequency to few kHz.

Resonator Tank: The Resonator Tank, in which the radio frequency system is housed, is a vacuum-tight enclosure fabricated from 38 mm thick copper clad high tensile strength steel plates on three sides, and boiler quality steel plates on the other three sides. The tank is of overall dimension 2.362 m x 3.125 m x 2.386 m, weighs about 12 tonnes. It was required to be vacuum-tight, since the operating pressure would be around $10^{-5}$ Torr. The two large aluminium doors for the tank were fabricated from 40mm thick aluminium alloy plates.
Corner post replacement for K-130 Cyclotron beam chamber

The air leakage through sealing of “O” ring at the Resonator tank to Dee tank mating interface of K-130 Cyclotron was successfully rectified by replacing the four Corner posts along with “O” ring / “H” seal of new design. All major components of the K130 cyclotron had to be dismantled and reassembled with proper planning to ensure that the normal operation of Cyclotron is restored in 35 days of shut-down.
The 4648 Burle tube assembly, Dee Dee-Stem Assembly, Deflector assembly, Pick off, Target probe, Puller, Beam probe, Beam exit port line components etc. were dismantled and taken out of the Cyclotron. The resonator tank (12 ton) was rolled out by 70 mm over the rail, along with both the Diffusion pumps and vacuum systems. After replacement of “O” ring and “H” seals, the resonator tank was rolled in and evacuated to $2 \times 10^{-2}$ mbar for qualifying He leak rate $< 2 \times 10^{-7}$ std. cc/s. The cyclotron is working satisfactorily after this rectification of vacuum tank with new design of corner post and “H” seal.

**Development of high power blocking capacitor**

Development of high power blocking capacitors required for the RF amplifier system of the cyclotron has been taken up. A prototype has already been made and tested [refer the Figure].

- 260 ND x 207 mm long
- ETP Cu + 3 layers of 125µ Kaptan
- Useful to replace Burle 4648 Tetrode in K-130 Cyclotron RF to EIMAG 150000
- Economical
- Insulation tested upto 30 KV (requirement 20 KV)
- Capacitance achieved 10000 pf
- Fault rectification very simple
- Fabrication technique applicable to any other size of co-axial capacitor model.

**Modified vacuum chamber for Analyzing Magnet (AM) of K-130 Cyclotron beam line**

The design, fabrication and installation of a Stainless Steel vacuum chamber (see Fig.3 to 5) for AM at the “Feeder Line i.e. Channel-4” in the BTS line feeding to RIB
applications was carried out upon planned shut-down of the Cyclotron by removing and re-assembling of 11 nos. shielding planks weighing ~27 tonnes each, upper pole cap, pole tip, coil etc. A trapezoidal x-section, welded type SS vacuum chamber (~ 4.4 meter outer dia. x 65 mm height x 210 mm width x 159.50 arc coverage ) free of “O” ring sealing had been designed to take care the frequent vacuum leakage. The feeder line is commissioned in achromatic mode. Poor vacuum was unsuitable for beam transport with previous “O” ring sealed type vacuum chamber made of aluminum alloy. The same was replaced with newly designed and fabricated welded type vacuum chamber. The achievable vacuum in the modified beam line is better than $1 \times 10^{-6}$ mbar with new vacuum chamber in position.

![Image](image1.png)

**Fig. 3:** Von-Mises stress contour in vacuum chamber for Analyzing Magnet.

![Image](image2.png)

**Fig. 4:** Upper pole cap of Analyzing Magnet, covered for installation of Advanced Vacuum chamber.

![Image](image3.png)

**Fig. 5:** Installation of Vacuum Chamber on Analyzing Magnet, R-130 Cyclotron.

**K130 cyclotron extraction system**

There are two deflectors, upstream deflector and downstream deflector having a total span of 108°. Each deflector consists of two water cooled electrodes; high voltage electrode and ground electrode. High voltage electrode is made of Inconel. The spark shield is made of SS 304. A voltage of about 50 kV is fed into the high voltage electrode. The high voltage electrode and the ground electrode can be given independent movement so that the gap between the high voltage electrode and the ground electrode can be changed. Fabrication of new deflector is being explored.
Fig. 1: Electrostatic deflector assembly

During operation of the cyclotron, high energy beam impinges on the deflector and it has large residual activity. Maintenance of the electrostatic deflector has to be done carefully to reduce radiation dose to the maintenance staff. A remote handling device for removing the septum from deflector assembly, keeping it in a lead shielded camber and fixing it again in deflector assembly when required will reduce the radiation dose to the persons doing that work. The design and development of manual robotic arm which can be operated from approximately one meter distance to take out and insert the septum in deflector assembly by one person very quickly has been completed and tested (Fig. 3).

Fig. 3: Model of remote handling device

*Air-lock Tank for K-130 cyclotron*

Air-lock tank in RTC is used for maintenance of ion puller and Dee insert without breaking the cyclotron vacuum. In the existing system one inclined gate valve is used to isolate the air lock tank vacuum from cyclotron vacuum. This inclined gate valve is not sealing and is not being used for long time. The width of the opening is also not sufficient for DEE insert to extract from the cyclotron directly. As a result every
time we want to do maintenance for the puller or Dee insert we need to break the cyclotron vacuum. This leads to a considerable down time for the cyclotron operation. Present tank is made from carbon steel and is quite heavy. So our objective is to redesign it with a lighter material, (Al) with proper selection of gate valve and making proper opening dimensions for easy and smooth removal of Dee insert. Fig. 1 gives a 3D model of the Air-lock tank for K130 cyclotron.

Fig. 1: 3D model of Airlock Tank