224 CM VARIABLE ENERGY CYCLOTRON AT CALCUTTA

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Summary

Progress of work on the construction of the 224 cm. Variable Energy Cyclotron, being installed at Calcutta is described. The cyclotron, with maximum expected energies of 70 MeV protons, 65 MeV deuterons and 130 MeV alphas, follows the design of the 88" cyclotrons at the Lawrence Berkeley Laboratory and the Texas A & M University, with some modifications incorporated for facilitating indigenous fabrication and for improved performance. The yokes and yoke legs of the 250 tonne magnet have been cast and tested for composition and porosity. The machining of yokes, yoke legs and pole pieces is under way. The main coil winding has started. The trim and valley coils will be epoxy potted. The rf system, utilising the RCA 6949 oscillator tube, is a combination of a self-excited and a driven system. Power supply fabrication is nearing completion and two 89 cm diffusion pumps have been fabricated for the vacuum system. The building is in the final stages. Beam transport layout envisages three high intensity and six high resolution channels. A small 8k on-line computer is being planned. Various other facilities are also being planned.

Introduction

The Bhabha Atomic Research Centre is constructing a 224 cm Variable Energy Cyclotron for installation at Calcutta. The design of the cyclotron is based on the 88" cyclotron at the Lawrence Berkeley Laboratory and at the Texas A & M University with some modifications incorporated for facilitating the indigenous fabrication and for improved performance. It is expected that the cyclotron would be able to accelerate protons to around 70 MeV, deuterons to 65 MeV and alphas to 130 MeV.

Magnet

The 'H' type magnet frame consists of upper and lower yokes, yoke legs, poles, valley floor/dee tank cover plates and pole sectors. Upper and lower yokes are both made of 5 slabs of 6096 x 889 x 447 mm size, each weighing about 20 tonnes. The two yoke legs have trapezoidal shapes and weigh about 18 tonnes each. The magnet fabrication is being done by the Heavy Engineering Corporation Ltd., Ranchi, India (HEC). In the original Berkeley design these pieces have been specified as forged pieces. Owing to the limitations of the forging facilities available in India at the time of starting, the feasibility of using cast pieces for the magnet frame was explored. After undertaking studies pertaining to the carbon content, magnetic properties and porosity, it was decided to use castings. In order to obtain sound castings for the blocks, the pieces were cast with large riser portions. Special moulds were made for this purpose and the weights of the as-cast pieces were around 50 tonnes. This allowed the rejection of the top portion of the castings, where most of the blow holes were concentrated. The bottom portions of the castings, which are used for the magnet, were subjected to ultrasonic tests and found to be free from blow holes and other internal defects.

The composition of steel as per specifications and as obtained at the HEC is shown in Table I.

Table I

Comparison of specified and achieved steel composition

	Specified composition	Achieved composition (Typical)
Carbon	0.12% max.	0.11%
Silicon	0.35% max.	0.25%
Manganese	0.50% max.	0.30%
Phosphorous	0.04% max.	0.011%
Sulphur	0.05% max.	0.023%
Iron	Balance	Balance

Heat treatment of the castings involved annealing at 950°C for 24 hours with two intermediate soaking periods. Sample pieces obtained from the same melt as the castings were tested for the magnetic properties. Measurement of the dynamic hysterisis loop was done using a cathode ray oscilloscope. The results obtained compared favourably with those of known high quality magnetic steel (Tata 'A' grade steel).

All the castings have now been completed, rough-machining of the yokes and yoke legs finished, and finish machining is under way. Fig. 1 shows the machined yoke slabs at the HEC factory.

The pole pieces, valley floor plates and the sectors, however, are being made from forged steel, imported from the USA. The two pole pieces (2240mm dia x 323 mm thick) have been machined. Both the carbon steel valley floor plates and the S. S. dee tank cover plates have been rough-machined and welded. Three out of six sectors have been machined. The completed magnet frame is expected to be ready by June, 1973.

The magnet coils are being fabricated at the Heavy Electricals (India) Ltd., Bhopal. The winding operation for the main coils, made of 28 mm square hollow copper conductor, is shown in Fig. 2. Two coil pancakes have been made and the remaining eight will be ready by June, 1973.

The trim and valley coils are being made using hollow copper conductors. These are insulated with "Samicatherm" tape, laid into machined grooves made in the copper base plate, and epoxy potted. The design is shown in Fig. 3. The valley coil assemblies are manufactured and cast with epoxy separately and then screwed on to the trim coil base plate. Epoxy mixture being used in this case has the composition by weight, (i) Epoxy resin 100 parts (ii) Aeromatic Hardner 10 parts (iii) Marble Powder 60 parts (iv) Silica flour, 60 parts. The radiation damage effects on the epoxy were tested on samples by subjecting them to an intense neutron dose in the Apsara reactor at Trombay. No specific deterioration of the electrical and mechanical properties was observed.

R. F. System

A full scale mock-up of the entire resonant system of the cyclotron was constructed to determine if the maximum resonant frequency of the system could be increased from 16.5 MHz to 18 MHz so that the maximum proton energy available could be increased. After some trials at low power, the shape of the corrugations of the panels and dee-stem were redesigned to give an estimated maximum resonant frequency of 18 MHz. The radio frequency system being adopted is a combination of a self-excited and a driven system. Fig. 4 shows the system, wherein a frequency synthesizer capable of giving a highly stable frequency output from 5.5 to 20 MHz has been used. The output of this synthesizer is fed to a distributed amplifier having a flat top frequency response in the frequency range of 5.5 to 20 MHz and output of 1 KW across 400 ohm load. The output of the distributed amplifier is fed to the grid of the RCA 6949 oscillator tube along with the output from the grid line of the cyclotron. This system, therefore, combines the good features of both the self excited and driven systems (the injection of synchronizing pulse was tried out successfully on the mock up.). It is expected that the difficulties due to the multi-pactoring losses will be overcome in this design, without the use of a pre-exciter. All the rf panels, dee stem and the drive system are now ready, at Trombay. The solid copper dee of the cyclotron is nearing completion. The resonator tank is under fabrication at the Garden Reach Workshops Ltd., Calcutta.

Injection, Extraction and Control Systems

Fabrication of the ion source and its drive system is nearing completion at Trombay. Deflector and probe fabrication has been started. Control console is being made.

Vacuum System

Two 89 cm. diameter diffusion pumps were designed and fabricated at Trombay. Each pump has a pumping speed of 50,000 litres per second for nitrogen. It is planned to instal two such pumps below the resonator tank of the cyclotron. Two additional pumps will be installed on the dee-tank, one of which is likely to be an orbitron pump.

Power Supplies

A prototype SCR controlled main coil power supply capable of giving 3000 A DC. at 175 V has been made and tested. Its stability is better than 0.01% against combined mains and load functions of upto 10% each. It will be reassembled in the final form soon.

All the 17 trim coil power supplies, transistor controlled, capable of giving an output current varying from 750 to 2500 A DC, are ready and tested. They are also stabilized to better than 0.01%. All the 5 valley coil power supplies of 300 A DC at 15 V are being installed at site. 50% of the work on rf power supply, capable of giving 20 A DC at 20 kV, is completed. Its oil-cooled power transformers will be installed outside the shielding walls with the rectifier units in the pit. All the other power transformers are air cooled and are incorporated in the respective cabinets. All these power supplies will be installed in the pit of the cyclotron laboratory below the main vault.

Beam Transport and Data Processing

Fig. 5 shows a detailed layout of the experimental area of the VEC Laboratory, showing the vault, the high intensity caves, the high resolution caves, the control room, the data processing rooms, and other areas. Fabrication work for the quadrupole magnets, switching magnets, 160° analysing magnet ($n=1/2$) and other beam transport accessories has started. The three high intensity channels are expected to provide beam currents upto $100\mu A$ with an energy spread of 300-400 keV. The six high resolution channels are expected to provide beam currents of $1\text{-}2\mu A$ with an energy spread of 15 keV, for 1 mm slit width. A pneumatic conveyer, leading to the chemistry laboratory has been provided.

For data processing an 8 K, 16 bit on-line computer will be available.

Building and Services

The cyclotron building covers an area of about 12,000 sq. metres comprising of the following:

Accelerator Wing	6,100 m^2
Services Wing (Electrical & Mechanical Services, Workshop and A/C Plant)	3,100 m^2
Laboratory & office Wing	2,800 m^2

A 30/5 tonne crane has been provided to cover the entire span of the accelerator wing.

The building, which is located in the Salt Lake area in Calcutta, is in the final stages of completion.

Cost and Time Schedule

The total project cost is Rs. 62.8 million (1 Rs. = $ 0.14), and the detailed break up is as follows:

	Rs. (million)
Accelerator	18.8
Beam Transport, Data Processing & other accessories	12.7
Building & Services	24.3
Salary & import duty	7.0

The total foreign exchange component involved is about Rs. 7.5 million. The construction work of the cyclotron started in June, 1969. It is expected that the internal beam will be available by September, 1974 and the analysed beam by May, 1975.

Experimental Facilities and Utilization

Under Phase II of the project, plans are being finalised to have facilities like target preparation facility, detector fabrication facility, a 150 cm scattering chamber, a cryogenic scattering chamber, a magnetic spectrometer, and other standard facilities. It is proposed to develop an axial injection system and a polarised ion source. A large computer facility has also been planned. Apart from the above, electronics support facility, cryogenic systems, on-line mass separator facility, facilities for isotope production and for chemical and biological studies have also been planned.

It is proposed that the Variable Energy Cyclotron facility will be available for utilization to users from institutions and universities all over India.

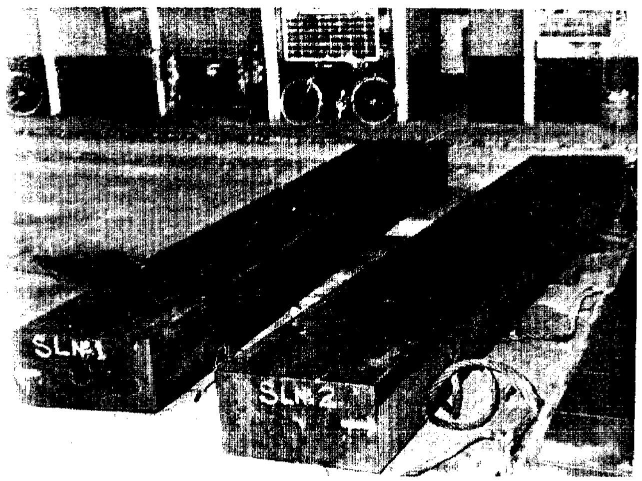

Figure 1.

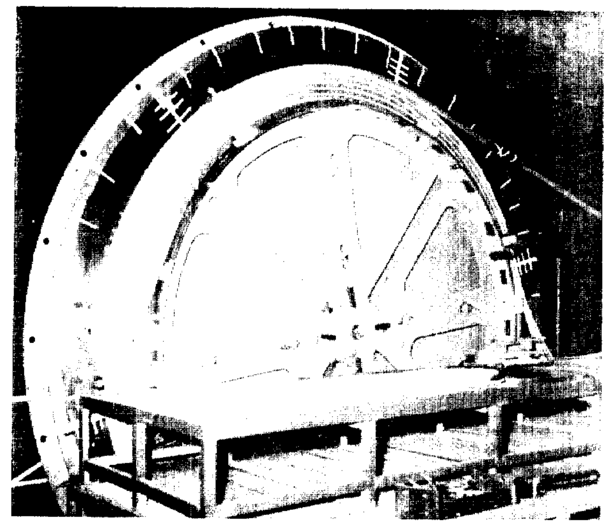

Figure 2.

TRIM AND VALLEY COILS

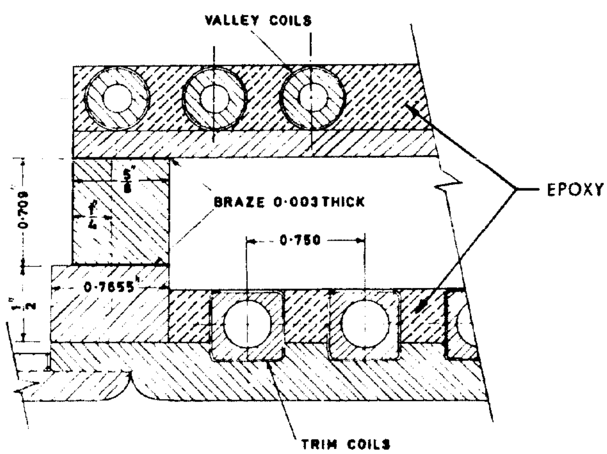

Figure 3A.

VALLEY COILS

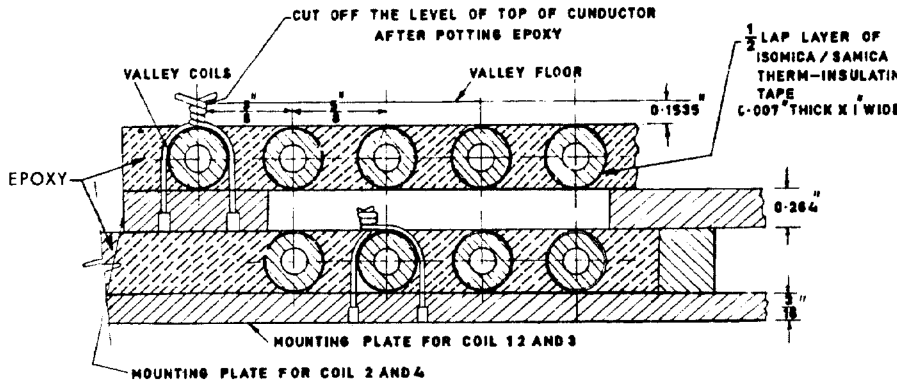

Figure 3B.

R. F. SYSTEM

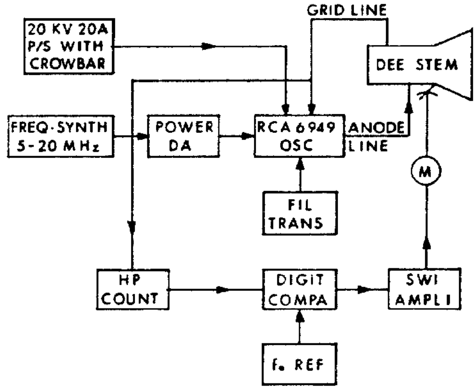

Figure 4.

V.E.C. LABORATORY — EXPERIMENTAL AREA

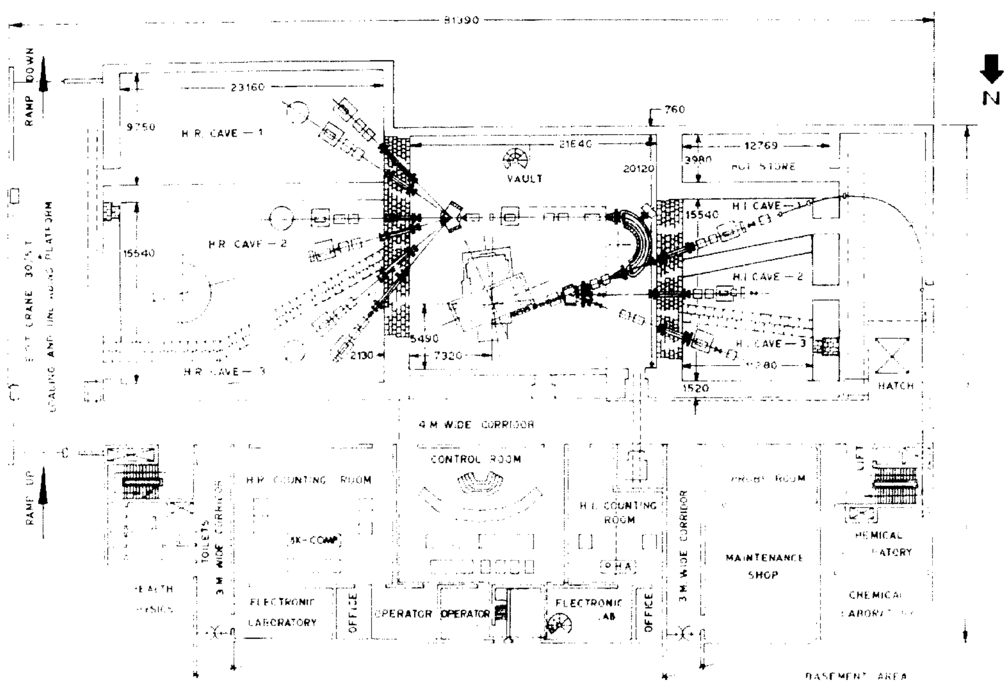

Figure 5.