BEAM TRIALS AT 1 MeV OF A DC ELECTRON ACCELERATOR

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Abstract

A 3 MeV, 30 kW DC accelerator is under development at the Electron Beam Centre, Kharghar, Navi Mumbai for industrial applications and currently beam trials are on at 1 MeV, 5 kW. The paper gives a brief description of the beam-line and reports on the results of beam transmission experiments during these trials.

INTRODUCTION

D.C. electron accelerators of energy ranging from a few hundred keVs to few MeVs and power from a few kilowatts to hundreds of kilowatts have industrial applications like medical sterilization, rubber vulcanization, polymerization & cross-linking, pollution control from thermal power stations etc. A 3 MeV, 30 kW DC accelerator is under development at Electron Beam Centre, Kharghar, Navi Mumbai by BARC to demonstrate such industrial applications. A schematic of the accelerator is shown in Fig. 1.

ELECTRON GUN & ACCELERATING COLUMN

The electron gun uses a thermionically heated 10 mm diameter LaB_6 cathode which can be heated to about 1300^0 C by a Tungsten Filament fed by 100-150 watts of power. Cathode-anode voltage can be varied between 1-5 kV. The filament power supply and cathode-anode supply derive their power from the high voltage column.

The accelerating column consists of 10 accelerating tubes of National Electrostatics Corporation (NEC) make. Each tube is about 30 cm. long and can sustain a voltage of 335 kV with evacuation inside and outside in pressurized SF_6 environment. The accelerating tube consists of titanium electrodes with Alumina insulators separating consecutive electrodes with diffusion bonding between the ceramic and metal. The accelerating voltage derived from the accelerating column located in Nitrogen/SF_6 environment is divided by a resistor chain and the voltage applied to the electrodes. It is evacuated to 10^{-7} millibar by Sputter Ion Pumps in the beam-line. It has an external pressure of 6 atmosphere.

BEAM-LINE ELEMENTS

After the accelerating column, beam-pipe of 9.5 cm internal diameter is used for beam propagation. The beam-pipe consists of four separate sections, consecutive sections joined by conflate flanges.

A steering magnet is positioned 40 cm. away from the exit of the accelerating column in the first section and is inside the pressure vessel. The coils are toroidally wound on iron half cylinders of 12 cm. internal diameter, 5 mm thickness and 20 cm height. The half–cylinders can be assembled around the beam–pipe to form a complete cylinder. X-Y fields can be generated by this arrangement to correct beam-straying by using a power supply able to provide current in the range of 0-5 A.

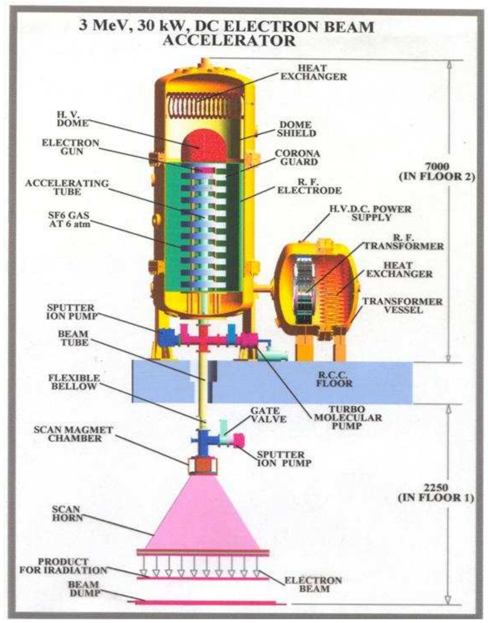

Figure 1: Schematic of DC Electron Accelerator.

The third section of the beam-pipe has access for a sputter ion pump of speed 500 litres/s. This section is joined to the next section by a bellow. In the fourth section of the beam-pipe, a focussing coil is wound over the beam-pipe along a length of 15 cm. It can provide a maximum of 5000 ampere turns to reduce beam size if required.

After about 3 meter distance from the end of accelerating column, the scanning section is located. In the scanning section, the cross-section is obround so that magnetic field can be provided in a region of 7.5 cm (Z) x 10 cm(X), the magnet gap being 5cm.(Y). Z direction refers to the initial beam direction, Y to the direction of the magnetic field and X to the direction of scanning. The wall thickness of the scan chamber is 1.25 mm to allow penetration of flux into beam-line to cause deflection. An H-shaped scanning magnet made of 0.23 mm thick silicon steel laminations is used to scan the beam at 100 Hz. It generates bipolar symmetric triangular current waveform. A 30^0 scan horn with fins and water-cooling is used.

Exit window of length 100 cm and width 5 cm utilizes a 50 µm thick Ti foil which is given a profile so that it is concave towards atmospheric side and convex towards the vacuum side. This is achieved by using two rectangular flanges. The first one has two humps at either ends to provide proper shape to the foil. The second flange is shaped at the ends to fit snugly into the the humps with the Titanium foil in-between.

There is a device called Beam Sensing Aperture shown in Fig.2 before the scan section to protect the thin-walled scan chamber from beam-hit. It is a stainless steel flange with an inner concentric copper disc having a 45 mm diameter central hole. Thermocouples can be inserted through the periphery of the stainless steel flange into the copper disc radially. Beam-straying can be detected by monitoring temperatures of the thermocouples and thus adjusting the steering coil currents. The readings of the thermocouple can be displayed on an LCD panel along the circumference of a circle mimicking the positions of the thermocouples. A spot moves towards the high temperature thermocouple indicating the direction of beam-straying.

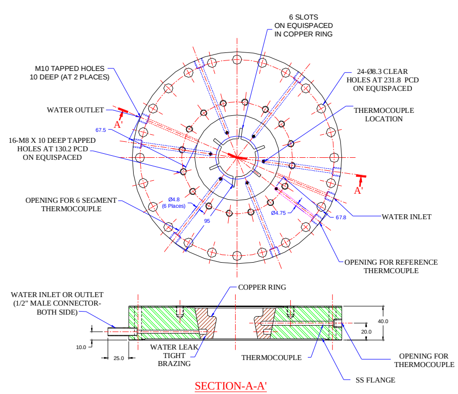

Figure 2: Beam Sensing Aperture.

The current is collected by a 3 mm thick Aluminium collector of 10 cm width and 100 cm length, bent on either side over the length giving a depth of 10 cm and thus electron back-scatter is prevented.

BEAM TRIALS

Initial beam trials were conducted at 1 MeV beam energy with high voltage column at nitrogen gas at 6 kg/cm^2. No significant current transmission was seen without the steering coil. A current of 0.75 A and 0.07 A was required in the X-Y coils respectively to increase transmission up to 80%. Without the focussing coil, temperature up to 70^0 C was noticed at the Beam Sensing Aperture at a power level of 1 kW. When the focussing coil was operated at 5A of current, the temperature rise was negligible indicating that the beam size was greater than 45 mm at the aperture before focussing.

The current transmission was studied as a function of cathode-anode voltage of Electron Gun at beam power of 1 kW. Best current transmission was observed at 1.5 kV anode voltage as shown in Fig.3.

As power level increases from 1 kW to 4 kW, with anode voltage at 1.5 kV, transmission of current was seen to decrease from 80% to 65 % as shown in Fig.4. It was expected that beam transmission will improve to some extent at higher energy. In a subsequent trial at 1.5 MeV with SF_6 at 3 kg/cm^2 in the pressure vessel, the transmission was increased by about 7%. The vacuum in the scan-horn region declines from $2x10^{-7}$mbar to $3x10^{-6}$ mbar during 3 kW operation.

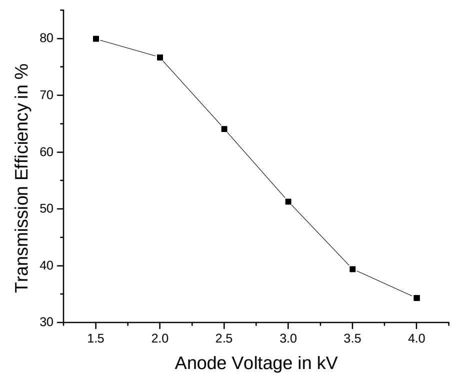

Figure 3: Transmission Efficiency & Anode Voltage.

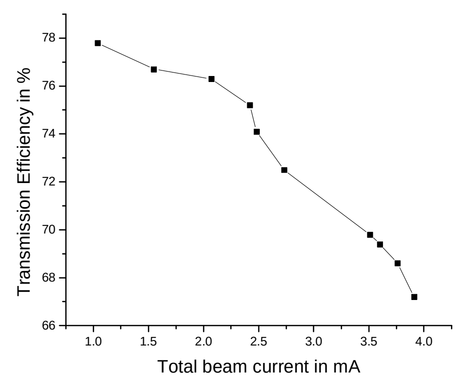

Figure 4: Transmission Efficiency & Beam Current.

The top flange of the exit window registered a temperature of 70^0 C after an hour of operation at a power level of 3 kW. This indicates that the beam electrons, diverging after focussing inside the scan-horn, are hitting outside the margin of the Titanium window. Focussing closer to the window was no solution, as in such a case, the beam diameter in the scan chamber has to be more than before and beam-loss will occur there. A new window with larger width is being planned to solve this problem.

CONCLUSION

Initial beam trials have been carried out at 1 MeV with 65% beam transmission at 5 kW. The beam loss pattern is being studied to adopt suitable measures to optimize beam transmission at higher powers.