International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 4 Issue 11, November-2015

Cross-sectional Presentation and Basic Operational Principles of 3MV Van de Graaff Accelerator at Atomic Energy Centre, Dhaka

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ABSTRACT

In 1964, a positive ion horizontal type Van de Graaff accelerator (KN3000) was installed at Atomic Energy Center, Dhaka (AECD). This accelerator was manufactured by the High Voltage Engineering Corporation, Burlington, Mass., USA. Van de Graaff accelerator consists of a number of operating parts related each other. This accelerator can produce and accelerate 3 MeV proton beam using Hydrogen, Helium, and Deuterium ion source gas. Ion Beam Analytical (IBA) techniques Proton Induced X-ray Emission (PIXE) and Proton Induced Gamma Emission (PIGE) are used for data acquisition.

Keywords: IBA, PIXE, accelerator, AECD, VDG, experimental, irradiation.

1. INTRODUCTION

The 3 MV Van de Graaff (VDG) accelerator machine consists of three main operating parts. A high voltage generator, an accelerator tube with associated parts and a control panel. Supporting systems of the VDG accelerator are a charging belt, a metal spherical shell, two combs, an ion source bottle, drive motor, alternator, source magnet, column resistors, an insulating tank, high vacuum pumping system, an analysing magnet, a quadruple magnet, the beam line, IBA scattering chamber, and the detectors with associated circuitry [3]. All of these are operated from the control console. The main task of the machine is to ionize the Hydrogen gas in ion source bottle and accelerate positive ion to the target.

2. BASIC CONSTRUCTION

A cross-sectional presentation of Van de Graaff accelerator is projected in the following figure. A drive motor, the alternator, charging belt, accelerator tube, spherical metal shell, ion source bottle, charge spray & collecting screen and 50 kV power supply are shown in the presentation. A Van de Graaff accelerator is an electrostatic generator which uses a charging belt to accumulate very high voltages on a hollow metal shell. A charging belt of insulating material is run by the drive motor to run the alternator [7]. A sharp metal comb maintain at a potential difference of a few kV between itself and the drive motor. When a high electric field is produced at the comb, the electrical discharging occurs on the belt from the comb to the alternator. The belt carries positive charges those are collected by the charge collecting comb and accumulated on the metal shell of the accelerator. Within a few minutes, the Van de Graaff accelerator can reach at a very high electric potential of a few million volts. An ion source bottle is used for source gas ionization that accumulate the positive charges and pushes them into the accelerator tube for acceleration. The mixture of Nitrogen (N_2) and Carbon dioxide (CO_2) gas at the ratio of 4:1 is used for insulation and cooling purposes [6].

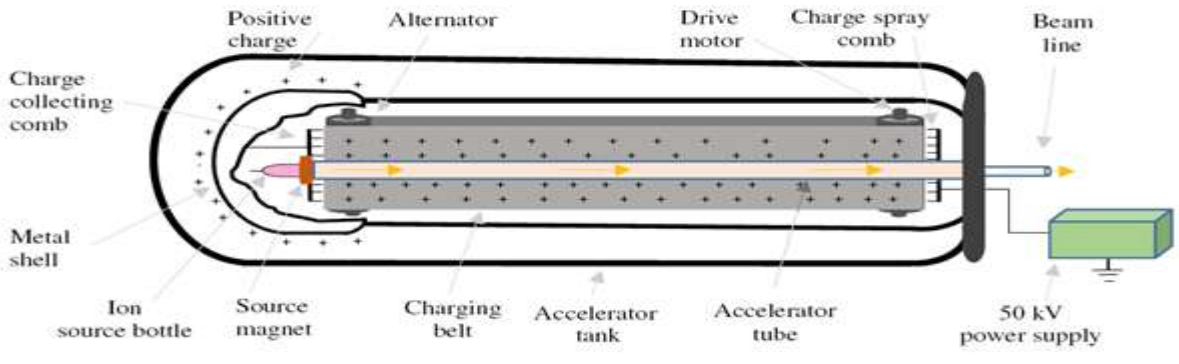

Figure : Cross-sectional view of 3 MV Van de Graaff accelerator at AECD.

3. ION SOURCE

3 MV Van de Graaff accelerator of Atomic Energy Centre, Dhaka is operated to produce and accelerate positively charged ions. Hydrogen, Helium or Deuterium source gas is applied to produce positive ions [9]. Radio Frequency (RF) ion source bottle is used in the VDG accelerator of AECD and the source gas flow is being controlled by a Thermo – Mechanical (TM) leak. A beam current in the range of 1 - 200 nA is required for the most of the applications. But the accelerator produces a beam with the current range of 1-3 μA. So, to protect the samples from the burning or damage, the beam current needs to be substantially reduced. For this purpose a manually controlled and water cooled tantalum slit, with an opening in the range of mm is used. The slits are followed by a quadruple doublet magnet, which is used to focus the beam onto a viewer at a distance of 30 cm.

4. ACCELERATOR TUBE

An accelerator tube is one of the most important part of the Van de Graaff accelerator. It is tubular mounted on the accelerator base, and extending through the column to the high voltage terminal. The tube electrodes are discs cut from aluminum sheet, while the tube insulators are short glass cylinders. The accelerator tube performs two important functions; one is to focuses the positive ions into a well collimated beam and secondly it accelerates the proton beam to the target. The acceleration of the beam is a constant because the voltage gradient in the tube is stepwise uniform and is the same as the voltage gradient of the column [5]. The acceleration of the particles can only be to the energy provided by the terminal voltage. Accordingly when the generator is operated at 3 MV, the beam has an energy of 3 MeV. A beam current is controlled as the user requirement.

5. THE CHARGING BELT

The charging belt is the essential part of the accelerator. The color of the charging belt is brown. It is made of rubber, tolerated both the electrostatic and the mechanical loads imposed upon it. The belt is driven by an inverted synchronous motor (HP is 20, i/p is 208V/50 Hz, 3-phase) and the rotation is 3450 rpm. The column supports the terminal and provides a path for the charging belt. The belt transports the positive charges from ground level to the high voltage terminal [7].

6. THE ALTERNATOR

The alternator is a generator, mounted inside the upper pulley on the upper end of the column**.** 125-volt, 400 Hz and 1500-watt output are produced by this alternator. A permanent magnet is mounted inside the pulley shell, which is mounted on bearings and rotates about a fixed shaft so that no slip rings are required to connect the output to the load. The alternator coil is mounted on the fixed shaft. Since the output of the alternator depends upon the belt speed and hence the drive motor speed [1]. The power of all electronic circuitry are supplied from this alternator.

7. THE DRIVE MOTOR

The drive motor used in 3 MV VDG accelerator is the inverted synchronous motor. It's position just before the base of the accelerator. The input supply of the drive motor is 208V/50 Hz, 3- phase. The Horse power of the motor is 20 and speed is 3450 rpm. The main task of drive motor is to drive the charging belt.

8. THE 50 KV POWER SUPPLY

The 50 kV regulated power supply is used to spray positive charges on the charging belt in 3 MV Van de Graaff accelerator [10]. These sprayed positive charges are being transported by the moving belt from ground level to the high voltage terminal and accumulated on the spherical metal shell. The circuitry of the 50 kV power supply are mounted a Lucite brackets and immersed in oil to avoid the burning probability. A 22 kV transformer is used in a conventional voltage-meter circuit using ten selenium rectifiers. A filter network of two 0.02 mF capacitors and a 1000 $M\Omega$ bleeder resistor are also utilized in the circuitry.

9. HIGH VACUUM SYSTEM

The vacuum path is essential for beam acceleration. Three turbo pumps are used to highly evacuate, the accelerator tube, the beam line and the scattering chamber due to minimize the collisions among accelerated particles and gas molecules. One is positioned just before the analysing magnet, one is at the right port and one is at the left port. In the VDG laboratory of AECD, the normal operating pressure of the accelerator system is of the order of 6×10^{-6} mm of Hg. The maximum permissibility in continuous operation is 1.5 - 2×10^{-5} mm of Hg. If the pressure exceeds 2 x 10^{-4} mm Hg, a safety relay operates to disconnect the belt drive motor and so shuts down the accelerator [7].

CONCLUSION

The Van de Graff accelerator in Atomic Energy Center, Dhaka is old, simple and manually operated [6]. The proton beam of the accelerator is used to irradiate different type of samples. The researchers from different universities and research organizations are using the VDG accelerator laboratory for their research works. MS, MPhil and PhD students are also doing their thesis experiments using the Proton Beam of the accelerator.

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