

Major Parts and Their Working Procedure of 3 MV Van de Graaff Accelerator at Accelerator Laboratory of 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 (AECDC). 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 among each other. This accelerator is capable to produce and accelerate 3 MeV proton beam using the source gas Hydrogen, Helium, or Deuterium. The major parts of the generator are: Accelerator Tube, Drive Motor, Alternator, Charging Belt, Ion Source Bottle and Terminal Electronics.

Key words: beam, alternator, accelerator, source, ion, charging.

I. INTRODUCTION

The Van de Graaff Accelerator is being used to produce and accelerate proton beam. The accelerated proton beam is applied for the irradiation of environmental health, industrial and biological samples [3]. Supporting systems of the VDG accelerator are a charging belt, a metal spherical shell, charges spray and collecting screen, 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 lines, IBA scattering chamber, and the detectors with associated circuitry [5]. All of the systems are controlled from the control console. The main task of the machine is to ionize the Hydrogen, Helium or Deuterium gas in ion source bottle and accelerate positive ion to the target [6]. Required vacuum should be achieved before start the accelerator.

II. NAMING THE ACCELERATOR

The accelerator was developed in 1929, by physicist Robert J. Van de Graaff at Princeton University with help from colleague Nicholas Burke and the name was given as Van de Graaff Accelerator [2]. The first model of accelerator was demonstrated in October 1929. In 1931 a version was described in a patent disclosure which was able to produce 1,000,000 volts [8].

III. MAJOR PARTS OF THE VAN DE GRAAFF ACCELERATOR

A. 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 [7]. The accelerator tube performs two important functions; one is to focuses the positive ions into a well collimated beam and second one is to accelerate 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. 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 [7].

The accelerator tube and its extension system is operated under high vacuum to minimize collisions between the accelerated particles and gas molecules. The operating pressure of the of the accelerator tube system is 1.0×10^{-5} mm of Hg. The maximum permissible continuous operating pressure is $1.5 - 2 \times 10^{-5}$ mm Hg. If pressure exceeds 2×10^{-4} mm of Hg, a relay operates to disconnect the belt drive motor and so shuts down the accelerator [5].

B. The Charging Belt

The charging belt is the essential part of the accelerator. The belt transports the positive charges from ground level to the high voltage terminal [2]. 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 whose HP is 20, i/p is 208V/50 Hz and 3-phase and the rpm is 3450. The column supports the terminal and provides a path for the charging belt [7].

C. The Drivemotor

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

D. 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 [9]. 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. The power of all electronic devices are supplied from this alternator.

E. The 50 kV Power Supply

The 50 kV power supply is used to spray positive charges on the charging belt in 3 MV Van de Graaff Accelerator [7]. 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 Ω bleeder resistor are also utilized in the circuitry [10].

F. Ion Source

3 MV Van de Graaff accelerator of Atomic Energy Centre Dhaka accelerates positively charged ions. These positively charged ions are produced by the ionization of the source gas. Hydrogen, Helium or Deuterium source gas is applied to produce positive ions. The source gas ionization is done in a Radio Frequency (RF) ion source bottle and the gas flow is being controlled by a by a Thermo – Mechanical (TM) leak [7].

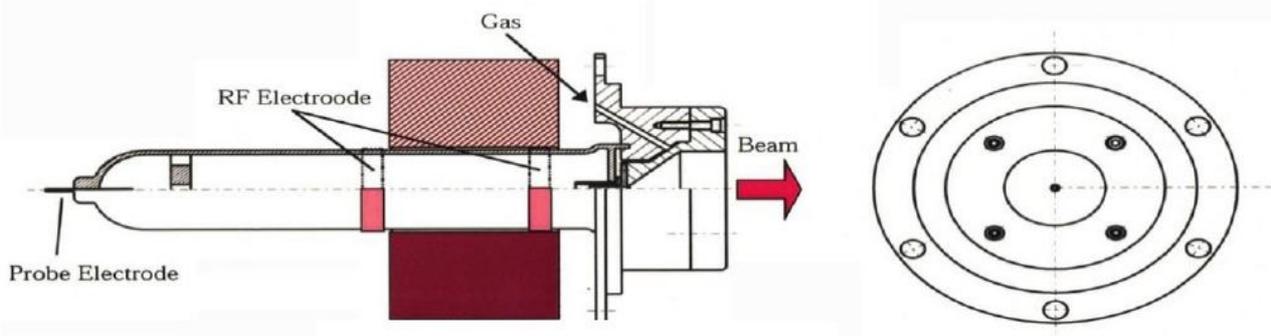


Fig: Cross-sectional view of a RF ion source bottle.

G. Terminal Electronics

The circuitry of terminal electronics of 3MeV Van de Graaff Accelerator is divided into two major sections-

1) The Terminal Top Plate circuit:

The major circuits of the terminal top plate are-

The RF Oscillator Circuits: The Radio Frequency (RF) oscillator is of the self-excited type. The grid and anode circuits are pre-tuned and do not require adjustment. The RF output is capacitive coupled to the source where it ionizes the source gas H₂.

The Probe Power Supply: The probe power supply is a variable 0 - 7.5 kV at 10 mA dc power supply. It is connected to the probe and use to control the beam current [7].

The Source Magnet Power Supply: The source magnet power supply is a variable 0 – 135 volt, 1.5 ampere dc power supply. The magnet current is preset during the ion source tuning procedure and no external control is provided [5].

The Source Gas Supply Unite: This includes the gas cylinder, gas leak and all associated components. The gas supply is controlled from the accelerator console by the source pressure control. There are two source gas supplies and control options-

One is controlled by a thermo-Mechanical leak and other controlled by a palladium leak.

2) The Terminal Mid-Plate:

The major circuits of the terminal mid-plate are-

The Source Focus Power Supply circuit: It is a variable 30 kV dc power supply. It is connected to the terminal top-plate, the source and through a voltage dropping resistor to the second element of the einzel lens.

The potential gradient between the second element of the einzel lens and the first and third elements, brings the beam to a focus at the chopping aperture[2].

The Isolation Transformer: The main task of the Isolation Transformer is to provide input power to all the circuitry mounted on the top plate. The second task is to maintain the isolation between the Top-plate and the Mid-plate. It is the 40 kV/400Hz transformer [1].

The Accelerator Focus Power Supply: It is a -40 kV dc power supply. The output is connected to a resistor which forms a voltage divider. The other end is connected to the +30 V source focus power supply. The variac is adjusted to bring the beam to a focus at the target.

The Power Supplies for RF: The power supplies for RF deflection system are also located on the mid-plate. This include Power supply which contains a 6.3 volt heater supply, a +300 volt plate supply for oscillator and a -150 volt bias supply. Power supply contains a plate supply (variable up to 2.0 kV) for the main deflection amplifier and a +500 volt plate supply for the auxiliary deflection amplifier [2].

IV. CONCLUSION

The 3 MV Van de Graaff accelerator of Atomic Energy Center, Dhaka is very old and simple accelerator. The major parts of this accelerator are operated manually [4]. This accelerator installed 1964 at Atomic Energy Centre is being used to produce and accelerate proton beam for sample irradiation [7]. The researcher of Bangladesh Atomic Energy Commission and from different university as well as research organization have been using the accelerator beam for their research purpose on different fields like environment, health, industry etc.

REFERENCES

- [1] ERIC J. UNDERWOOD, Dept. Of Animal Science and Production, University of Western Australia, "Trace Elements in Human and Animal Nutrition" Fourth Edition (1977).
- [2] M. Govil, Proton Induced X-ray Emission – A tool for non-destructive trace element analysis, *Current Science*, 80(12), 2001, 1542-1549.
- [3] J. R. Bird and J. S. William (eds.) "Ion Beam Materials Analysis" Academic Press, Sydney, Australia, 1989.
- [4] Md. Joynal Abedin, Shirin Akter, SK. Abdul Kader Arafin, "Chromium Toxicity in Soil around Tannery in Hazaribagh, Dhaka, Bangladesh and its Impacts on Environment as well as Human Health" International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163, issue 4, volume 2 (April 2015), pp, 119-122, www.IJirae.com.
- [5] Md. Joynal Abedin, Shirin Akter, Md. Lokman Hossen, "Ion Beam Analytical Technique PIXE for Pollution Study at Dhaka van de Graaff Accelerator Laboratory" IOSR Journal of Applied Physics (IOSR-JAP), e-ISSN: 2278-4861, Volum, 7, Issue 2 Ver. II (Mar.- Apr. 2015), pp 22-25, www.Iosrjournals.org
- [6] Md. Joynal Abedin, S M Azharul Islam, S. M. Fahad, A.K.M. Fazlul Hoque, Shirin Akter, Asad Shariff, "Characterization of IBA facilities at the 3MV VDG accelerator laboratory of Atomic Energy Centre Dhaka" ISSN 1022-8594, JUJS 2013, vol. 36, No. 2, pp, 37-48
- [7] Md. Joynal Abedin, "Study of the effects of industrial pollutants using ion beam analytical techniques" doctoral thesis, Jahangirnagar University, Savar, Dhaka, 2012.
- [8] Md. Lokman Hossen, "STUDY OF MAJOR AND TRACE ELEMENTS OF SOME MEDICINAL PLANTS OF BANGLADESH USING PIXE TECHNIQUE" MS Thesis, MAY, 2014, Department of Physics, Jahangirnagar University, Savar, Dhaka-1342.
- [9] Almas K, Al-Zeid Z, "The immediate antimicrobial effect of a toothbrush and miswak on cariogenic bacteria" a clinical study. *J. Contemp Dent Pract* 2004;5:105-14.
- [10] Md. Hedayet Ullah, "ELEMENTAL ANALYSIS OF SOIL OF ODELIA TEA GARDEN, FATIKCHARI, CHITTAGONG" MS Thesis, 2013, Department of Physics, University of Chittagong, Bangladesh.