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14 MEV NEUTRON GENERATOR FACILITIES FOR MATERIAL RESEARCH FOR FUSION REACTORS

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ABSTRACT

Accelerator based neutron generator is designed for the generation of 14 MeV neutrons for carrying out the benchmark experiments for fusion blanket and shielding materials for demo fusion reactor. Deuterium ion beam current of 1mA is extracted from the Electron Cyclotron Resonance (ECR) ion source and accelerated to 300 keV and then impinging on 10 curie tritium target produces 10^{10}, 14 MeV neutrons per second via D(T,n)He nuclear fusion reaction. The subsystem of the neutron generator is consists of ECR ion source and its power supply kept on the high voltage platform, 300 kV acceleration column and 300 kV / 10 mA DC High voltage power supply for accelerating deuterium ion, beam line and vacuum system to maintain 10^{-5} mbar inside the beam line and tritiated target. The Ion source is operating on the test bench and deuterium ion beam has been extracted from the ion source at 7.5kV extraction potential. Another compact sealed pulsed 14 MeV neutron generator facility has been installed with the neutron flux of 10^{10} neutrons per second and repetition rate of 100Hz. few experiments for explosive detection were carried out with pulsed neutrons.

Key words: *accelerator, acceleration column, high voltage power supply, **n**eutron, ion source, tritium target.*

INTRODUCTION

Fusion power offers the prospect of an almost inexhaustible source of energy for future generations, but it also presents so far insurmountable scientific and engineering challenges. A lot of research is going in the world to magnetically confine the plasma in TOKAMAK. D(T, n)He nuclear fusion reaction will produce 14Mev neutrons in tokamak and blanket is required to remove these neutrons and heat generated from kinetic energy of neutrons, provide continuously supply of fuel(tritium) and protect the mechanical structure of vacuum vessel and super conducting coils from direct neutron and gamma radiation. The blanket material requires a tritium breeder and a neutron multiplier that can withstand high temperature and high neutron flux. Benchmark experiments can be carried out with a 14 Mev neutron generator to study the properties of blanket/shielding materials [1,2,3,4]. Neutron can also be used as a tool to detect the explosive material [5, 6, 7].

NEUTRON GENERATOR

Accelerator based neutron generator will produce continuous high neutron flux. These neutrons are produce by D + T → He + n nuclear fusion reaction [8]. The sub-systems of the accelerator (Fig. 1) based neutron generator has an E.C.R Ion source housed in a high voltage dome, acceleration column, High voltage power supply, beam line, vacuum systems and target assembly. Electrical power to the dome is supplied through a dc Isolation transformer. Mono-atomic deuterium ion beam is extracted from the Ion source and then the ions are uniformly accelerated in a uniformly gradient acceleration column it then impinge on the tritium target and produces neutrons. The neutron generator operation is assisted by several auxiliary systems which ensure personal and machine safety the most relevant are the vacuum exhausts clean up unit, the experimental hall venting system, the target cooling system, the environment radiation monitoring system and the control system. The specification of neutron generator is shown in Table 1.

ION SOURCE AND HIGH VOLTAGE DECK

Deuterium ion beam of 1mA is extracted from the ECR ion source and then it is focused into the uniform grading

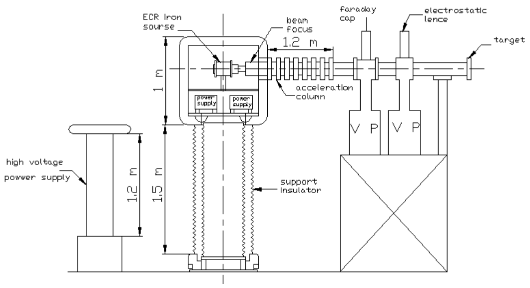

Fig. 1 Accelerator based neutron generator

Table - 1 Specification of 14 MeV neutron generator

Neutron flux	10^{11} , neutrons/second
Maximum Beam energy	320 KeV
Beam current at the target (D+)	1 mA
Beam spot at target (mm)	10 mm
Ion source	ECR type
Extraction voltage	20 kV
High Voltage power supply	300kV/10mA
D.C Isolation transformer	350kV/5kVA
Vacuum pump	400lps
Tritium target	10 Curie

acceleration column. ECR ion source is preferred as compared to other ion source because it doesn't require filament replacement and produces high current beam [8]. The plasma is produced inside the ion source by rf heating of the deuterium gas and it is the confined by axial and radial magnetic field produced by permanent magnets. The deuterium ions are extracted with two electrode assembly at 7.5KV. The gas flow in the ion source is regulated by needle valve. The ion source, extraction assembly, focusing element and its power supply are housed inside a high voltage deck floating at 300 kV and power to the deck power supply is fed by 350KV, 5KVA isolation transformer. The control and command signals are transmitted

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through fiber optic to control room to ensure proper electrical isolation.

ACCELERATION TUBE

The deuterium ion beam is focused into the acceleration tube (Fig. 2) after it is extracted from the ion source. The acceleration tube consists of four sections and each section is metal and ceramic bonded assembly with no organic compounds in the vacuum volume and each tube has ten insulation gaps. This is to provide uniform potential gradient for best reliability and optics consideration. The tube is fully bakable up to 200^0C for contaminant free and ultra high vacuum operation. Each section is conservatively rated at 75 kV in air and 200 kV in SF_6 (2 atm). Each section of the tube is connected with 1” diameter limiting electrode between the tubes and conflate flange to keep the radiation from back streaming electron as low as possible and to focus 25mm beam to the target. A multiple series of resistor string in air is used to distribute the electrostatic potential uniformly along the tube. The holding voltage of tube is 300 kV in air.

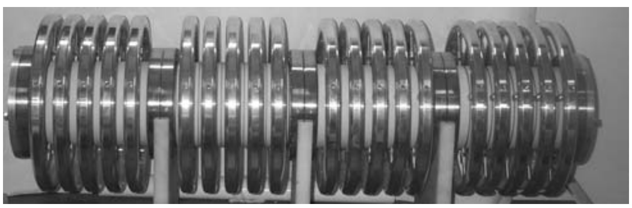

Fig. 2 Acceleration Column

HIGH VOLTAGE DC POWER SUPPLY

Apart from ion source and extraction power supply on high voltage deck another high voltage power supply is used to accelerate deuterium ions. This high voltage power supply (Fig. 3) is Glassman make 300 kV dc with a maximum current of 10 mA. It is characterized by high reliability, high terminal voltage stability, low terminal voltage ripple and low voltage regulation. Operating voltage will be 200-250 kV. The high voltage power supply is connected with RS 232 port to computer for online voltage setting.

Fig. 3 High Voltage power supply

BEAM LINE AND VACUUM SYSTEM

Ultra high vacuum of the order of 10^{-8} torr can be achieved in the acceleration tube by turbo molecular pump with the pumping speed of 500 l/s back up with is 6 m^3/hr rotary pump which is connected at the ground potential. Vacuum exhaust from the beam line is pumped outside the experimental hall in order to prevent the tritium leak inside the experimental hall. The experimental hall will have separate ventilation system. The target is kept 2m away from the acceleration tube by means of drift tube to minimize the contribution of backscattered neutrons.

TARGET ASSEMBLY

The target assemblies of neutron generator are consists of target holding, target cooling and suppression of secondary electron. The target holders are cooled with water or air. Water cooled target are used for beam current higher than 500 micro Amp. Target is kept at the distance of 4m from the floor, roof and the sidewall. Circular stationary tritiated-titanium target of 10 curie activity is used. Tritium is absorbed in the titanium layer which is later deposited on the bottom of OFHC. The beam power dissipated on the target is removed by cold water flowing in a turbulent region on the external surface of copper cup which ensure the target temperature is less than 200^0C. The target is housed in a support designed to minimize the neutron scattering.

NEUTRON GENERATOR APPLICATION

Neutron generator is designed for conducting neutronics experiments in the framework of research activity on controlled thermonuclear fusion. The neutronics design of blankets and shield of next step fusion devices requires verification that the neutron cross section data sets used in the calculations are as accurate as possible and confirmation that the calculation methods used to transport the neutrons are as reliable as practical [9]. To ensure that both these criteria are met suitable experimental activity (benchmark experiments) will be conducted using this facility. Neutron induced material damage and material swelling studies, fast neutron activation analysis, neutron radiography can also be done with this neutron generator. Explosive detection experiments using neutron as a tool can also be carried out.

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