SF_6 GAS HANDLING SYSTEM FOR 3 MeV, 30 kW ELECTRON BEAM ACCELERATOR AT EBC, KHARGHAR, NAVI MUMBAI

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Abstract

The 3 MeV Accelerator Project involves designing, fabrication, installation and commissioning of a 3 MeV, 30 kW Industrial Electron Beam Accelerator with a terminal voltage of 3 MV and is housed inside the Electron Beam Centre building at Kharghar, Navi Mumbai. The Accelerator has capability of delivering electron beam of 3 MeV energy for radiation processing applications. For ecological and economical reasons, the SF_6 gas is reincorporated into a closed cycle because gas should not be released into the atmosphere. The aim of the SF_6 gas handling system is to introduce the gas at high pressure to the accelerator tank after evacuation and to bring back into the storage tanks with minimum loss. The gas handling system also provides purification of gas, prevention from mixing with air or any other substances, which may contaminate and thus bring down the high voltage insulation characteristics of the gas. A heat load of 12 kW is coming due to high frequency transformer, electron gun, power supplies, motor alternator system, fan motor and blower etc. A radiator type heat exchanger with high-pressure blower and finned tube has been used for cooling the gas.

This paper discusses about mechanical design, fabrication, testing and safety of different components of SF_6 gas handling system such as gas piping, non lubricating compressor, dryer, vacuum pump, dust & oil filters, storage tanks etc. It also discusses about mechanical and thermal design of heat exchanger, which includes calculations of heat transfer coefficient, surface area, pressure drop, design and selection of high-pressure blower, 5-ton chiller unit, insulation and cooling tower.

INTRODUCTION

3 MeV Accelerator is an electrostatic accelerator in which terminal is floating at a voltage of 3 MV and the accelerator tank is at ground potential. As shown in the fig. 1, from voltage gradient point of view there is two geometries, coaxial cylindrical and spherical geometry. Design calculations show that SF_6 is the most suitable medium for insulation and cooling purpose. Apart from excellent electrical properties, SF_6 has good chemical stability, thermal properties and nontoxic. SF_6 Gas Handling System of 3 MeV project mainly covers SF_6 gas **transfer** system and SF_6 gas **cooling** system. The Accelerator Pressure vessel [1] is the main body of the 3 MeV Accelerator, which will house high voltage multiplier columns, RF electrodes, corona shields, high voltage terminals, electron gun, accelerating tubes, motor generator set, heat exchangers, RF transformer etc. All of these components require SF_6 gas insulation and efficient cooling. Hence there is a need of SF_6 gas and its handling system. Normal operating pressure inside the accelerator is 6 kg/cm^2. The accelerator tank has to be evacuated to vacuum of 10^{-1} torr before filling the gas.

Detail design [1] and fabrication [2] of the accelerator pressure vessel using ASME B&PV SEC-VIII, DIV-1 Code was carried out and reported earlier.

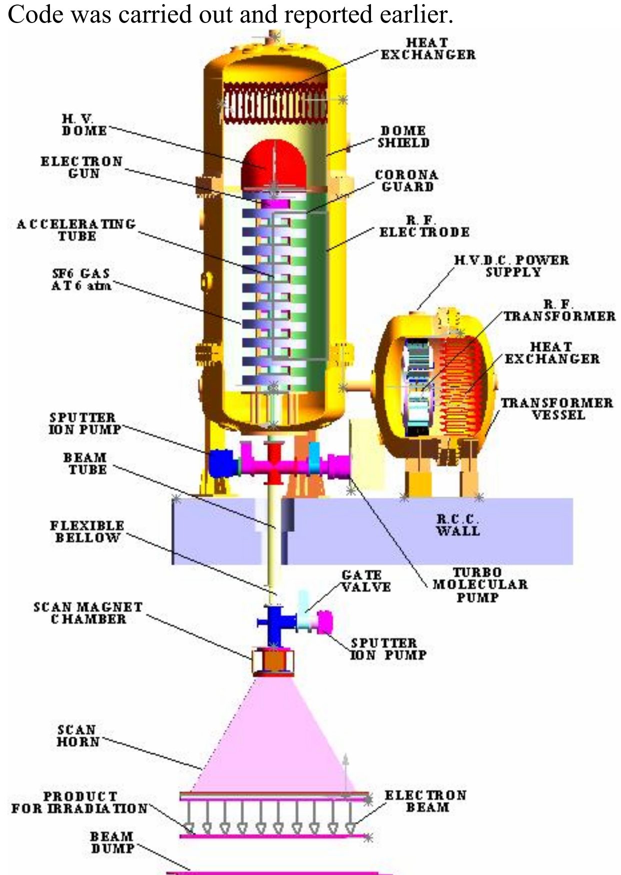

Figure 1: 3D Schematic of 3 MeV Electron Beam Accelerator

SF_6 GAS TRANSFER SYSTEM

The main objectives of SF_6 gas handling system is:

► Transfer of SF_6 gas from SF_6 cylinders to SF6 storage tank for storage.

► Transfer of SF_6 gas from Storage tank to accelerator tank while starting the accelerator

► Transfer of SF_6 gas from accelerator tank to storage tank for maintenance

► Recirculation of SF_6 gas during accelerator operation for removal of moisture and secondary products.

This 150-meter long pipe line is mainly comprises of 3" size pipeline, compressor, vacuum pump, dryer, filter, heater and blower. SF_6 **compressor** is a non lubricating type, vertical double acting, single stage air compressor de-rated for SF_6 use with a free air delivery of 83 CFM and a maximum discharge pressure of 125 psi (g). The compressor is used for transferring the gas from storage tank to accelerator and vice versa. The compressor is rated for a maximum discharge pressure of 125 psi (g) and a suction pressure of 1 atm. pressure. The 3000 lt capacity **rotary vacuum pump** is used to pump all the gas remaining in the tank after one atm pressure, which is supplied to compressor and then transferred to storage tank. About 0.5 Torr vacuum is achieved in the accelerator tank, storage tanks and pipeline.

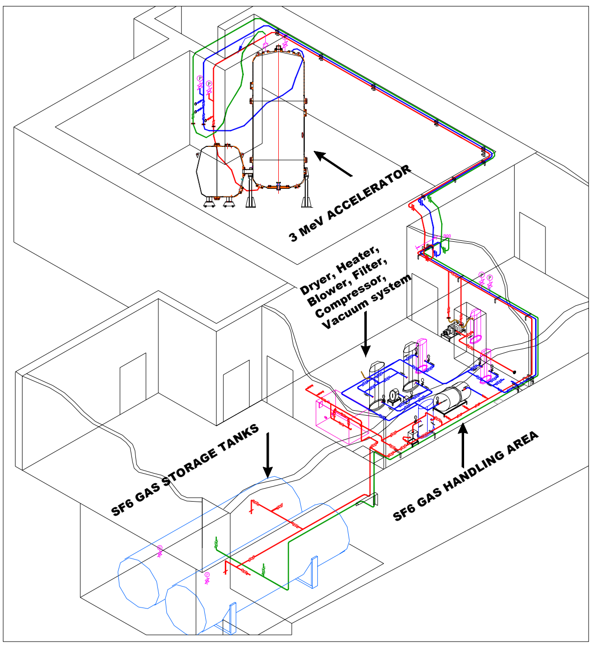

Figure 2: SF_6 Gas Transfer System

Vertical vessel twin column activated alumina filled **dryer** is used for removal of moisture and breakdown products. Activation of alumina balls is done by passing preheated air at 150^0C through alumina bed via blower & heater. Coarse and fine **filters** are provided to make sure that dust free gas is circulated through the accelerator column. Coarse filter is Pleated Bag type filter suitable for filtering 0.3-micron size dust particles. Fine filter is a cartridge type filter having borosilicate glass fiber cartridge mounted into a SS housing, suitable for filtering 0.01-micron size dust particles.

SF_6 GAS COOLING SYSTEM

This system is mainly comprises of 1.5" and 1" SS pipe line, radiator type heat exchanger and blower combination, 5 ton chiller unit, cooling tower, pressure transmitter, temperature sensors, safety interlocks, flow meter, pressure gauges and other instrumentation.

The high-pressure blower has been designed and commissioned to achieve special heat transfer requirements under 6-kg/cm^2 pressures of SF_6 gas. Ready made finned tube bundle with header have been purchased as per the area available inside the accelerator tank. Heat exchanger assembly is made of such four numbers of bundles and makes an enclosure of size 800x800x100 mm. High-pressure blower sits inside this enclosure and through SF_6 gas centrifugally outward direction. A design calculation for proper surface area of fin tubes and convective heat transfer coefficient in SF_6 environment at a pressure of 6-7 Kg/cm^2 for each bundle, have been calculated. Heat exchanger and blower combination along with 3 and 5 HP motors has been installed and tested for desired flow rate, pressure drop and motor current. Blower has sent for dynamic balancing after getting desired flow rate to reduce vibration.

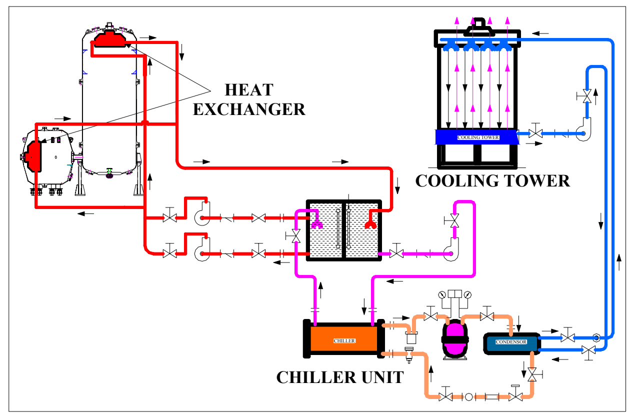

Figure 3: SF_6 Gas Cooling System

Figure 4: 5-Ton Chiller Unit and its Control System

Detailed chilled water flow and heat transfer calculations were done to make sure that high voltage RF Transformer, which is having a maximum heat load of 8 kW, is maintained within the permissible temperature limit. It was estimated that a total flow rate of 50 lpm of chilled water at 10^0C is required through the heat exchanger for cooling of transformer inside the accelerator tank. Similarly other accelerator components having a maximum heat load of 3 kW requires a flow rate of 20 lpm of chilled water at 10^0C. It was also estimated that a total pressure head equivalent to 3000 mm of water column is required to maintain the above mentioned flow rate in the main chilled water process circuit. Valves and flow meters are provided to regulate and control the flow rate in the heat exchanger to meet variable heat loads.

Figure 5: Rectangular Radiator Type Heat Exchanger inside the Top Portion of Accelerator Tank

Freon-22 refrigeration pipeline of chiller unit was flushed with Nitrogen gas, evacuated and filled with Freon. Control panel of Chiller Unit checked and activated. Chiller plant along with heat exchanger & blower was run for eight hours to check its safety features, interlocks, trips and performance. We are getting chilled water of 100 lpm at 8^{o}C, which is satisfactory. Fabricated pipeline pneumatically tasted at a pressure of 10 Kg/cm^2 and there was no drop in pressure recorded.

FABRICATION AND TESTING

Fabrication and testing of SF_6 gas transfer system and sf6 gas cooling system was similar. In this paper, it is mentioned for SF_6 transfer line. The material of the piping was stainless steel. The size of the Piping for SF_6 gas transfer line is 3” Sc 40. The length of this piping is approximately 150 meters along with 40 numbers of Audco make Butterfly valves, 10 numbers of pressure gauges, 4 numbers temperature gauges, 10 numbers flexible hose assembly, 70 numbers of weld neck flanges, 15 numbers of elbows, tee, rigid pipe supports with clamping etc.

Quality assurance plan was prepared by indicating various hold and witness stages of fabrication. Welding Procedure specifications, Welder Performance tests and Performance qualification records were prepared as per ASME SEC-IX.

Material Selection and Mechanical Testing: Raw Material [4] identified in the form of 3” pipe as per ASME SA 312 TP Gr-304L. Based on heat numbers involved, one sample per heat was analyzed for chemical and tensile properties. It also tested for Inter granular Corrosion test (IGCT) as per ASTM A 262, practice A and practice E and checked for seamless configuration as per microscopic analysis.

Welding Procedure Specification: WPS was carried out as per ASME SEC-IX, QW-482. Manual welding was carried out using GTAW welding process in pipe with 700 single V groove and internal gas purging. Non-consumable Electrode used was Tungsten and filler wire was ER308L as per specification number SFA-5.1. Size of the filler wire was 3.2/1.5 mm diameter and test has been taken in 6G position. Six numbers of coupons were given for mechanical testing in laboratory. Two numbers transverse tensile test and four numbers side bend tests were carried out and found satisfactory. In WPS 85-150A current, 18-24V, DC straight (EN) polarity, 160-170 mm/min speed was used.

Fabrication: Most of the pipe fabrication was carried out in 1G position. Insitu welding were carried out as per 2G and 5G position. Proper supports were provided for distortion control.

Non-Destructive testing: We have used “double wall double image” technique for radiography with X-ray and γ-rays source. In the radiographic film linear distortion like cracks, incomplete fusion, incomplete penetration, undercut etc, and rounded distortion like porosity, slag, tungsten inclusion was checked. 100% radiography was carried out on all butt weld joints including nozzle to shell joint. Dye penetrant testing was carried out on each layer of weld deposit and on pipe.

Pneumatic Test and Helium leak Test: Complete pipeline including all flexible hoses, valves, pressure gauges, etc was pneumatically tested at a pressure of 13.0 kg/cm2 (g) and found satisfactory. Pipeline was evacuated to a pressure of 1 X 10^{-4} Torr and 2 nos. of storage tanks was also evacuated to a pressure of 1 Torr. All the welded, flanged and threaded joints were helium leak tested to a leak rate of 2 x 10^{-7} std cc/sec and found satisfactory.

Fabrication of 3 numbers of coarse, fine and oil filter for SF_6 gas transfer system of size 300 mm diameter and 1500 mm height were completed. It was tested with helium leak detector and leak rate observed was less than 1 x 10^{-9} std.cc/sec. It was painted with one layer of red oxide primer and two layer of epoxy paint.

CONCLUSION AND STATUS

SF_6 Gas Cooling System has been fabricated, erected and commissioned. In SF_6 gas transfer system 150 meter long pipe line got fabricated and helium leak tested, Fabrication of course, fine and oil filter completed. Compressor and dryer system is under procurement.

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