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A GAS FOIL STRIPPER SYSTEM FOR A HEAVY ION VAN DE GRAAFF

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Summary

The charge exchange process in the centre terminal of the 30 MV tandem Van de Graaff under construction at Daresbury Laboratory is achieved by a combined unit with an option of gas or foil stripping. The foil stripper can hold 280 foils, any one of which can be selected at any time. The gas stripper, using nitrogen originally, is cryo-pumped to maintain the tube vacuum pressure of 10^{-7} torr, and the whole is controlled via the serial data link using a modulated light system.

Introduction

General

The Daresbury Laboratory of the Science Research Council in the United Kingdom is building a 30 MV tandem Van de Graaff accelerator mainly for use with heavy ion beams. The accelerator operates vertically in a pressure vessel 45 m long and 8 m diameter. The ion source in use injects negative ions through a 90^0 inflector magnet into the accelerator and the positive electric field accelerates them towards the centre terminal.

In the centre terminal the ions pass through a gas or thin foil stripper which removes the excess electron and some of the atomic electrons, leaving the ions positively charged. These are then accelerated by the negative field back to ground potential. The charge state of these ions is high so the energy gain in the second half of the accelerator is much higher than in the first. This effect may be further increased by the use of a second stripper to provide even higher charge states.

After leaving the accelerator, the beam is deflected into the horizontal plane by a 90^0 analysing magnet and is conveyed to the experiment by a system of vacuum tubes with focusing elements.

This paper describes the design and testing of the combined foil and gas stripper assembly with its pumping system used in the high voltage centre terminal, and foil mechanisms for 2nd and 3rd strippers. Fig.1 shows the positions of the strippers in the tandem.

Stripper operation

Energetic heavy ions passed through a gas or thin foil lose (or gain) electrons. If the foil or gas is of sufficient density, the ions will emerge with a distribution of charge states which is independent of the initial charge and thickness, and only a function of the charge state and its energy. The higher the energy the more the distribution is shifted towards more positive charge states. Foil strippers produce ions more positively biased than gas strippers but suffer from limited operational lifetime.

Design of the Stripper Assembly

The assembly, shown in fig.2, has two parts, a gas canal and a foil stripper, either of which can be brought into operation remotely as required.

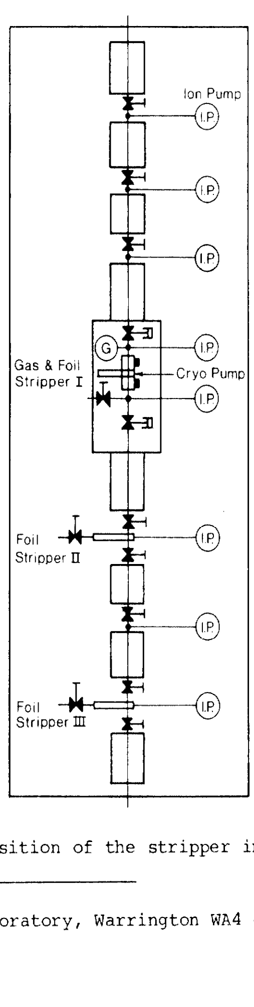

Fig.1 Position of the stripper in the column.

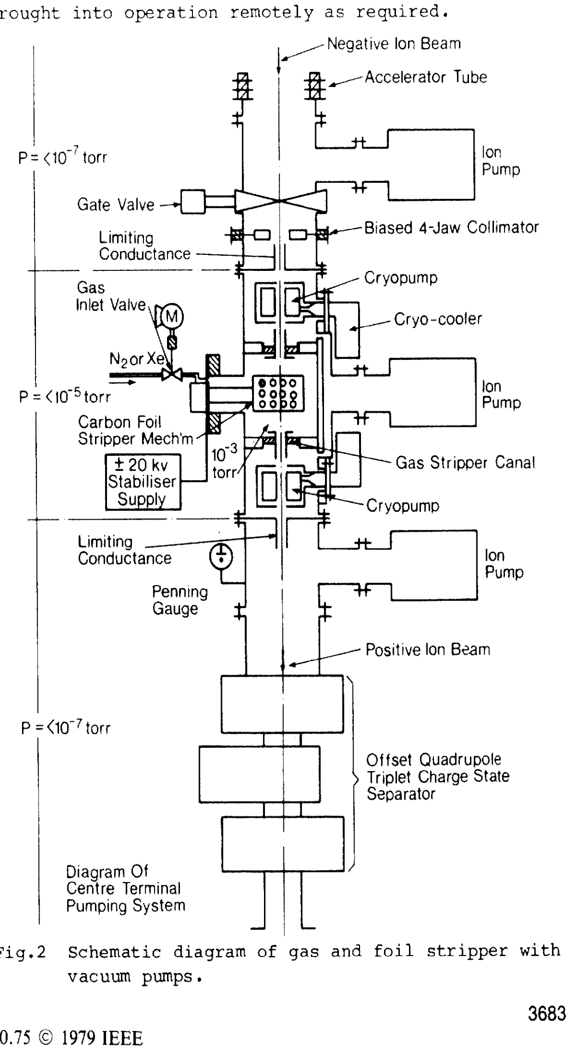

Fig.2 Schematic diagram of gas and foil stripper with vacuum pumps.

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To provide fast stabilisation of the final beam energy, a ± 20 kV modulation with a response frequency of 100 Hz can be applied to the gas canal and foil holder, the correction signal being derived from the exit slits after the analysing magnet. The signal to the stripper is transmitted via the serial data link[1].

The Gas Stripper

The beam path through the high density gas canal is 440 mm long with an entrance and exit diameter of 5 mm. These exit tubes emerge into two volumes, one at the top and one at the bottom, each containing a specially designed cryopump with a pumping speed for nitrogen of 2000 ℓ/s. The cryopump chambers are each connected to a 120 ℓ/s sputter ion pump, and a pressure not exceeding 5×10^{-6} torr is maintained. This pressure is too high for the accelerator beam tubes so a limiting conductance of 1 ℓ/s is placed in each cryopump chamber, limiting the gas flow to the beam tube and maintaining the rest of the centre terminal at $<10^{-7}$ torr.

The gas flow to the central chamber is controlled by a fine leak valve driven by a stepping motor. The flow rate may be retained from run to run by the use of an upstream solenoid valve which can completely stop the flow of gas from the supply cylinder. This fine valve can control the flow from zero to 10^{-2} torr ℓ/s which is the estimated maximum for stable and optimum charge distribution.

The cryopumps have a useful life of 1600 hours with maximum flow, and greater life proportional to any reduction in flow. When the cryo deposit reaches a thickness where the surface temperature of the deposit is sufficiently high to permit the incident nitrogen atom to be reflected rather than trapped, regeneration of the pump must take place. At the entrance and exit of the beam tube into the centre terminal, there are two full bore 100 mm gas operated gate valves which will close when the Penning gauge reaches 10^{-5} torr and these will be closed before the cryopumps are warmed up to permit regeneration. This will be carried out by the use of a portable turbomolecular pump on the annular service platform and will re-pump the centre terminal to about 10^{-5} torr when the cryopumps can be restarted if required. When the foil stripper is required at the start of a run, then the cryopumps do not need to be chilled until the need for gas stripping occurs. The temperature of the cryosurface is held at 18 K by a closed cycle helium refrigerator and the heat shield surrounding the cryosurface is held at 70 K by the same refrigeration. The compressors for these refrigerators are housed in a large thick aluminium crate which is designed to screen electronic equipment elsewhere.

The cryohead temperatures are read by means of linear temperature sensors bonded to the cold surface and use the standard temperature monitoring technique used elsewhere on the NSF[2].

Initially nitrogen will be used as the stripper gas but tests are under way[3] to study the use of argon, krypton and xenon. Initial tests have given an indication that this may cause argon instability of the sputter pumps but this is being further investigated.

The Foil Stripper

The useful lifetime of foils produced by the standard carbon arc evaporation method has always been very short, so a considerable number of foils have to be stored in the centre terminal to be used in turn. Recent work[4] has shown that longer life foils may be successfully made by hydrocarbon cracking in a glow discharge but provision for a considerable number of foils still has to be made.

The first foil changer mechanism (Mk.I) shown in fig.3 was gas pressure operated as early experience elsewhere showed that spark damage could destroy stepping motors, but work on shielding of electrical components has shown that this can be prevented.

This first changer consists of nine wheels, each having thirty foil mounting holes which are mounted on a common shaft and drive by it through individual fric-

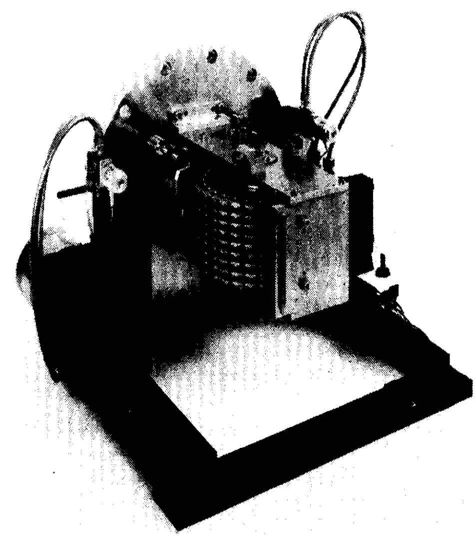

Fig.3 Mk.I stripper

tion clutches in a manner similar to that use in the foil stripper designed by the Australian National Laboratory, Canberra[5]. The drive shaft is rotated by a piston which engages a thirty toothed ratchet wheel and the one unlocked wheel is drive round the shaft to the next foil location while the other eight remain stationary. Spring loaded rollers provide positive location of the foils by engaging indents around the periphery of the wheel. Special indents are used to lock the wheels not in use. Each wheel rotates one complete turn, locks and transfers the drive to the next wheel and so on, until all nine have been used. Reversal of the wheel in use is possible by using a second piston so that the previous foil can be recovered when desired. The mechanism has a storage capacity of 252 foils with an aperture of 9 mm. To enable the stripper modulation (± 20 kV) to be applied to this type of foil stripper, it would have been necessary to insulate the whole of the assembly with a large ceramic spacer, which would have created a large capacitance and greatly increased the modulator power required. This changer may be used as a second stripper where modulation is not required and the foil life is very much longer.

To overcome the modulation problem and have greater flexibility of selection, a second (Mk.II) foil changer unit shown in fig.4 has been developed and consists of a half drum providing mounting for 280 foils which can be individually positioned in the beam by external stepping motors. The drum can be rotated and positioned axially by two linear movements. The axial movement is obtained by a nut and screw driving a bellows sealed shaft which, by use of the wheel and differential axle principle, has an amplified final linear travel of 150 mm. The rotational movement of 170° is obtained by a similar linear motion this time pulling a metal tape secured to the spring loaded drum. Positional indication of the drum is given by two capacitive

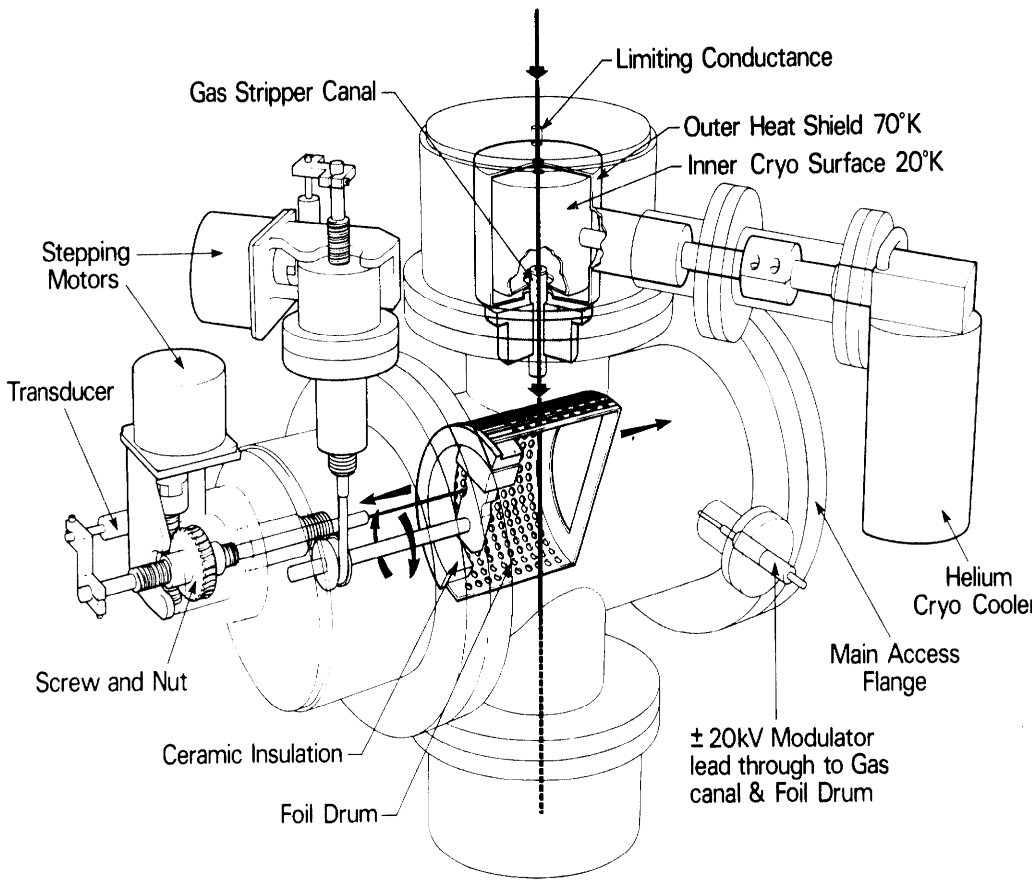

Fig.4 Illustration of the gas and foil stripper

transducers and over travel prevented by limit switches and mechanical stops.

The drum is electrically insulated from the mechanism by a ceramic spacer and moves inside a stationary tubular liner with suitably placed beam holes. The liner is also insulated from the housing and held at the same potential as the drum to provide a screen to prevent the electrostatic forces of the modulation voltage rupturing the foils.

The modulation voltage is applied to the liner via a high voltage feed-through, the connection to the foil drum being made by a rolling ball contact, and to the exit tubes of the gas canal by spring contacts.

The drum is easily removable from the housing for re-loading with fresh foils and a precision dovetail enables exact re-positioning. Spare drums can be preloaded in the laboratory.

The Mk.I foil changer can reposition any foil on each disc but as soon as the drive is transferred to another disc the previous disc cannot be re-used. The Mk.II foil changer enables any foil out of the 280 to be selected or re-positioned at any time.

Testing the Assembly

The Mk.II stripper unit has been fully operated mechanically with internal vacuum and external working pressure of SF_6, the cryo pumps have been operated down to 18 K. A voltage test of the stripper assembly was carried out and easily withstood the $\pm$ 20 kV applied with a very low leakage current.

References

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