A Modernised Terminal for the ANU 14UD

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I. Introduction

The equipment in the 16 MV terminal of the 14UD accelerator has recently been extensively upgraded. The main feature of the new installation, is the recirculating gas stripper. This is a differentially pumped gas canal that provides gas at 20 mtorr pressure, as a medium to strip electrons from heavy ions traversing it. The resulting multiply charged positive ions, are accelerated back down to ground potential. The old gas stripper used titanium sublimers to pump the gas from the canal. These pumps were difficult to control and the emerging gas was immediately exposed to the accelerating tube. The consequent rise in pressure in the accelerating tube, caused charge changing reactions along the tube producing a wide spectrum of ion energies. Such ions were an unacceptable background which interfered with Accelerator Mass Spectrometry, AMS, measurements.

The main feature of the new equipment is that the gas emerging from the canal is pumped by a pair of turbo-molecular pumps which then recirculate the gas back in to the centre of the canal. The pumping is consistent and is not limited by titanium sublimer lifetime. Additional ion pumps and pumping impedances, isolate the region of gas pumped by the turbos from the accelerating tubes. The average pressure in the tubes is more than a factor of 10 lower than with the old system, thus reducing the background in AMS experiments.

The second feature of the new equipment is the exploitation of several computer controlled power supplies to serve the turbo pumps, ion pumps, vacuum gauging and the electrostatic quadrupole triplet lens. The use of sophisticated electronics in the terminal has required the development of devices to protect the equipment from lightning like 16 MV sparks.

The third crucial feature is the invention of a protection scheme for the fibre optic pair which communicate between the ground based computer control system and the device interfaces in the terminal. This protection eliminates both mechanical damage and spark damage to the fibres.

II. The Recirculating Gas Stripper

The gas stripper equipment has been manufactured by National Electrostatics Corporation is shown in the figure. The 15 MeV negative heavy ion beam enters from the top where the vacuum is maintained near 2x10^-8 torr with a 60 l/s ion pump. The beam then passes through the first differential pumping impedance: 8 mm diameter, 42 mm long. The impedance also serves as an electron stopper to minimise the production of x-rays. It has a .25 mm thick
tantalum shield covering glassy carbon disks, 16 mm long. All this is enclosed in a heavy metal x-ray adsorber. The beam then enters the 2x10^6 torr chamber pumped by two 400 l/s Leybold turbos running at 80% speed powered by an NEC controller. The pressure here is monitored by a Varian 2 l/s ion pump. The beam now traverses the actual stripping region, a canal 8 mm diameter, 852 mm long with the recirculated gas reinjected at the centre where the pressure is 2x10^-2 torr. Oxygen stripper gas is added to the turbo backing line via a Granville Phillips, GP, metering valve. The pressure in the centre of the canal is monitored by a GP Convectron gauge.

Another turbo pump at the canal exit is followed by the ANU foil stripper assembly whose isolation valve provides two impedances, 8mm diameter, each 75 mm long. A beryllium electron stopper is next then the beam enters the region pumped by the other ion pump to 1 x10^-8 torr.

Beam scattered through small angles in the foil is focussed by the electrostatic quadrupole triplet lens and then enters the high energy accelerating tube. At the entrance to this tube, a 12mm diameter aluminium electron stopper is installed. The electron stoppers between the foil stripper and the entrance to the high energy accelerating tube have lead sheet wrapped outside the vacuum system to adsorb x-rays.

III Spark Protection

When the terminal of the 14UD discharges, a lightening like surge of voltage and current will destroy
unprotected electrical devices. Modern developments in shielding from electromagnetic pulses have made accessible commercial solutions to these problems. Since the commissioning of the 14UD in 1973, all but the most robust electrical equipment failed and was eliminated from the machine. The wiring and voltage doubler power supplies, were adequately protected by enclosing all wiring in metal pipes or conduit.

To fully exploit the new equipment, sophisticated power supplies and computer control were essential. The inventory of electronics comprises: the NEC turbo controller, NEC ion pump controllers, 4 Glassman High Voltage supplies for the lens and 1 for the 2 l/s ion pump, the GP Convectron Gauge, DC supplies, the Group 3 Control Net Device Interfaces, DC valve motor and read-out. A version of “double shielding” was adopted featuring all equipment being housed in copper plated steel boxes and the Group 3 interfaces separately housed within these in a additional RF shielded box. All wiring to and from the Group 3 box does not leave the outer shielded box and penetrates the Group 3 box via pi-filter feed-throughs. Wiring leaving the outer box is in flexible metal conduit grounded at the box wall and at the load device. The coax in the conduit is grounded only at the power supply and the centre conductor has a spark gap at the load end. The mains power wires from the alternators are attached to MOVs near where they enter the outer shield box. All wire penetrations are tightly grouped at one corner of each box to limit circulating currents in the box walls. Ventilation is provided by RF honey comb units near the tops and bottoms of each box. Temperature monitoring in the Group 3 box has never exceeded 26 degrees Celsius. The access doors are sealed with RF woven wire gaskets and held by 4 quick release clamps. All electronic units are mounted on a copper plated frame which hinges in the outer box and is grounded to it near the penetration window. An RF ground link between the outer boxes and the 14UD structure is also near the penetration windows.

Spark hardening has also been incorporated in all the power supplies. For the Glassmans, additional copper ground planes under the circuit board have been added. The DC rails and ground have been close coupled with capacitors and fast diodes and the voltage monitoring circuits are protected by transors. The NEC turbo pump controller has had its grounds concentrated on the front panel, a filtered mains socket installed, varistors close coupled at the output connector and DC rail to ground modifications similar to that on the Glassman supplies. The NEC ion pump supplies will soon be replaced by Glassmans so the tale of modifications will not be listed. All units are voltage controlled by the Group 3 interface and communicate by shielded twisted pairs with the shield grounded at the unit.

Since the installation of the new equipment, the 14UD had sparked about 30 times with 60% above 13 MV. There has been no interruption to the computer control let alone any damage to electronic equipment.

IV Fibre Optics Protection.

Fibre communication with the high voltage terminals of accelerators has been successfully employed in many accelerators around the world. One still hears of failures even in well established facilities. We sought to incorporate lessons learned in the years of successful use of nylon tubing in the 14UD in the design of a fibre optics protection system.

A long insulator traversing an electric gradient will have charge travelling along its surface. If the insulator is electrically attached to the electrodes at both ends of the gradient region, it
acts like a distributed resistor and the voltage on it varies smoothly from that on the electrodes. If, however, the contact between the insulator and the electrodes is poor and the insulator passes through a hole in the electrode, then the charge travelling along the insulator will create a voltage difference between the insulator and the electrode. When this voltage difference gets large enough or if there is spark elsewhere in the structure, there will be a discharge between the electrode and the insulator. This will damage the insulator. The nylon tubes in the 14UD are in good contact with the many electrodes they pass through on their way from ground to 16 MV. The challenge in installing the optical fibres was to achieve similar contact.

A pair of fibres exposed between for about 470 mm between electrodes are too vulnerable to mechanical damage in the normal maintenance procedures needed in an accelerator. So we combined the successful aspects of the robust 1/4 inch nylon tubing with the fibres by threading the fibres through the tubes. A temporary problem was caused by the manufacturer changing the properties of the previously successful nylon tube that necessitated its replacement with perfluoroalkoxy PFA tubing. This material has sufficiently high resistivity to sustain the 1.2 MV over 470 mm between electrodes and low enough resistivity to distribute the gradient along its length.

Although good contact between the tube and electrodes was assured by the old techniques, contact between the plastic optical fibre and the inside of the tube had to be reliably achieved. This was accomplished by causing the tube to abruptly change direction at least every 470 mm thus pressing the fibre against the inside of the tube. This had also to be done in the nominally ungraded sections of the machine since during a spark, high gradients penetrate theses regions too.

The bottom 2 units of the 14UD were equipped with fibre protected in this way. Light transmission measurements confirmed that machine sparks did not alter the performance of the fibre. Subsequent extension of this philosophy to the entire machine has resulted in trouble free operation.

V Conclusion

The new gas stripper installation in the 14UD has successfully achieved the required vacuum performance reducing the backgrounds in AMS experiments. The spark protection scheme has achieved zero fault operation in a spark plagued period. The innovative fibre optics protection system has also demonstrated the desired mechanical and spark robustness.