1 Introduction

Singly charged negative ion of desired species is produced at ion source and injected to pelletron accelerator for acceleration. 15 UD pelletron accelerator at NSC consists of a high voltage terminal, a low energy section and a high-energy section. Both low and high energy sections have 15 units and a dead section. All of these parts are housed inside a stainless steel tank. The environment inside tank is high voltage and the electric field is of the order of million volts. SF₆ gas filled inside the tank, used as an insulator between the tank body and terminal along with full column. Devices like ion pumps, electron trap, foil stripper, gas stripper and few quadrupoles are installed in this high voltage area. These devices are distributed in low energy dead section, high voltage terminal and high energy dead section. The operation of all these devices can be controlled from control room. All control signals to control the operation of these devices must be carried to their respective controllers. The ordinary signal cable, made out of conductors, cannot be used for this purpose as those signal cables will not be able to withstand such high voltage and hence it will damage. Therefore, media used to carry control signal in such environment must be able to withstand such high voltages. One of such type of media is fibre optic cable. To use fibre optic cable as a media, the voltage level of the control signal must be converted to equivalent light signal. Therefore, the control signal for devices in high voltage environment will be first converted to equivalent light signal. This converted light signal is then carried by means of fibre optic field cable, in high electric field, up to devices and after reaching there this light signal will be reconverted back to voltage levels and used to control the operation of devices. Similarly, voltage read back signals from devices, inside tank, should be first converted to equivalent light signal and then transmitted through fibre optic cable in high electric field. This light signal will be reconverted back to voltage signal as soon it comes out from high voltage tank. In NSC pelletron, this conversion from voltage levels to light and vice versa is done electronically by means of light link box. The total arrangement described above is shown in Fig. 1.

The injected singly charged negative ion would be accelerated up to high voltage terminal. After reaching mid-terminal, negative ion must be transformed to positive ion by stripping off electrons for further acceleration. Two types of stripers used at high voltage terminal viz. gas stripper, for heavy ions and foil stripper, for light
ions. 200 carbon stripper foils can be loaded at a time in the terminal area. All the 200 foil holders are mounted in separate slots on a steel conveyor belt. Foil stripper, to be used for stripping of negative ions, must be positioned properly in the beam path. Moving conveyor belts either in forward or backward direction through an electrical drive does this. If stripper foil no. 1 gets damaged, it should be replaced by either foil no. 2 or foil no. 200. The mounting arrangement of stripper foils is shown in Fig. 2. An exact position (number) read back of foil in use is important to ensure its condition for better beam transmission.

Nitrogen gas is used as a stripper gas. It will be injected in a stripper canal at terminal for the stripping of negative ion. The efficiency of gas stripper depends on the density of the gas in stripper canal. A sublimation pump was earlier used to pump
out the gas from stripper canal in order to maintain a base vacuum near the stripper canal area. In this method more amount of gas had to be injected into the canal for better stripping. This results in bad vacuum around canal region and vacuum gets affected up to low energy and high energy regions away from terminal. Consequently, the beam transmission through machine reduces. To improve the stripping efficiency of gas stripper for better transmission of beam through machine, two turbo pumps were connected to gas stripper chamber. Then, the exhaust port of both turbo pumps are connected together and then connected back to gas inlet of stripper canal. No sublimation pump is used in this case. A small amount of nitrogen gas will be injected into stripper canal this gas will be fed back to stripper canal again. This improves the density of gas in canal, hence improves stripping efficiency.

2 Problem Encountered with Fibre Optic Cable

The control signal fed to devices, in low energy dead section, terminal and high energy dead section areas, individually by three different bunches of fibre optic cables. The devices in low energy dead section are an ion pump, an electron trap and a quadrupole. A bunch of 16-fibre optic cable carries control signals for low energy dead section. In one of the normal beam run, it was observed that the devices in low energy dead section went off. The reason for this was the damage of total bunch of fibre optic cable in unit #9, which is just above the low energy dead section. This whole bunch got divided into two pieces. This damage restricts the flow of control signal for devices in low energy dead section. Now, to operate the devices in low energy dead section it was essential to repair the damaged fibre cable. The solution for this was either to change whole length of fibre cable or to replace the damaged portion by a patch. As change of whole length of fibre cable is expensive, it was decided to replace the damaged portion by a patch. Proper connector, to connect the patch in place of damaged cable, was not available. Therefore, it was decided to develop an indigenous connector, which can connect a bunch of 16-fibre cable. Fig. 3 shows the damaged portion of fibre optic cable.

2.1 Design, installation and testing of fibre optic cable connector

Fibre optic connector should connect two-fibre cable properly with minimum light leakage. This design requirement is essential because the light
leakage may not able to trigger circuit at the other end. The overall diameter of fibre optic cable used for signal communication is 1000 μm, core diameter used to carry light signal is 960 μm and the signal attenuation is 0.3 dB/m at 660 nm. In low energy dead section the damaged fibre cable is a bunch of 16-fibre cable. Therefore a fibre cable connector, that can connect 16 numbers of above specified fibre cable, was designed and fabricated in NSC workshop. A cylindrical aluminium piece 30 mm in diameter and 16 mm in height was machined.

To connect all 16-fibre cable, 16 through holes at the pitch circle diameter (PCD) of 26 mm on machined aluminium piece were drilled axially. Diameter of these holes is designed in such a way that it will be just sufficient to insert single fibre cable. This is essential as there should not be any play in fibre cable position inside hole, otherwise there will be a mismatch in the cross-section of two fibre cables to be connected. This mismatch will cause leakage in light signal at the connector point. The two fibre cables to be connected will be inserted into a drilled hole from the two sides of the connector. The other necessity is to hold these fibre cables in a proper position tightly in the connector so that any of fibre cable should not leave its proper position in order to establish positive and rugged connection. The fibre optic cable must hold softly otherwise it will get damaged. For this soft holding, two slots were cut at an approximate distance of 1 mm from each end. The width of these slots is around 4 mm and depth is around 2 mm. A simple cable tie can be used to hold fibre optic cables and these cable ties will be placed inside the slots. The drawing of the connector is shown in Fig. 4. To replace the damaged part of fibre cable, 16 fresh fibre cables of equal length were taken. Length of each fibre cable is around 1 metre. The damaged portion of total bunch was removed after cutting. Now two open ends of fibre cable were available, one end was of the fibre cable coming from top of tank and other was of fibre cable going to shielded distribution box inside low energy dead section. The other ends of both the pieces were terminated to regular fibre optic connector of Amp make, which is a 21-core connector. One-to-one connections of all 16-fibre cables of both the pieces were first
identified and labeled properly. This identification is essential in order to make sure one to one connections of each fibre cable while connecting them with a patch. A light source was used for this identification. Two indigenously developed connectors were used to connect the patch. All the 16-fibre cables of upper fibre cable end were connected to fresh pieces of fibre cables of 1-m length.

Open end of fresh fibre cables were then connected to the lower bunch from shielded distribution box inside low energy dead section. These connections were done with the help of indigenously developed connectors. Optical cement BC-600, of ORTEC make, was applied on every end of each fibre cable before connecting them together. This was done to make sure the minimum leakage of light signal through connectors. After this, cable ties were put at both the ends of both the connectors to hold the fibre cables firmly. One-to-one connections of entire bunch of fibre cable (from tank top to shielded box) were confirmed. For the hardening of optical cement, both the connectors were left for a period of around 6 to 8 h (overnight). Placement of both connectors is another important aspect. These connectors are made of aluminium, which is a good conductor of electricity. Therefore, these connectors should not be kept in high electric field. Hence, the upper connector was placed inside the casting between unit #8 and unit #9 and lower connector was placed in low energy dead section. In both places the potential difference across connector is zero. The way in which connections were made and connectors were placed is shown in Fig. 5.

Presently, out of 16-fibres cable only 8 are used for signal communication and the remaining 8 are spare. After this, the signal communication through 8 used fibre cables was checked. For this checking, a variable voltage source (0V dc to 10V dc) was connected at input of an optical transmitter analog (OTA) card. This card converts the different voltage levels to different frequency light signal. 0V dc to 10V dc-voltage signal corresponds to frequency of 1 kHz to 10 kHz light signal. Light signal from this card was then fed to fibre cable, under test, from the dead section end. This light signal carried through the entire length and fed to the input of an optical receiver analog (ORA) card at tank top (286 msl). This card converts the different frequency light signal to different voltage levels. Frequency of light signal from 1 kHz to 10 kHz corresponds to 1V dc to 10V dc. If condition of fibre cable is good and it is connected properly, the voltage at output of ORA card must be equal to the voltage fed to input of OTA card. This arrangement used is shown in Fig. 6. Out of 8-fibre cable used, 4 were found in good condition with proper connection. Out of these four, presently three fibre cables are used for ion pump at
low energy dead section (IP D-1). One for status control, second for status read and third one for pressure read back. The fourth one is used for quadrupole (EQ CT-1) status control signal.

3 Problem Associated With Original Foil Stripper Position Read Back

Original stripper foil position read back system, which came along with machine, consists of a mechanical counter and a 5 bit DAC. The block diagram of the original read back system is shown in Fig. 7. Following drawbacks (problem) were observed in this original system:

1. Mechanical counter had slippage problem in its gear.
2. It counts from 0 to 999 and does not reset to first count after 200 counts.
3. DAC used is made of OP Amps and resistors; hence its output is non-linear.

All of above mentioned problem lead to the error in the position read back of foil stripper in use and did not give the absolute position (number) of stripper foil in use. For example the foil stripper at 100 position may be read by original read back system could be either of 99, 100, 101, 299, 300, 301 positions. This erroneous reading creates difficulty to access the status of foil in use.

3.1 Development and installation of new foil stripper position read back system

An entirely new system was designed, fabricated and tested in NSC to solve the problem. This system...
can count precisely, the position of foil stripper from 1 to 200 in increment mode and 200 to 1 in decrement mode. The new features of this new system are:

1) An electronic UP/DN Counter used instead of mechanical counter. This avoids the problem of incorrect reading due to slippage.
2) Counts from 1 to 200 and reset to initial count 1 for next count after 200.
3) It uses a much-improved 8-bit DAC that gives accurate and linear output.
4) This system has local display of stripper position read back.
5) Battery backup to hold the counts during power failure.

This new read back system was kept on for duration of about a week and tested thoroughly. There was absolutely no drift in count and DAC output was quite stable and linear within ½ LSB. The stripper read back system was then installed. Fig. 8 shows the installation of system. The information of change of foil stripper in increment or decrement mode is fed to stripper position read back electronics from terminal through fibre optic cable. This will change the count of up/down counter by one count. If the position of foil stripper is incremented, the count will change in upward direction and vice versa. Suppose the read back display is 1 and foil stripper position is kept on incrementing, it will count up to 200. After this if again it is incremented, it will read 1 and so on. Similarly, in case of decrementing it will read from 200 to 1 and if it again decrements it will read position as 200.

3.2 Circuit description

Circuit diagram is shown in Fig. 9. Suppose position of foil incremented by one step. A +5V signal will appear and fed to upper monoshot. The output of upper monoshot will become +5V and output of lower monoshot will remain zero. The output of OR gate will go high (+5V). This OR gate output will serve as a clock signal for three digit BCD UP/DOWN counter. Outputs of both monoshots are also fed to two different analog switches. For the incremental change, output of upper analog switch will go high and output of lower analog switch remains high. Consequently, output of AND gate goes high. This AND gate

![Image of circuit diagram](image-url)
output, fed through a delay to UP/DOWN pin of counter, will serve as UP signal. Output of three-digit BCD counter will get incremented by one count and the local display will show the next count. An EPROM will convert three-digit BCD output data (12 bit) of counter to 8-bit binary data. This EPROM is programmed to do so. This 8-bit data will get converted to equivalent analog signal by 8-bit DAC. The analog output of this DAC is then fed to CAMAC system for display of foil stripper position (number) read back on computer screen in centralized control room. Similarly, if stripper position is decrement by one step clock signal will generate at output of OR gate due to high output of lower monoshot. Both inputs to AND gate will become low as the output of lower analog switch goes low and upper analog switch remains low. The low output of AND gate will be then fed to UP/DOWN pin of counter through delay. This signal will serve as down signal. Now, counter will decrement by one count and as a result, local display will show the previous count. The foil position read back will be displayed in a similar way as explained above.

4 Controller Problem in Modified Gas Stripper System

The modified gas stripper was tested after installation. But after about two hours of operation system broke down due to the electronics problem in system controller. Mains transformer of controller burnt off.

The block diagram of controller is shown in Fig. 10. The secondary current of mains transformer used was 4.5 A at 24 V. This controller operates at 120V ac mains, hence the primary voltage to mains transformer is 120V ac. Therefore, mains transformer was designed for 0.9 A of primary current. Main fuse used in this controller was of 6.5 A. It means that fuse will not blow off until primary current becomes more than 6.5 A, or secondary current becomes more than 32.5 A. The reason of burning of transformer was investigated and two of the power transistors (2N 6059 and 2N 6052) were found to be faulty. Collector of this transistor got shorted to its emitter. This leads to high collector
current. For a normal circuit design, protection fuse must blow off in such conditions. As rating of fuse was quite high (6.5 A) it did not blow. As a result mains transformer got loaded and ultimately its insulation failed. This caused shorting of primary and secondary windings and finally fuse blew off.

4.1 Modification of controller electronics

There were two basic problems in the design of controller; one was the wrong selection of transformer and second was the wrong value of main fuse. According to manual, the starting current of both turbo pumps together was more than 10 A, and under no load condition this current falls down to 1.5 A at normal speed. Therefore, the secondary of mains transformer should be designed to deliver at least 10 A of current. A new transformer replaces the damaged transformer. Secondary of this new transformer is designed for 10 A of current at 24V ac. During a test run after replacement of transformer, starting current at the input of controller was measured to be −12A. It remains at this value for a very short duration and then falls. Turbo pumps come to normal speed after 3-4 min. Value of main fuse of controller was calculated to be 2.4A. The blown fuse of 6.5A value was replaced by new 2.5A fuse.

After these modifications, the new gas stripper system was again kept under test. After duration of about five hours, the controller again broke down. This time only main fuse blew off. The reason was investigated and it was found that insulation used for power transistors was failing at high temperature and resulting in high collector current. To solve this problem mica insulators replaced all the insulators. The system was kept on overnight without any problem.

5 Results and Conclusions

The indigenously development of 16-core fibre optic cable connector was done in September 1998 and it is working satisfactorily since then. This design can further be modified by use of some insulating material, like lucid, instead of aluminium and by providing proper holding arrangement for fibre cables to be connected. New design of foil stripper position read back system and modification of gas stripper controller, using turbo pumps, were carried out a year before. The performances of both developments are satisfactory since then and helped a lot to improve the performance of Accelerator.

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References

2. Chopra S et al., loc. cit.