IEEE Transactions on Nuclear Science, Vol.NS-22, No.3, June 1975

MODIFICATION OF THE ARGONNE FN TANDEM*

J. L. Yntema and P. Billquist
Argonne National Laboratory, Argonne, Illinois 60439

Summary

The Argonne FN tandem now uses Pelletron chains for its charging system and a closed corona system for the voltage distribution along the column. This change has improved the stability of machine operation significantly. The maximum voltage on the terminal is now 9.8 MV compared to 8.6 MV attainable previously in normal operation. The voltage fluctuations in the terminal have decreased by an order of magnitude.

The Argonne FN tandem is the first tandem to use a closed corona system for the distribution of voltage along the column and the first FN tandem to use Pelletron chains for charging. Both the closed corona system and Pelletron chains were purchased from National Electrostatics Corporation[1] and were installed in December 1973. The original type of aluminum-electrode inclined-field tubes from HVEC[2] have been retained in our present operation.

The change from belt to chain charging was expected to lead to a cleaner interior of the accelerator, to allow operation at higher SF_6 tank pressures and hence higher terminal voltages, and to reduce fluctuations in terminal voltage. Because of space limitations in the FN tandem it was only possible to install two chains, one on the high energy side and one on the low energy side of the machine. Fig. 1 shows the chain arrangement in the terminal of the accelerator.

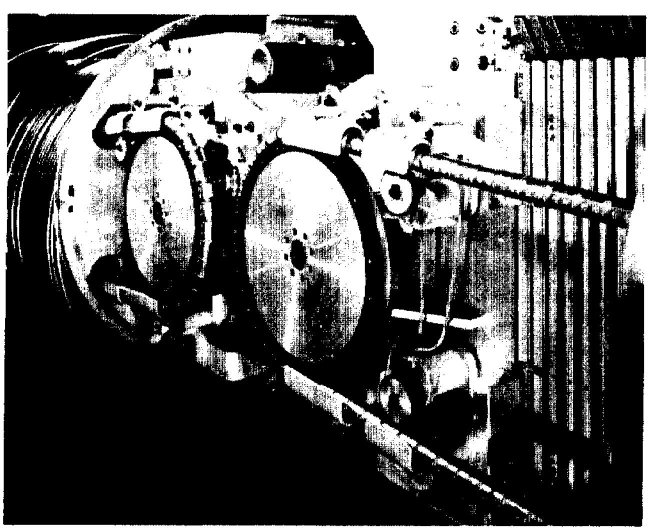

Fig. 1. View of the Pelletron chain arrangement in the tandem terminal.

Fig. 2 shows the arrangement at the low energy end of the machine. The chains are supported and stabilized by insulating wheels located at the dead sections between the two accelerator tubes.

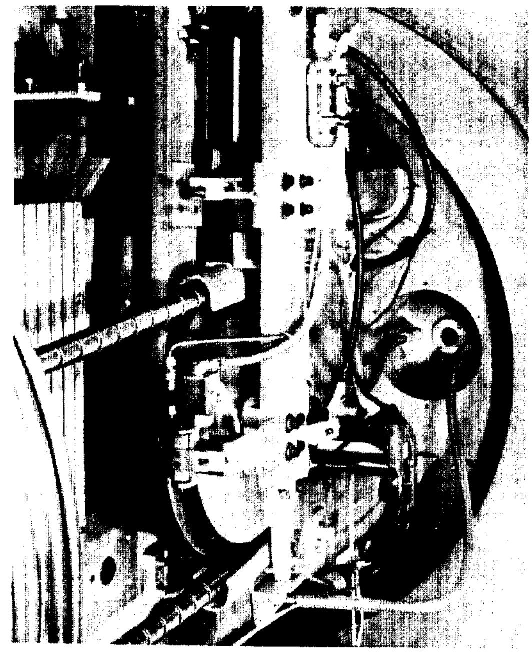

Fig. 2. View of mounting of Pelletron chain at the low energy end of the tandem.

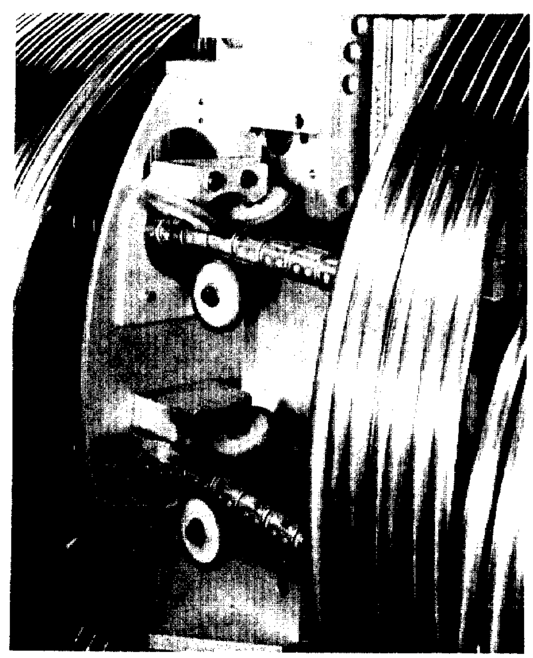

Fig. 3. Idler wheels in the dead section between the accelerator tubes - serve to stabilize and support the chains.

The arrangement of the idler wheels is shown in Fig. 3. The operation of the chains has been trouble free for over 6000 hours of operation except for the replacement of the idler wheels in the dead section which was necessary after about 4000 hours.

The maximum upcharge which can be obtained from either chain is about 85 μa. With a total upcharge of only 170 μa the operational flexibility of the machine would be severely reduced if one continued to use a fixed resistor chain for voltage distribution along the column. Therefore it was decided to use a closed corona system for the voltage distribution. The closed corona system is installed in the space formerly occupied by the belt and a top view of two corona tube sections is shown in Fig. 4.

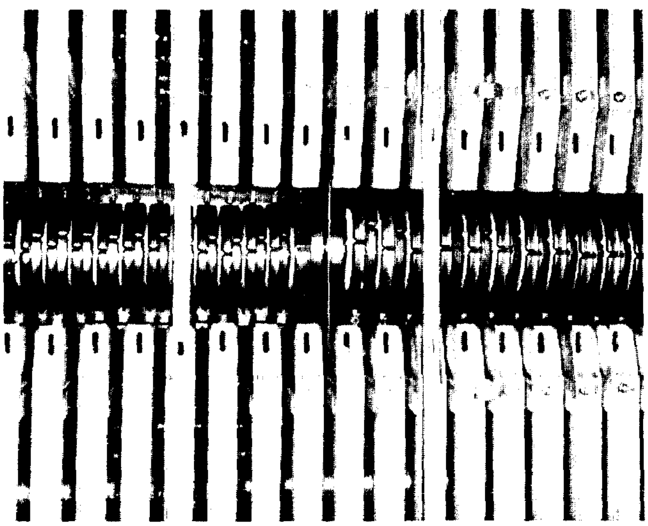

Fig. 4. View of the arrangement of the two sections of the closed corona system in the space formerly occupied by the belt.

Each section of corona tube attaches to 12 electrodes and in order to allow proper spacing the units are staggered. Each plane in the corona tube has three needles and, in the final version, an internal spark gap. The gap length has been adjusted so that the voltage drop between two electrodes in the first 20 electrodes is about half that of the drop between two adjacent electrodes elsewhere in the machine. The corona system is filled with a gas mixture of 33% SF_6 and 67% N_2. The pressure is controlled from the control room to give a current between 20 and 35 μa through the corona system. In the original system the high energy and low energy corona tubes were independently pressurized and dead ended at the terminal. The change in resistivity of the gas filling with time, together with the flow restrictions in the system, caused serious trouble especially when the change from one experiment to the next required a large increase in terminal voltage. The flow through the system has been improved and the tubes connected through the terminal so as to have uniform pressure throughout the corona system with the possibility of continuous gas flow. In order to minimize undesirable focussing effects, the corona planes were selected to have a 30 μa current and a potential drop of 8.25 ± 0.5 kV across the gap in air at atmospheric pressure except for the first 20 sections of the low-energy tube, where the current is 30 μa and the potential drop is 4.1 ± 0.25 kV. With this change, and the introduction of internal spark gaps, the corona system has operated without failure for more than 3000 hours.

The installation of the chains has greatly decreased the voltage fluctuations at the terminal of the accelerator. The fluctuations with the belt charging system, measured by capacitive coupling with a frequency response from 0.5 Hz to 2 kHz, was about 3 kV. Now, with the chain charging system the terminal-voltage fluctuation measured in the same way is only about 400 V peak to peak. The dominant frequency of the voltage fluctuation is about 1.5 Hz. This frequency is the same as the chain frequency, and since vibrations in the terminal would also give a voltage fluctuation signal, it is quite possible that this measurement overestimates the actual voltage fluctuations. At any rate, the stability of the terminal voltage has improved by an order of magnitude with the installation of the Pelletron chains.

The maximum operating pressure of SF_6 in the tank was about 50 PSI (gauge) when the belt was in use. Above that tank pressure, excessive loading of the belt drive motor occurred and the maximum terminal voltage at which the machine could be operated consistently was about 8.6 MV. The chain has operated well at tank pressures of 100 PSI. With this tank pressure a terminal voltage of 10 MV was obtained with an O^{16} beam. The analyzed current of 70-MeV O^{6+} ions on the shutter was about 0.3 μa with negligible loading while using a 10 μg/cm^2 foil stripper. With gas stripping the maximum attainable voltage with O^{16} was about 9.8 MV. At that energy the loading exhausted the available upcharge. The analyzer beam current of 58.8-MeV O^{5+} ions was 0.6 μa. The analyzed current of O^{6+} beam at this terminal voltage was 0.22 μa.

Experimental data have been taken with 19-MeV proton beams and 29-MeV α-beams. The terminal-voltage metering system is attached to a recorder and a section of the trace of a 29-MeV α-particle experiment is shown in Fig. 5. The beam current was about 0.7 μa on target in the split-pole spectrograph. The last 10 hrs of the run are shown starting at 0 hrs and terminating at 12 hrs at which point the next experiment (with 23-MeV α-particles) started. In that time interval there were about 4 large sparks and a number of small instabilities. Starting at 3 hrs the instability becomes more pronounced until at 5-1/2 hrs the operator decided to take corrective action. The action taken was the evacuation of the corona system and refilling it with new gas. This operation took less than 10 minutes and the machine returned to its terminal voltage immediately and appeared to be more stable. There is no ready explanation why the flushing of the corona system should improve stability except for the possibility

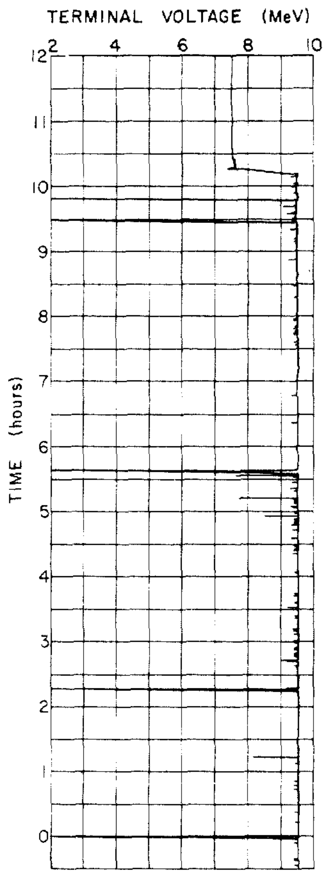

Fig. 5. Tracing of the terminal voltage recorder during a 10 hr section of an experimental run with a 29 MeV α-particle beam.

that the frequent sparking across the spark gaps inside the corona tubes produced significant changes in the gas composition. The larger sparks in this experiment are usually associated with small shifts of the ion source conditions. It takes a fairly long time to condition the accelerator. When one introduces the beam at a safe terminal voltage, around 8.5 MV, it is necessary to readjust the beam-optics parameters for beam optimization for each increment of 100 or 200 kV. Above 9.3 MV the accelerator is quite sensitive to small changes in the potential of the 5 in. einzel lens and the deflection plates at the input of the machine. A slight parameter change produces a tank spark quite quickly. Similar effects can be obtained by sudden changes in the operating conditions of the source itself. It is clear that the ion-source optics and the machine optics have to be matched quite carefully. Part of the sensitivity of our present arrangement may be due to the low injection energy (about 45 keV for He^- and 60 keV for O^- ions) in use at the present time. On occasion a chain can create fluctuations, e.g. by a displacement of an inductor or failure of a feed through connector. In those cases it is often possible to continue operation with a single chain. Experiments with 19 MeV proton beams and 28 MeV α-particle beams have been performed with a single chain with beam currents in excess of 0.5 μa on target in the split-pole spectrograph.

The spark gaps of the column structure and the accelerator tube do not represent effective protection of the accelerator when it is operated at tank pressures of 100 PSI of SF_6. The spark gaps fire if a potential difference of about 175 kV is applied at this s gas pressure. In normal operation of the accelerator, the discharge should occur at a potential difference of about 80 kV. The accelerator tubes in use are Aluminum electrode inclined-field tubes which have been reconditioned by HVEC, but with the spark gaps left out. We gap these tubes with leaded steel spark gaps with the desired characteristics, and so far this arrangement appears to have provided adequate protection for the accelerator tubes. The protection of the column structure is difficult to achieve. Several years ago insulators in three sections at the low energy side of the accelerator were shattered by high frequency surges possibly associated with resistor failure. It became necessary to short out these sections by wedging in strips of copper between the electrodes. In a number of cases tracks have appeared through the insulators close to the edges. To protect the column structure effectively it would be necessary to replace the original spark gaps located close to the insulators. This is, at this point, an impractical solution. Since the development work on the closed corona system was completed we have relied on the chains, the external spark gaps on the corona tubes shown in Fig. 4, and the accelerator tubes to provide the necessary protection to the column. While the development work on the corona system was in progress, spark gaps were placed on the top and bottom of the electrodes of the column structure to provide protection against gross overvoltages resulting from improper voltage distribution. With the closed end corona arrangements, which were tried during the early stages of the development work, such overvoltages did occur and the protection did prove quite effective. If the high frequency transients which are thought to cause the insulator damage in the column structure are indeed due to resistor failure, the corona system would reduce the effect. If all three needles in a plane disappear or if two neighboring corona system planes short out, this is immediately observable in the fluctuations of the corona current and these fluctuations make machine operation impossible.

With a better injection system into the machine, other accelerator tubes and the addition of terminal pumping, the FN tandem should be able to operate consistently at 10 MV without endangering the column structure or the tube.

References

*Work performed under the auspices of the United States Atomic Energy Commission.

[1]National Electrostatics Corporation, Middleton, Wis. 53562

[2]High Voltage Engineering Corporation, Burlington, Mass. 01803