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Status of the Fermilab Electron Cooling Recirculation Project*

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The electron cooling project requires a high current electron beam with high reliability to provide the consistent cooling required by Fermilab's physics program. We are using a 5URE-2 Pelletron to provide this beam. The program is developing a high current DC recirculating electron beam with high recovery efficiency. The present layout uses 2 sets of tubes with acceleration, a 180° bend, and deceleration for a total of about 10 meters of beam line. The project's nominal operating parameters are .5 A at 4.3 MeV with the emission cathode immersed in a 200-600 G magnetic field.

- High Voltage
  - While initial conditioning has gone well; in accordance with our previous experience and that of others; we have not been able to maintain that conditioning once high current DC beam has been established even with new tubes installed. The maximum stable voltage degrades to about 90% of the rated voltage. Without beam, the columns can be conditioned to above 5 MV and the new tubes have improved the ability to maintain this voltage. Once beam is started, multiple discharges degrade the maximum voltage to about 4.3 MV.
- Stability - A large effort has gone into trying to understand what processes lead to beam interruptions.
  - Halo electrons from gun – Based on work done at NEC in 1999, we have used a negative potential on the gun control electrode and a diaphragm in the anode.
  - Secondary Electrons from collector – The primary beam loss mechanism is electrons emitted from the collector, backstreaming down the decelerating column, and striking the beam pipe in the first bend. At .6 A primary current, this loss current is 3μA.
  - Secondary Ions – We have configured 4 sets of BPMs as blocking and clearing electrodes. The blocking electrodes prevent ions from entering the accelerating and decelerating columns from the rest of the vacuum line. The clearing electrodes are placed in the vacuum line at ground potential and remove ions. Both have resulted in increases in beam lifetime of at least an order of magnitude.
  - Minimize charge transfer to tubes – Extensive work has been done to understand and minimize the amount of charge transferred when the beam is interrupted. We have reduced as much as possible the capacitance of components on the terminal deck. By monitoring a fast CPO signal, we can turn off the gun quickly to, in most cases, avoid a large spark.

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- Crash scraper – A scraper has been placed in the beamline at a high dispersion point after the 180° bend. As the voltage droops during a beam interruption event, the crash scraper intercepts the beam rather than allowing that energy to be deposited on the tubes. This greatly improves the recovery time as large pressure bursts are not generated.

- Gun
  - Problems with insulator for control electrode – Previous insulators were ceramic/copper and have broken 3 times. Have just installed a ceramic/titanium insulator.
  - Control electrode material – In January we replaced the copper electrode with a tantalum one. This reduced spontaneous dark current from the electrode face.
  - Anode size – The diaphragm was increased from 8 mm to 10 mm diameter. This increased the maximum current by 100 mA and allowed us to open the gun fully at high magnetic field on the cathode, 670 G.
- SF6 handling
  - Recent improvements to the SF6 gas recirculation system involved the elimination of bends and pipe lengths in order to reduce the pressure drop and reversing the direction of SF6 gas flow. These changes improved the SF6 gas mass flow rate through the water heat exchanger and increased the heat removal from 9 kW to 13 kW. Presently, the operational power generated by the Pelletron is 15 kW. The temperature rise of the SF6 gas and Pelletron shell under these conditions is approximately 6 °C. Some additional improvements are still necessary to limit the operating temperature.
- Control System
  - A Finite State Machine is being developed to automatically maintain voltage and current on the Pelletron. It monitors the voltage of the terminal, the current produced by the power supply that transfers current from the collector back to the cathode, and the vacuum of the system. There is also a fault box that monitors some parameters the most effective of which is the fast CPO and can switch the gun off quickly to prevent sparks that release large amounts of energy that require long recovery times. An 8 hr run on 6 Sept resulted in 20 crashes and a duty factor of 98%.
- Results
  - We are regularly able to operate at .5 A but at 3.5 MeV.
  - Mean time between beam interruptions is ~ 20 minutes.
  - Recovery from most interruptions is about 20 seconds.
  - Vacuum in the beam line is $.5 – 1 \times 10^{-9}$