8 Accelerator and Ion Sources

8.1 Van de Graaff accelerator operations and development

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The tandem was entered 19 times this year. The ion species was changed during eight of the openings. The #3 accelerator tube was changed during three of the openings. The tube voltage gradient was changed eight times. The terminal ion source (TIS) canal was changed twice. Two different pelletron chain links were repaired during two of the openings. The internal components of the TIS were all replaced once during a routine servicing. One opening each was required to make repairs to a leak in one of the steerer feedthroughs, an idler, the TIS extraction supply, the terminal computer, and the TIS oscillator. One opening was used to install a parallel gas bottle tee to increase the available run time using protons. The TIS was removed and the foil stripper was installed during one opening. The accelerator tubes and stripper box were aligned during one opening.

Difficulty tuning the beam prompted us to check the alignment which we had not done since the earthquake of 28 February, 2001. Our survey showed that the optical target in the analyzing magnet was displaced 5 mm from the tandem line. Also, the accelerator tubes were no longer straight in the tank. Our conclusions led us to move the high energy end of the tandem 1.5 mm north and 0.75 mm up and to move the low energy end of the tandem 1.5 mm south. This brought the accelerator and analyzing magnet back onto the same line. The accelerator tubes and all other beam optics components were put onto the new line. The accelerator beam is now easy to tune and the object and image diagnostics indicate that the beam is well centered.

The tandem has begun producing x-rays in bursts when the terminal is raised above 6.5 MV. The x-rays can be substantially reduced by shorting two adjacent column planes somewhere in the tube #1 region with the shorting boat. The tank must be entered to pinpoint the location of the emitting plane and then further studies of this problem must be done.

During the 12 months from April 1, 2002 to March 31, 2003 the tandem pellet chains operated 1545 hours, the SpIS 758 hours, and the DEIS 62 hours. Additional statistics of accelerator operations are given in Table 8.1-1.

ACTIVITY SCHEDULED	**DAYS SCHEDULED**	**PERCENT of AVAILABLE TIME**
Molecular research, deck ion sources only	41	11
Nuclear physics research, deck ion sources	27	7
Nuclear physics research, terminal ion source	68	19
Subtotal, molecular or nuclear physics research	136	37
Machine development, maintenance, or crew training	81	22
Grand total	217	59

Table 8.1-1. Tandem Accelerator Operations April 1, 2002 to March 31, 2003.

8.2 Injector deck and ion sources

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A vacuum leak developed on the injector deck side of the deck accelerator tube. The seal in that region was disassembled, cleaned, and reassembled. The gridded lens was examined and found to be intact at the same time.

A molecular physics experiment required use of rubidium in the cesium oven of the modified 860i sputter ion source (SpIS).[1,2] Also see Section 6.1. Despite use of higher oven temperatures, repeated Rb blockages occurred. A redesigned oven and delivery tube assembly with 1/4 inch OD stainless steel tube and 1/4 inch VCR (Swagelok TM) fittings works well. A copper shell (part of the heater assembly) surrounds exposed parts of the delivery system maintaining tube and fitting temperatures above regulated oven temperature (as demonstrated with additional thermocouples).

The airlock for the SpIS cathode probe had screw caps electrically insulated with silicone rubber and consequently could not be easily disassembled for regular cleaning. Redesign of the acrylic air-lock insulator and associated flanges with long 1/4-20 nylon screws passing through clearance holes in that acrylic now allows rapid disassembly and reassembly for routine cleaning.

The direct-extraction ion source (DEIS) was put back into operation this year after being idle during the last reporting period. The DEIS was used in beam transport tests for a 3.5 MeV $^{1}H^{+}$ beam and for crew training. A spark during operation of the 860 SpIS punctured two of the DEIS HV cables. These have since been replaced.

The terminal ion source (TIS) was used for the $^{7}Be(p,\gamma)^{8}B$, $^{7}Li(d,p)^{8}Li$, and $^{6}Li(^{3}He,n)^{8}B$ experiments during this reporting period. The ions used were $^{1}H^{+}$ at terminal voltages from 0.16 MV to 1.5 MV, $^{2}H^{+}$ at terminal voltages from 0.77 MV to 1.4 MV, $^{3}He^{+}$ at a terminal voltages from 5.0 MV to 6.0 MV, and $^{4}He^{+}$ at a terminal voltage of 1.37 MV. The TIS was used in 68 of the 95 days scheduled for nuclear physics research this period. The internal components of the source were replaced once during routine servicing. The extractor supply and the RF oscillator supply were each repaired once.

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[1] CENPA Annual Report, University of Washington (2002) p. 80.
[2] CENPA Annual Report, University of Washington (2001) p. 82.

8.3 A ^{8}B beam at the Tandem

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We have developed the first radioactive beam at the UW Tandem. In order to be able to detect the ground-state decay of ^{8}B, in which the daughter ^{8}Be decays into two alpha particles with a total of 92 keV, it is necessary to implant the ^{8}B in the detector. (See Section 3.3 for a description of the experiment.) We realized that the Tandem switching magnet and beam transport can be used as a separator for radioactive ions created in a reaction. The object for the switching magnet is the tandem analyzing-magnet image, and our detector is placed just down stream of the center of the 24" scattering chamber on the 30° right beam line. We first tried making ^{8}B with the ^{6}Li(^{3}He,^{8}B)n reaction. However, this reaction requires the neutron to go backwards to make ^{8}B going at 0° into the narrow acceptance of the switching magnet, while the neutron angular distribution[1] is forward peaked. Consequently, we built a gas cell which is placed at the image of the Tandem analysing magnet, and we use a 24-MeV ^{6}Li beam (6 MeV in the cm) which produces ^{8}B of about 15.5 MeV at 0°. Detailed studies of the beam-line optics using Turtle[2] indicate that tuning a monoenergetic beam of 7.44 MeV $^6Li^{3+}$ through a small aperture in the chamber requires beamline settings that are optimum for the radioactive beam, with its relatively large energy and angle spreads. The system accepts approximately ±3% energy spread and ±5 mr horizontally by ±8 mr vertically. The energy and angle are correlated because the dispersion of the switching magnet is not canceled completely at the detector.

The gas cell is 28 mm in diameter with 2.5-μm Havar[3] windows and is filled with about 0.7 atmospheres of ^{3}He. With this configuration the energy spread of the outgoing ^{8}B is 10%, so a larger or higher pressure cell would be of no value. At those energies both B and Li are fully stripped. The magnetic rigidity of the 24-MeV $^6Li^{3+}$ is 1.8 times that of the $^8B^{5+}$. The gas cell will run indefinitely with 600 nA of Li beam, and has survived short periods of over 1 μA. Backgrounds can be measured by filling the cell with ^{4}He.

It is necessary to take great care to operate with the least amount of material that can degrade the beam. We run with the image slits open to 0.7 inches and use the generating-volt-meter control to stabilize the Tandem terminal voltage. The beam is focused and steered carefully to avoid hitting any limiting apertures in the beam line after the analyzing magnet. The Li beam is stopped in a cup placed in the switching magnet, but only about half the current present at the location of the gas cell is measured in this cup. Presumably the rest is lost in the entrance to the switching magnet and against the poles because of multiple scattering in the gas cell windows. The detector itself has an 17-mm lead aperture in front of an annular scintillator with a 19-mm aperture. Another lead aperture of 15-mm diameter is 60-cm upstream of the detector, and this intercepts most of the ^{8}B which would otherwise hit the detector aperture. With this aperture system, we typically operate at a singles rate, predominantly degraded ^{6}Li, of 800 s^{-1} while tagging about two ^{8}B s^{-1} in our detector.

[1] P. van der Merwe, W. R. McMurray and I. J. Van Heerden, Nucl. Phys. A **103**, 474 (1967).

[2] PSI Graphic Turtle Framework by U. Rohrer based on a CERN-SLAC-FERMILAB version by K. L. Brown *et al.*; http://people.web.psi.ch/rohrer_u/turtle.htm.

[3] Hamilton Precision Metals, 1780 Rohrerstown Rd. Lancaster, PA 17601.