7 Accelerator and Ion Sources

7.1 Deck and ion sources

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With the terminal ion source in use, the injector deck is available for other research activities (see Section 7.3). Concern that LiF used to prepare neutron-capture targets might be depleted in ^{6}Li led to use of the 860 sputter ion source for crude mass spectrometry. For a test of alternate neutron-capture targets, ^{10}B was implanted using the SpIS, deck and offdeck steering magnet.

The computer code SCAN steps the steering magnet current in x from x-minimum to x-maximum, then steps once in y to scan a new line from x-maximum back to x-minimum. When y-maximum is reached a new scan is begun at y-minimum. At program startup one specifies six parameters: x-minimum, x-maximum, y-minimum, y-maximum, time interval per step, and step size. As noted in Section 7.3, SCANELP is an enhanced version of SCAN designed to save time by scanning only the inscribed ellipse within the specified rectangle.

7.2 Van de Graaff accelerator operations and development

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The tandem was entered 18 times this year. The ion species was changed during four of the openings. The #3 accelerator tube was changed during three of the openings. The tube voltage gradient was changed four times. The internal components of the TIS were all serviced during three routine servicings and the einzel lens was changed to the 2.5 cm diameter version during one of these. One opening was required to make repairs to the power lead to the TIS einzel supply and to replace the F/O connectors on the fiber optics on the terminal computer side of the telemetry link. The TIS and the foil stripper were exchanged during three openings. The electrostatic deflector supplies were either tested, repaired, or replaced during six tank openings. The electrostatic deflectors were removed and the TIS permanent magnet scheme was reinstalled during one opening. The machine was entered twice to refoil. A short in plane #55 in tube #3 was removed during one of the service openings in which a column spark problem was also solved.

Most of the problems which temporarily halted experimental use of the tandem were related to failures in the electrostatic deflector high voltage power supplies. We finally removed the deflectors entirely and returned to the operational mode in which one of a set of permanent magnets is installed for the ion species of choice. The design of a rugged power supply scheme using adequate transient suppression and potted power supplies using technology newer by 20 years has been completed. The construction of the package is complete except for the circuit boards that house the suppression circuits and connectoring scheme.

The tandem produces x-rays in bursts when the terminal is raised above 7.5 MV, an improvement from last year. 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, 2003 to March 31, 2004 the tandem pellet chains operated 1401 hours, the SpIS 1576 hours, and the DEIS 298 hours. Additional statistics of accelerator operations are given in Table 7.2-1.

Activity Scheduled	**Days Scheduled**	**Percent of Available Time**
Molecular research, deck ion sources only	7	2
Ion implants, deck ion sources only	39	11
Nuclear physics research, deck ion sources	47	13
Nuclear physics research, terminal ion source	41	11
Subtotal, molecular or nuclear physics research	134	37
Machine development, maintenance, or crew training	136	37
Grand total	270	74

Table 7.2-1. Tandem Accelerator Operations April 1, 2003 to March 31, 2004

7.3 Progress toward UCN detectors with the 860 SpIS

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We used the 860 sputter ion source (SpIS) to help manufacture ultracold neutron (UCN) detectors. This was done in two ways. We implanted ^{10}B into a 2000Å layer of vanadium evaporated onto nickel foils to make one possible UCN detector. Another possible detector is ^{6}Li in a layer of LiF evaporated onto a 2500Å thick nickel foil. We evaporated LiF onto its substrate. However, only ^{6}Li is useful to make a UCN detector, so we used the SpIS to check that the ^{6}Li was present in the LiF in its natural abundance.

We used medium grit, crystalline boron (enriched to 96% ^{10}B) mixed 1:1 with Ag to obtain our beam for boron implantation. With a detector area of about 2×10^{-4} m^2, and an absorption layer of vanadium approximately 2000Å thick, we needed to implant about 10^{18} ^{10}B's at 80 keVfor a 1:1 B/V ratio. Beam currents averaging 1μA on target require two full days to reach 10^{18} implants, so this was a time intensive process. To produce uniform implantation across the whole target, the beam was scanned by the offdeck steering magnet. We modified a program to raster the beam more efficiently, with elliptical boundaries instead of rectangular, to minimize beam time. Disregarding damaged foils and foils on which the beam was not well focused, we made four foils for UCN monitors.

The LiF detectors were created in an evaporation chamber, but we needed to use the SpIS to test the abundance of ^{6}Li. The natural abundance of ^{6}Li is 7.5%, but commercial sources could be depleted and contain far less ^{6}Li. The SpIS is good for rough mass spectrometry, because the charge to mass ratio of the ions in the beam is constant at a given magnetic field. Thus one can use the fact that the magnetic field required to tune the beam of a particular isotope is proportional to the square root of the mass. We tested the composition of the LiF by tuning the magnetic field to obtain the peak beam currents of Li$^-$, LiF$^-$, and LiF$_2$$^-$ for both ^{6}Li and ^{7}Li. Then we were able to estimate the isotopic composition from the ratios of the beam currents. The results are in the table below. The results suggest ^{6}Li is present in its natural abundance, so the LiF we used should work for the UCN detector foils.

Q/M	Expected Ion	B (Gauss)	Expected B	B Shift	Current	Li Percentage
1/6	^{6}Li$^-$	788	791.8	-2.8	17.7nA	6.8
1/7	^{7}Li$^-$	852	855.2	-3.2	240nA	93.2
1/19	^{19}F$^-$	1409	Calibration	N/A	12.7μA	N/A
1/25	^{6}LiF$^-$	1619	1616.2	2.8	3.7nA	9.7
1/26	^{7}LiF$^-$	1652	1648.2	2.8	34.3nA	90.3
1/44	^{6}LiF$_2^-$	2148	2144.2	3.8	13.7nA	8.9
1/45	^{7}LiF$_2^-$	2172	2168.2	3.6	140nA	91.1

7.4 Removal of large pieces of the old cyclotron

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We received funds from the College of Arts and Sciences for disposal of the low level radioactive parts of the old cyclotron. We removed the dee-stem tanks, the dees, the vacuum chamber, and the associated piping. The disposal scheme initially involved a single large box (100 cu. ft.) for removal of low level radioactive waste. There was a 17,500 lb weight limit for the box and contents. At the same time, the University Hospital was doing construction in their neutron therapy site, and had produced a significant amount of low-level radioactive demolition waste. By combining their waste with ours, we were able to share 4 of the large boxes and get about 2.5 boxes full of our own waste, while meeting the weight requirements for the boxes. In total we disposed of 27,600 lbs of metal with low-level activation.

After disassembly of the parts, they were cut into pieces that would fit into the boxes. The pieces were surveyed, as some materials were not measurably radioactive and could be disposed of by normal means. The main radioactive materials were copper and steel, both of which had measurable levels of ^{60}Co, presumably resulting from neutron capture on ^{59}Co present in those materials. As the cyclotron had not been operated since the early 80's, shorter lived activities had died out. By careful sorting of the materials, we were able to get the radioactive material into the available boxes without exceeding the weight limits.

The result of this effort was the creation of an additional 150 square feet of floor space in the old cyclotron circle room. This space is near the middle of the room and is being used mainly for the LISA development, (see Section 1.8) as well as other gravity experiments. The cyclotron magnet yoke remains, but it is relatively compact compared to the entire structure. The room has a much neater appearance besides having more space for research.

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*retired staff, served as consultant.