COMPLETION OF THE K500 CYCLOTRON UPGRADE

T.L. Grimm, T. Berenc, J. Brandon, S. Bricker, C. Compton, G. Horner,
F. Marti, J. Ottarson, D. Sanderson, J. Vincent and R.C. York

An element of the Coupled Cyclotron Project (CCP) is the refurbishing and upgrading of the K500 cyclotron [1]. The K500 was operated from mid-1993 through 1995 to determine the required upgrades, develop beam diagnostics, and measure beam parameters for the injection and coupling beamlines. Many upgrades were implemented during this time including; second harmonic buncher, second harmonic spiral inflector, M4 diagnostic probe, improved extraction optics, and a non-intercepting beam probe. Experimental results showed the extracted beam achieved the CCP requirement for bunch length of 3 degrees, and was within a factor of two of the required intensity of 1.2 pμA, and emittance of 3 πmm-mrad [2]. The remaining upgrades will make it possible to reliably achieve all of the CCP specifications for K500 operations.

Work Complete

Construction and commissioning of the new injection line took place during most of 1996. During that time, most of the K500 subsystems were disassembled, and only main magnet operation was maintained to verify that the injection line's magnetic shielding and compensation performed adequately[3]. In September 1996, the injection beamline was shutdown and disassembly of the K500 steel began. At that time, the vault had been completely stripped with only the K500 steel, cryostat and injection line remaining. All designs were complete and construction of the subsystems were underway in 1997[4]. Fig. 1 shows a schematic of the K500 vault and subsystems.

The return yoke's median plane was modified to decrease the azimuthal asymmetry in the magnetic field which had forced the coil to operate off-center. The cryostat outer diameter was also modified to decrease any azimuthal asymmetry. New center plugs were designed to simplify and improve the vacuum, allow use of the inner trim coil (trim coil zero) without steering the injected beam, and improve axial injection by smoothing the field along the vertical injection line inside the yoke.

The inner diameter of the cryostat was stripped and plated. Vacuum leaks through the liner were repaired. Since some of the cooling lines on the liner had been pinched, modifications were made and the lines replaced. A second O-ring groove was cut in the lower beam chamber seal for increased reliability. Many of the trim coil fittings and all of the trim coil vacuum feedthroughs were replaced. The pole caps had many cracks in the casting which were identified and welded to reduce leaks into the liner vacuum.

By the end of March 1997 all repairs to the K500 cyclotron were complete and reassembly of the machine started. The vault electrical, lighting and low conductivity water distribution were installed. A new main magnet power supply and trim coil solid state reversing switches were completed. Also, a new adjustable, combined quadrupole/dipole magnet was installed in the extraction line at the return yoke. The main coil was cooled and ramped to full field in August 1997.

The median plane mapper was installed in September 1997. A search coil and NMR probe were used to map the field over the entire range of excitations along with the trim coil fields. Additional steel was added and hill extension steel removed to fully compensate measured imperfections before the final measurements were taken[5,6]. The median plane mapper was removed in February 1998 and Hall probe mappers were installed to measure the field in the vertical injection line[7] and the extraction line[8].

The vacuum system was assembled and tested with blanks over the rf ports to confirm all inaccessible vacuum seals were good. The liner vacuum was about 10 mTorr and the main chamber vacuum reached $2x10^{-6}$ torr at the 500 l/s turbo in a few days. This pressure confirmed that the low pressure required for the heavy ions is achievable once the cryopanels are operational.

The injection line, including new RTECR section, was tested in March 1998 by transporting beam from the ion source through the beamline and spiral inflector onto the median plane with the cyclotron at field and under vacuum.

The transmitters were constructed in parallel with installation of the cyclotron and the magnetic mapping. In April they were tested individually into a resistive load to about 50 kW over the required frequency range. This power level is adequate to obtain the maximum 75 kV dee voltage. During the transmitter tests, the upper resonators were mechanically completed, leak checked and low level rf measurements made which were consistent with the design values.

Future Work

By the end of April 1998, all systems required for commissioning were complete, except for the lower resonators, valley liner sections, coupling/extraction beamline, control systems, and resonator cooling water circuits. Full rf and vacuum system testing will begin at the end of the cooling water shutdown in June 1998. Commissioning will begin in the summer of 1998 with completion by the end of the year.

During commissioning several systems required for operation, but not needed to verify that the cyclotron will meet specifications will be completed. These systems include; first and second harmonic buncher, anode power supply, final phase and amplitude control systems, high power deflector modifications, internal bunch length diagnostic and magnetic extraction element modifications.

References

1. R.C. York, H. Blosser, T. Grimm, D. Lawton, F. Marti, J. Vincent, X. Wu, and A. Zeller, “Proposed Upgrade of the NSCL”, Proc. of the 1995 Particle Accelerator Conference, (1995)
2. T.L. Grimm, G. Horner, F. Marti, X.Y. Wu and R.C. York, “K500 Operation for Coupled Cyclotron Development”, 1995 NSCL Annual Report, p. 157 (1995)
3. T.L. Grimm, G. Horner, F. Marti, J. Ottarson, X.Y. Wu and R.C. York, “Commissioning of the K500 Injection Line”, 1996 NSCL Annual Report, p. 212 (1996)
4. T.L. Grimm, J. Bennsinger, S. Bricker, C. Compton, C. Heckman, G. Horner, F. Marti, J. Ottarson, and R.C. York, “Status of the K500 Cyclotron Upgrade”, 1996 NSCL Annual Report, p. 209 (1996)
5. F. Marti, T.L. Grimm, G. Horner and D.A. Johnson, “Compensation of Magnetic Field Imperfections in the K500 Cyclotron”, 1997 NSCL Annual Report (1997)
6. T.L. Grimm, G. Horner and F. Marti, “Magnetic Field Measurements of the K500 Main Field”, NSCL-CCP18-1998 (1998)
7. T.L. Grimm, G. Horner and F. Marti, “Magnetic Field Measurements of the K500 Vertical Injection Line”, NSCL-CCP16-1998 (1998)
8. T.L. Grimm, G. Horner and F. Marti, “Magnetic Field Measurements of the K500 Extraction Path”, NSCL-CCP17-1998 (1998)