Cyclotron Institute Upgrade Project

H.L. Clark

On January 3, 2005 the Cyclotron Institute Upgrade Project (CIUP) began with the approval of the CIUP management plan by the Department of Energy Nuclear Physics Office. The project will extend to the first quarter of calendar year 2011. When completed, the upgraded facility will provide high-quality re-accelerated secondary beams in a unique energy range in the world. Funding for the upgrade comes from several sources: the Department of Energy, matching support from TAMU, the Robert A. Welch Foundation and beam time sales for testing electronics components at the Cyclotron Institute.

The CIUP is divided into three major tasks: (1) Re-commission the existing K150 (88") cyclotron and refurbish beam lines; (2) Construct light-ion and heavy-ion guides and produce 1+ radioactive ions; (3) Transport and charge boost radioactive ions and accelerate in the K500 cyclotron.

Most of the effort during this reporting period focused on Task 1, restoring the K150 cyclotron major equipment. This included design, procurement and installation of the K150 high vacuum system and equipment, procurement and installation of K150 electrical and LCW utilities, assembly of K150 RF system, installation of K150 coil power supplies, design and procurement of K150 ECR & injection line materials, procurement and assembly of K150 beam line equipment. Progress was also made on Tasks 2 and 3. This included assembly and testing of the light ion guide chambers, flanges and support structures, procurement of the light ion guide vacuum equipment, development of the ion guide beam dump by utilizing complex radiation transmission computer codes, development of heavy ion guide gas cell system and compiling the list of major equipment that will be needed to complete the CB ECR ion source provided by a DOE Small Business Innovative Research (SBIR) project. Below is a description of the progress made. Figure 1 illustrates the project schedule and major milestones.

TASK 1:

1) **K150 Cyclotron Vacuum System:** The design calls for vacuum equipment to be installed on the two main sections of the vacuum space (resonator tank and dee tank) as follows: The resonator tank will be equipped with one new 35" diffusion pump with a modern cryogenic baffle system and one new roots blower package (initial system). The initial system will provide a vacuum pressure of $5x10^{-6}$ torr for testing the RF System, identifying any major leaks and producing first beams. The dee tank will be equipped with one internal liquid nitrogen cryogenic panel and four external cryopumps (high vacuum system). The high vacuum system will provide a vacuum pressure of low 10^{-7} torr for beams later in the project.

   All pieces of the initial system have been procured. The bid for the 35" diffusion pump was awarded to Varian in July and was delivered to the cyclotron in late September 2005. The bid for the roots blower package was awarded to Aerzen and the equipment was delivered in late November 2005. The bid for the 35" diffusion pump cryogenic baffle system was awarded to Connecticut Vacuum Products Inc and was delivered in late December 2005. Upon inspection it was found that the baffle piece was damaged during delivery from the factory to the cyclotron. In an agreement

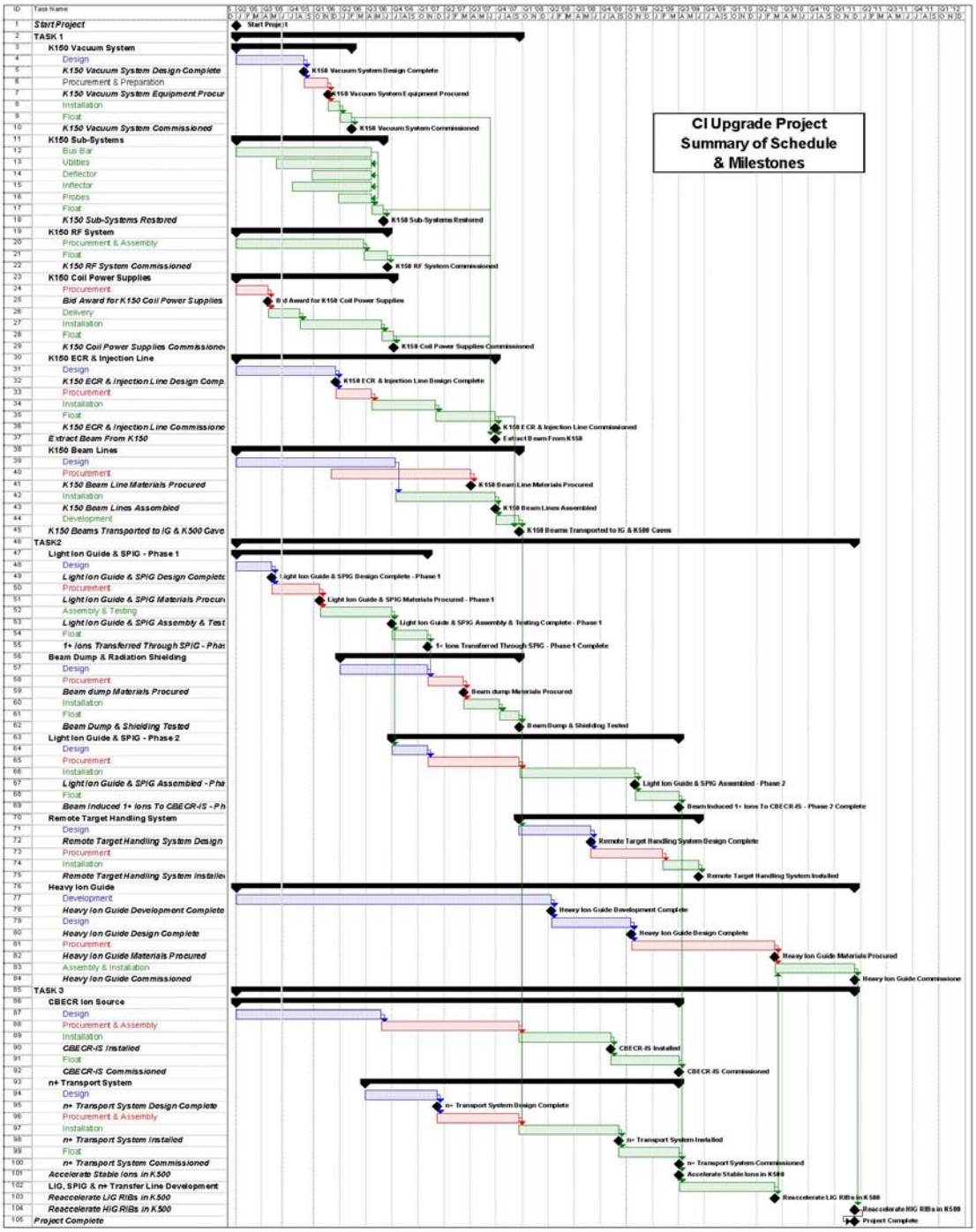

Figure 1. The project schedule and major milestones.

between the shipping company, Connecticut Vacuum and the Cyclotron Institute the baffle piece was sent back to the factory for repairs. The repaired baffle was returned to the Cyclotron Institute in early March 2006 which has subsequently delayed installation and commissioning of the initial vacuum system.

The roots blower system, the baffle system and the 35" diffusion pump are set in place on the cyclotron. Cyclotron engineering configured a lift system to safely remove the original baffle and install the new baffle and diffusion pump. Before the baffle and diffusion pump were installed, the large 35" gate valve was tested and found to operate properly and to be leak tight. Engineering also found that in the open position, the valve o-rings can be easily removed and replaced. The electrical and cooling water hook ups to these systems have been installed. The 12" diameter vacuum pipe/valve work between the roots blower system and cyclotron gate valve is nearly complete. It is anticipated that the initial vacuum system will be operational in late June 2006.

The pieces of the high vacuum system are currently being procured. The bid for the external cryopump system (four pumps, two compressors and helium transfer lines) was awarded to Austin Scientific in March 2006. The bid for the high vacuum isolation valves was awarded to VAT Inc. also in March 2006. The pumps and valves are scheduled to arrive in May 2006. The bid request for the liquid nitrogen transfer and dewar system is being prepared. This system will be used to feed liquid nitrogen to both the internal cryopanel of the cyclotron and the cryopanel system of the vertical injection line. A list of materials needed for the internal liquid nitrogen cryogenic panel is being compiled. Three sets of valves and external cryopumps will be installed along with the initial vacuum system; however the fourth set and the internal cryopanel will installed after the cyclotron is made operational.

2) **K150 Cyclotron Buss Bar Work:** Most of the original buss bar that connected the power supplies to the K150 cyclotron was salvaged for the K500 cyclotron project and needs to be replaced. As each coil power supply is set in place, final buss bar sections are cut, bent and insulated. After each supply passes inspection, the final buss bar sections are soldered into place. Final buss bar sections have been installed for twenty two of twenty three coil power supplies. It appears that buss bar installation will be complete in June 2006.

3) **Upgrade Project Utilities:** The bid for the building power improvement (to add electrical power capacity for the K150 cyclotron, K150 power supplies, K150 RF system, K150 beam lines, ion guides, etc.) was awarded to Britt Rice which is the same contractor that installed the electrical utility equipment for the K500 project. The transformer, motor controls, switch gear and building feed equipment were installed in November and December 2005. The "tie-in" of the transformer to the cyclotron building occurred in January 2006 during the K500 maintenance period. Currently, the K500 cyclotron, its equipment and beam lines and the Cyclotron Institute building are drawing electrical power from the new transformer. The original building transformer and its switch gear will power the K150 cyclotron and all of its associated equipment.

Construction of the new LCW loop (to add cooling water capacity for the K150 cyclotron, K150 power supplies, K150 RF system, K150 beam lines, ion guides, etc.) is in continuation. More than half of the system has been installed. All of the pipes, connectors, valves, pumps and control gear

have been procured. The bids for the large surge tank and demineralizer system have been awarded and these systems are currently being transported to the cyclotron. It is planned to "tie-in" the new LCW loop in fall of 2006.

A list of electrical and LCW utility items needed to restore the K150 cyclotron has been compiled and most of the electrical and LCW items have been procured. Items will continue to be procured over the next reporting period. Utility items include electrical wire, conduit, breaker boxes, cabinets, flow switches, flow indicators, strainers, valves and pipe. LCW plumbing and electrical restoration to cool the interior of the cyclotron (cooling lines to the rf panels, deflectors, etc…) is nearly complete.

4) **K150 Cyclotron Deflector:** The bid for two new deflector power supplies was awarded to Spellman in February 2006 and delivery is expected in May 2006. The trolley system used to remove the K150 deflector assembly has been restored. It is anticipated that the deflector assembly will be pulled from the cyclotron in April 2006 and the deflector and its controls can be cleaned and tested for proper operation.
5) **K150 Cyclotron Inflector:** The original K150 cyclotron "mirror" inflector was pulled from the machine, cleaned and tested. The mirror inflector will be used at initial start up of K150 cyclotron. A spiral inflector will be designed during the vertical injection design stage.
6) **K150 Cyclotron RF System:** All major components of the RF system have been procured including the filament power supply (plus a spare). Assembly is ongoing and it is anticipated that the RF system will be operational in early spring 2006 as planned.
7) **K150 Cyclotron Coil Power Supplies:** Twenty-two of twenty-three power supplies have arrived. Each supply has been tested for proper operation and control. All twenty-two supplies have been set in place in the K150 pit vault. Wiring, plumbing and buss bar hook ups are nearly complete. The last supply to arrive is the large main coil supply. The original "Ling" main coil supply is currently still in place and in addition is currently used to power the MDM spectrometer and the MARS velocity filter. This supply is very large and heavy and cannot be removed all in one piece, so it will be cut up and removed from the K150 cyclotron pit vault in several sections. Additionally, the MDM and MARS spectrometers will be powered by a new supply that was purchased in 2005. This supply is located in the sub-basement and is nearly ready for connection to the two spectrometers. It is anticipated that the remaining supply will be delivered and installed in June 2006.
8) **K150 ECR & Injection Line:** The design for the injection line was determined by closely following the design of the Berkeley AECRU – to – 88'' cyclotron injection line and incorporating the existing elements from our ECR2 injection line. To obtain the highest transmission efficiency possible, two additional focusing elements (Glaser lenses) and two additional sets of steering magnets will need to be procured. Power supplies and control equipment for these additional elements will be procured as well. Vacuum pressure in the low 10^{-7} torr will be obtained along the vertical injection line and into the inflector region with an internal liquid nitrogen cryopanel. A materials list for the additional magnets and the cryopanel system has been prepared and some items have already been procured. Materials for the vertical support structure and the new cyclotron center plug are being procured. Construction and installation of the injection line will begin in April 2006.

ECR2 was fit with a new plasma chamber and was put back online in November 2005. Beams created from ECR2 were accelerated in the K500 cyclotron in December 2005. As described in the CI Upgrade Management Plan, ECR2 will be the ion source for the K150 cyclotron.

9) **K150 Beam Line:** Plans for the vacuum chambers of the switching magnets are being drafted. A materials list for the entire beam line is being compiled and includes electrical utility, LCW utility, beam boxes, vacuum equipment, valves and shield wall plugs. A list of magnet power supplies and switch gear is also being compiled. Most materials needed to fabricate the quadrupole magnets, x-y magnets and their support structures have been procured, including insulated copper wire for the magnet coils. The insulated copper wire was delivered in March 2006. All magnets, support structures and beam boxes will be built by cyclotron personnel. All pole and yoke pieces have been machined and winding of eight complete quadrupole magnet coils has been completed using surplus copper wire. Two quadrupole magnets made entirely from surplus materials have been completed. Ten existing quadrupole magnets have been completely refurbished and are ready for installation. All pieces for x-y magnets have been machined and are ready for assembly. Stands for x-y magnets, quadrupole magnets and beam boxes have been constructed.
10) **K150 Control System:** A new *standard* for the K150 cyclotron project has been developed. The new system was developed since the equipment of the current K500 control system is being phased out by industry. A prototype unit using a "Rabbit" brand control card was developed and thoroughly tested by incorporating it into the existing K500 control system and was found to operate the K500 equipment properly. The prototype was also configured to control the new coil power supplies of the K150 cyclotron and was found to operate this equipment properly as well. Mass production of the new control equipment is currently under way. This new system is both simpler in design and much less expensive compared to the existing K500 control system.

TASK 2:

1) **Light Ion Guide:** Materials for the ion guide chambers, support structure, chamber flanges and gas control system equipment have been procured. The bid for the oil-free Roots1 and Roots2 systems was awarded to Pfieffer Vacuum Inc. in January 2006. The systems have been fabricated and are currently being tested for proper performance and operation at the Pfieffer factory. It is anticipated that the systems will arrive in April 2006.

   Both large ion guide chambers have been constructed, cleaned and vacuum tested. All flanges and connection pieces have been machined and tested. The support structures for the ion guide chambers have been constructed and are ready for installation in the ion guide cave. The internal spark discharge chamber has been fabricated. The electrical switch gear needed to power the roots systems and ion guide equipment has been installed. The ion guide cave is currently being cleaned and prepared for the roots systems and installation of the Phase 1 system. It is anticipated that the phase 1 system will be operational by June 2006.
2) **Beam Dump and Radiation Shielding:** Computer codes that model radiation transmission through various materials and system configurations have been procured. These codes (PHITS, MORITZ and MCNPX) have been installed on our computers and are being used to design the beam dump in the ion guide cave. Dr. Reg Ronningen (Senior Physicist & Radiation Safety Officer) from the NSCL

has agreed to help us with our design and has provided us additional software for studying the system. Dr. Ronningen will visit the Cyclotron Institute in May 2006. Before proceeding with construction, the CI will set up a review panel made from outside experts to study the design.

3) **Heavy Ion Guide:** The collaboration with the ANL gas cell group is in continuation. It is anticipated that the Cyclotron Institute will participate with future testing at ANL and GSI. The front-end separator design work is in progress with the Big-Sol spectrometer at the Cyclotron Institute.

TASK 3:

1) **CBECR Ion Source:** SBIR Phase 2 funding was awarded to Wayne Cornelius to build a CBECR-IS. The SBIR project schedule has been determined to be 18 months, starting in October 2005 with a delivery in March 2007. It has been estimated that ~half of major equipment will need to be supplied by the CI to complete the CBECR IS. This will include turbo pump systems, coil power supplies, microwave transmitters and control equipment. A memorandum of understanding is being drafted by the DOE SBIR Office and will state that the CBECR-IS will be delivered and tested at the Texas A&M Cyclotron Institute. Winding of the CBECR-IS magnetic coils will be underway soon and is reported to be on schedule for completion.