LABORATORY DEVELOPMENT

Accelerator Improvements

The major effort in this area during 1981 has been to identify and upgrade the systems which most influence accelerator reliability and ease of tuning. At the outset, a study of all accelerator systems was made and 255 possible jobs were identified. Each job was given a priority rating determined by its expected influence on accelerator performance and this rating became the yardstick for making budget and manpower commitments. In addition to these, the 75 jobs required for completion of the polarized neutron facility were also given a high priority. Of the 330 jobs studied, 228 were selected for action in 1981. Of these, 103 have been completed and 51 are presently under way. Results have so far been encouraging; the improvements in accelerator effectiveness are documented elsewhere in this report. The success of this effort has encourged us to continue the general approach; priorities for 1982 are being established in the same way.

In the ion source area several systems have been either expanded or improved. A ^{3}He recovery system which stores gases recovered from the arc source vacuum system is now in use. A system for the recovery and purification of ^{3}He is under construction. The arc source chimney (anode) has been redesigned to change the distribution of arc discharge. This has extended average filament lifetime from three shifts to nine and, as a result, a typical experiment using ^{3}He can be run to completion without interruption for ion source servicing.

The arc source has also gained a new extractor (puller), a new extractor box and a new slit box where slits and electrostatic steerer plates are mounted for easy servicing. All insulators for lenses and steerers have been replaced. A recently installed gas flow controller has eliminated ion source instabilities caused by gas pressure variations. The arc source vacuum system has been improved by the addition of a third D.P. baffle freon compressor (to eliminate load sharing) and an extra D.P. fore pump to simplify use of the vacuum controls, thereby avoiding accidents.

Several steps have been taken to improve cooling in high voltage terminal A. These include addition of a heat exchanger to cool the hydraulic oil which drives the alternator, an interlock to drop terminal A.C. power if cooling water temperature goes too high and an air delivery plenum to improve cooling in the polarized source 20kV racks.

In February 1981 a troublesome beam instability was traced to faults in the Terminal B acceleration column which had been in service for over ten years, frequently at greater-than-design voltage. The column was removed and replaced with a spare (a large job) and several improvements were made to the terminal which contains both the duoplasmatron and lithium source. These included optical alignment of the complete ion source system, installation of new bipolar steering power supplies, replacement of the voltage grading water resistor on the column with a commercial resistor string, and cleaning and/or replacement of lens and slit insulators. All of this work was completed in six weeks. Operational experience with the new column shows improved long term voltage stability. All power supplies were removed from Terminal B and bench tested for regulation and noise. Some of the supplies were modified while others were replaced with new commercial units. Finally the freon cooling system was completely overhauled. For Beam Line #1 adjacent to this system, several troublesome steering magnets have been insulated from ground and new magnets with improved insulation have been ordered.

The injector cyclotron required only minimal attention this year. Several insulation failures in trim coils were located and eliminated. A troublesome interaction between dee voltage and main magnetic field was eliminated by improving RF cable shielding and by re-routing load cables to all 10 trim coils. High voltage cables to the five electrostatic elements were rerun in conduit. Current monitoring shunts were also added in series with the trim coils at this time.

Several important RF improvements have been accomplished this year. An electronic phase shifter with a range of approximately 400° was installed at the control console, replacing a mechanical phase shifter. The operations group finds it slightly too coarse with a 12 bit DAC for setting the main cyclotron phase. The computer interface can provide a 16 bit DAC if necessary, but a better way of providing this feature was found later in the year and is currently being tested. Design and development of the low-level electronic upgrade for the injector RF system were complete in the first quarter. Construction commenced in the third quarter on the NIM bin and modules and was 50% completed and partially tested at the end of 1981.

An improved relative dee phase adjustment was installed on the main stage cyclotron. The new arrangement eliminates one mechanical phase shifter which can become noisy and degrade the phase control reference signal. For simplicity only 0° or 180° phase reference signals are available. This also provides a diagnostic cross check on other relative dee phase indicators. This is part of a project to provide remote operation of the main stage cyclotron phase controller. This project still requires the electronic phase shifter described earlier and a computer interface.

Preliminary development and testing of a synthesizer-type, phase-locked loop signal source for pulse selection was completed.

Design and development of a 10kW driver which would be added to the main stage power amplifier was completed during the second quarter. It was designed to provide more than five times the present drive power to the final amplifier. This allows an increase in dynamic range of the final amplifier and higher plate efficiency. The maximum available dee voltage should double. A prototype of the new final driver power amplifier with interstage tuning was constructed during the third quarter. Initial tests were inconclusive because of inadequate shielding. During the fourth quarter, all of the additional power supplies were set in place, the shielding was improved and modification to the west power amplifier enclosure was completed in preparation for final tests with the drive coupled to the west resonator.

Some persistent intermittent problems with phase stability caused by mechanical vibration of the resonators in both cyclotrons which exceeded the dynamic range of the phase controllers were resolved during the past year. The principal culprit was found to be a mechanical vacuum pump which excited a 15 Hz resonance in the metal floor of the cyclotron vault. This vibration was transmitted to the RF resonator tuning panels and dees. The resultant phase jitter led to beam loss on the deflector septum and reduced extraction efficiency.

In addition to eliminating vibration, we also completed a general overhaul of the main resonators. This included eliminating several water leaks, reclamping of several high-current connections, extension of the upper tuning range to 35.5 MHz, improvements to resonator supports where insulation failures had occurred, gap adjustments to the capacitors which couple RF power from final tubes to dees, and alignment of resonator shells and dees relative to the sector magnets.

In additon to RF improvements, other changes in the main stage cyclotron include relocation of the inflection magnet to improve beam matching between cyclotrons, addition of a safety cover to the inflector high voltage bushing, construction of a spare deflector assembly, first operation of a fast-handling system for the deflector to minimize radiation exposure, and addition of water cooling to the north kicker magnet slit jaw, which plays an important role in tuning for extraction. In the cyclotron north valley a 42" gate valve and 36" diffusion pump have been installed as a back up for the cryogenic pumping system.

Several improvements in the building/utilities area have been made. The cooling tower which handles the heat load for both accelerator and building has been extensively repaired and the mechanical drive for the tower fan replaced. Several standard wall blocks for radiation shielding have been replaced with blocks made from concrete with dense aggregate. The beam corridor, through which beam is transported from the cyclotron to experimental areas, has been modified and extended to accommodate the CSB experiment and a second interlocked escape hatch has been added. The main deionized water distribution system has been extensively revamped to balance loading of the four water systems and to avoid having large power supplies and their loads on different water pumps.

Extensive work on large power supplies has been done this year. The old injector magnet power supply, now called IUCF 1, has been rebuilt and now supplies the entrance magnet for the swinger facility. The main stage trim coil power supply network was modified to increase the isochronous tuning range at high energies. A new multi-channel power supply is now in operation; two channels power quadupole magnets on the QQSP spectrometer and two channels will handle quadrupole magnets for the polarized neutron facility now under development. In April the main 1600 amp power supply for the QDDM spectrometer was shut down by heat damage to its motor-controlled autotransformer. We were able to have this unit rebuilt in California and reinstalled with down time limited to eight weeks. During this period the QDDM continued to operate at reduced field by sharing a power supply with the QQSP spectrometer.

Polarized Ion Source

During 1981 the atomic-beam polarized ion source operated for 400 8-hour shifts for protons and 50 shifts for deuterons, with polarizations of about 70% for protons and 90% of the theoretical maximum for deuterons.

In 1981 the source was modified to attempt cryogenic cooling of the atomic beam as it leaves the dissociator. This reduces both the velocity and the velocity spread of the beam, leading to improved transmission through the sextupole magnet and better ionization efficiency. A two-watt helium refrigerator was installed, with its cold head (and a silicon diode temperature sensor) connected to a copper block clamped around the exit nozzle of a special dissociator bottle with a modified water-cooled jacket. Although the source had to be run (or maintained for running) through most of the year, we were able to learn the following information in tests of the cryogenic cooling of the atomic beam. It is essential that the bottle's straight glass nozzle be about two centimeters long in order to cool the beam effectively as well as to mimimize heat transfer along the length of the nozzle. It is necessary to maintain good uniform thermal contact between the copper block and the glass nozzle. We had previously found it useful to bubble the hydrogen gas through water to minimize recombination of atoms on the walls of the dissociator bottle. The use of the water bubbler with cryogenic cooling occasionally caused a droplet of water to freeze and plug the nozzle. Bypassing the water bubbler when operating the cryogenic cooling resulted in the bottle becoming coated with hydrocarbon contaminants in the gas. This contamination required that the gas pressure had to be continuously reduced in order to maintain dissociation, and the bottle became unusable after 24 to 48 hours. We have not yet been able to eliminate this contamination. In our tests the proton beam intensity extracted from the source increased by a factor of twelve or more when the nozzle cooled from room temperature to 20°K. However, the absolute proton intensity with cryogenically cooled atomic beam is at most two microamps, only 50% more than the output from the source with a conventional, uncooled dissociator bottle. Further tests with different nozzle configurations are necessary to develop the potential increase in beam intensity that should be attainable from cryogenic cooling.

During this past year we have changed from using a "V"-shaped tantalum ionizer filament (which tends to collapse with age) to an "Ω"-shaped filament. Of the various diameters of the "Ω", from 5mm to 10 mm, it was observed that the smaller diameter filaments produced up to 40% more beam.

Beam Transport System Development

Three-degree bending magnets are used at several places in the high energy beam lines at IUCF. These magnets are of a very compact, magnetically efficient design. They have been vacuum sealed (without the use of O-rings) by attaching the pole faces to the vacuum box directly with epoxy and silicon rubber. Vacuum leaks periodically opened up in these magnets, especially if they overheated for any reason. A somewhat less efficient magnet design, which opened the magnet gap to allow space for O-ring vacuum seals, was completed. The increased gap required the addition of a third coil to obtain adequate field strength. One such magnet was fabricated and installed. Experience has shown that, while radiation damage to the O-rings also causes periodic vacuum leaks, the new design is more quickly and conveniently repaired.

A cryogenically-cooled in-line cold trap was completed and installed in the high vacuum beamline just upstream of the 64" scattering chamber. The purpose of this trap is to prevent diffusion pump oil from migrating down the beamline and into the scattering chamber where it might deposit on targets.

Conversion of air driven actuators, which are used to insert/remove stops and viewers into/from the beam, from sliding O-rings seals to metal bellows seals has continued throughout the year.

Installation of the Polarized Neutron Facility (PNF) beamline from the last major bending magnet to the primary radiation shielding wall has been completed. Beam line hardware from the shielding wall to the target area is also in place and awaiting completion of utilities service installation. All magnets needed for the polarized neutron facility have been assembled, vacuum tested and field mapped. The large-aperture quadrupole magnet doublet for the PNF charged particle dump line has been installed and aligned. This required a special support and alignment stand because these magnets are located in a hole in the secondary shielding of the facility and at a 10 degree angle below the horizontal. Installation of the Faraday cup is complete and the stacking of dump shielding is nearly finished.

Computer Controls

An automatic pumpdown system based on a microprocessor was put into operation for the 160 cm Scattering Chamber. The vacuum system for this chamber is specially designed to be oil free, but achieves this at the cost of some complexity. The automated pumpdown not only sequences operations in an optimal way, but also protects the system from users who might be unfamiliar with it.

The original alphanumeric strips used to supply the operator with information relevant to the computer-driven analog meters on the control console were replaced by CAMAC driven models. The new strips have larger, more easily read letters and are not subject to the electrical noise which reduced the reliability and lifetimes of the original strips.

Our major efforts have centered on the replacement control computer, its purchase, installation and initial use. A PDP-11/44 with 256 KB of memory and dual RL02 discs was purchased as the basis for the new system. A CAMAC crate controller, two CRT terminals and a 9-track tape unit were purchased later. At the end of 1981 the basic system plus the crate controller were in-house and running. Programs to maintain the cyclotron data base have been completed and work on a CAMAC driver and acquire/control library package has been started. Current plans call for this system to replace the venerable Sigma-2 in 1984.

Shielding Improvements

Six special-shaped ordinary density concrete shielding blocks for the Polarized Neutron Facility (PNF) were formed and fabricated in house. These blocks augment the high density concrete blocks used to shield the neutron detector arrays from direct neutrons from the neutron production target. Four of these blocks are in place. In order to accommodate the PNF dump the wall shielding at the north end of the QDDM/PNF vault has been appropriately modified. Seven ordinary density concrete ($\approx$150 lbs/ft^3) 12 feet tall wall blocks at the northwest corner of the main cyclotron vault were replaced with high density concrete (220 lbs/ft^3) blocks in order to improve shielding near the entrance slits to the momentum analysis magnet.

Replacement of several other wall blocks with high density blocks already on hand will be done as access to experimental areas allows in the next year. The blocks to be replaced are at distributed locations throughout the experimental hall where geometrical considerations indicate additional shielding would reduce background at detector locations.