can be accelerated to about 300 MeV. Since no user has yet requested this beam, we may have to develop this beam just for the sheer pleasure of doing it!

1) 1985 IUCF Scientific and Technical Report, p. 116.
2) 1985 IUCF Scientific and Technical Report, p. 112.
3) 1985 IUCF Scientific and Technical Report, p. 118.
4) 1984 IUCF Scientific and Technical Report, p. 176.
5) 1984 IUCF Scientific and Technical Report, p. 140.

LABORATORY DEVELOPMENT

Accelerator Improvements - J. Hicks, J. Taylor and D. L. Friesel

During the last year, much of the effort which in the past was applied to major improvements and retrofitting of the accelerators and beam lines, was put into construction of the Dual Spectrometer. As a consequence, attention was limited this year to the most urgently needed cyclotron improvements.

A considerable part of the new work took place in Beam Line 1 and in the Injector. The beam chopper low level electronics was upgraded by the addition of standard ALC and autotune modules similar to those used in other rf systems. This change minimizes time loss in troubleshooting and repairing. For the f buncher, a low-level electronics back-up chassis was brought up-to-date and debugged to accomplish the same purpose. Use of a new modular system here will await a major rebuilding of all of the buncher systems planned for the future.

Major improvements were made in the Injector rf system. These include installation of a new input stage which requires less drive power and provides a better VSWR; conversion of the 4CW800B drive stage to modular form to provide fast replacement, ease of repair, and circuit optimization on the bench; and installation of new plate, screen and grid bias power supplies for the 4CW800B. In addition, interstage tuning was added between driver and final stages to improve the output frequency characteristic over the complete system operating range. As a result of these improvements, which are discussed in more detail in the following section, we hope to achieve high enough dee voltage to operate at a smaller inflection radius and thus accelerate 200-MeV protons with an ion source terminal voltage in the neighborhood of 550 kV. This would lead to a major improvement in operating reliability because of beam induced voltage holding problems of the accelerator column in Terminal B above 550 kV.

Also, the rf signal distribution system was improved last year. The system was expanded to provide more rf signals for a variety of needs (both for operations and for experiments), and a sytematic way of distributing the following frequencies: f/2, f/3, f/3(n+1), 2f and Harmonic Generator. Some of these are not now in use, but will be needed in the future. A separate "signal interface" has been installed to make all of these signals readily available to experimenters. Further improvements are planned for the coming year to take advantage of new frequencies as they become available.

Another Injector improvement involves the sector magnet system. The main magnet power supply (Alpha 20) has in the past obtained its feedback signal for current stabilization from a water cooled shunt which, in addition to having less than optimum stability, caused a 5 volt loss in output voltage. This shunt was recently replaced by a Hazemeyer current transductor (DCCT) which should not only provide improved stability but also, by removing the output voltage penalty, allow a 10% increase in output current. With this improvement, it may no longer be necessary to use booster coils wrapped around the sector magnet return yokes when operating at the highest magnetic fields. This will simplify cyclotron operation and also liberate a valuable power supply (Alpha 5) for other uses.

Rebuilding the Injector rf System - J. Redding, M. Ball, K. Berglund, M. Cary, D. Jenner, and A. Pei

After the summer shutdown for spectrometer construction, the cyclotron maintenance records showed that there had been an unusual amount of unscheduled maintenance attributable to component failures in the Injector rf systems. The failures were the result of a design problem that had been previously investigated, and partially solved. Material had been purchased for the required modifications but due to time limitations and personnel changes, the improvements had been postponed.

In the original design, the driver tube, an Eimac 4CW800 water cooled tetrode, was operated with the plate grounded and the cathode at a negative potential of -2700 volts. To provide the required grid bias of -50 volts, from the cathode to grid, a floating voltage regulator circuit was connected is series with the cathode and the -2700 volt source.

During start-up of the rf systems or at times when high current was drawn through the tube, the floating cathode bias network would fail. If the failure mode was a "short", excessive current would destroy the tube, if the cyclotron operator did not intervene in time. If the failure was an "open", then the lack of Injector rf voltage would prevent normal injector operation, but not destroy the driver tube.

The mechanical design was awkward and an unreasonable amount of time was necessary to replace the tube. The bias box operated at a potential that was hazardous to technicians engaged in maintenance. Injector modification was definitely required.

During the summer, a method of reconfiguring the driver biasing had been installed and partially tested. The key features of the new design were the grounding of the driver cathode, a grid bias supply, and a screen supply. In addition to the elimination of the bias box, the incorporation of interstage tuning between the driver tube and the final amplifier was proposed to allow greater injector dee voltage.

In October, the decision was made to convert the system during six weeks prior to the Christmas shutdown. The design was then reviewed and refined by the use of SPICE, a circuit analysis program on the VAX computer. A prototype was assembled and tested which allowed verification of the design calculations.

The new design incorporates a feature of a removable driver tube assembly. The driver tube and its associated circuitry are mounted on a bolt-in plate. The plate is used as a test fixture for tube testing and prealignment of the input network for flat frequency response. The pretested assembly allows rapid replacement during failure or routine replacement.

The driver input network design is a Chebychev low-pass filter optimized for impedance transformation and provides saturated operation of the 4CW800 at less than 6 watts drive. The input standing wave ratio to the input of the driver is less than 2:1 over the 25MHz to 35MHz operating range.

This is a significant improvement from the original configuration that required 30 watts drive and had a 5:1 s.w.r.

Preliminary testing showed that the design values of 25 kV at 25.6 MHz and 50 kV at 35 MHz were easily obtained. As the injector internal resonator construction was designed for 50 kV, it is probable that these limits should be tested before continuous operation above is begun. During testing, the new driver configuration seems to have allowed the fracture of a cathode resistor on the power amplifier stage due to overdriving the final amplifier tube. At that time, the rf voltage exceeded the design values. It is now possible to drive the power output tubes to their maximum rating.

Several design objectives that were desired were not obtained. The future improvements for the Injector rf system are the replacement of the 4CW800 with a less expensive, more reliable, and more powerful tube. The tube replacement will also allow the broadbanding of the system.

Broadbanding eliminates the necessity of the operator having to tune the driver stage after a frequency change. At that time, the filament supply of the power stage will be changed from a.c. to d.c. removing the remaining source of 60 hz noise in the injector system.

Main Stage Cryo Pump Improvements - J. Self and O. Dermois

Significant improvements were also made to the cyclotron vacuum pumping system this year. Four CTI manufactured 20" diameter cryopumps were mounted on the main cyclotron vacuum chambers in 1979, but were not routinely used. The main reason for this was that the refrigerator motor would stall after several days of continuous operation, causing the pump to warm up. This is often referred to as pump "ratcheting". This was originally thought to be caused by contaminates in the helium gas, which freeze out in the displacers, increasing friction and eventually stalling the motor. Extensive time and effort were expended in cleaning the helium system at CTI's recommendation, but only a slight improvement in the performance of these pumps was realized.

Two other problems were recently recognized as the cause of the pump ratcheting which prevented their use. The first one was that the fit of the displacer seals to the cylinder wall was critical. If the seals were too tight, the resulting excess friction caused the pump motor to stall (ratchet). If they were too loose, helium blow-by resulted in a reduction of the pump capacity. Experience has now shown that the displacers require cleaning and retrofitting about every 6000 hours of operation. The second, and dominant, problem turned out to be the deterioration of the permanent magnet AC motors themselves. The magnet's strength decreases over a period of time due to vibration, heat, and interaction with the cyclotron magnetic field. This was overcome by replacing all pump motors with new ones. The result of these improvements was that the cryodynes remained cold and pumping on themselves for weeks at a time without ratcheting.

Another problem was encountered when these pumps were opened to the main cyclotron. The pumps reduced the vacuum in the cyclotron rf valleys (east and west valleys) by about a factor of two, and significantly reduced the amount of rf sparking experienced during operations. However, during operation, the pumps slowly warmed up (over a few hour period) to the point that they would no longer improve the cyclotron vacuum. It became apparent that the capacity of these pumps was less than required for our pumping needs. The manufacturer of these cryodynes suggested replacing our 50 W refrigerators with larger 70 W pumps at a cost of about $50K. However, after careful study, we conceived and executed an alternate means of making the existing pumps meet our requirements.

These older cryopumps have a pumping speed of nearly 10,000 l/s for nitrogen, but are equipped with a refrigerator having a too small 80°K load capacity. For the 20" diameter frontal surface area of the 80° shield, an absorption coefficient of 0.9, and a black body radiation source, the 300°K radiation heat load is 78 W. The side and bottom wall of the 80°K shield typically receives another 9 W, assuming the walls are fresh aluminum surfaces. Over the course of time, an oxide layer grows over the aluminum surface and the 80°K surface collects impurities. This approximately doubles the heat collected by the side wall, and causes the pumps to fail after a short period of operation. The only way to improve the operation of the pumps was to reduce the heat load. This was done by shielding the entrance of the pump by a gold-plated copper aperture, which covered about one half the surface area. The aperture, which is in good thermal contact with the pumpwall, was designed, however, to reduce the initial pumping speed by less than 30%. Thus, the pumps, with the original 50 W refrigerators, now work continuously for periods of one to two months. The resulting reliability of these upper cryopumps has now allowed us to operate completely with the two 36" diffusion pumps in the north and south valleys, and the two small upper cryopumps in the east and west valleys. The operation of the high maintenance and unreliable lower cryodyne system is no longer required. This system is maintained in a ready condition, however, to improve the cyclotron vacuum even further for partially stripped ion acceleration, and as a backup system should such ever be required.

New Cooling Tower - C. Foster

As part of the Cooler building addition, a new evaporative-cooling tower with sufficient capacity to cool the presently operating cyclotrons and experimental equipment; the electron-cooled storage ring, now under construction, and associated experimental equipment; and the proposed tripler cyclotron was built. This removes dependence upon the old cooling tower, which is located on the roof of the accelerator building. This old tower will be used to provide cooling for air conditioning equipment in the accelerator building only. It may then be turned off and drained in the winter to prevent potentially dangerous ice-loading of the roof of the accelerator building.

In addition, the new cooling tower was designed with the goal of maintaining the temperature of the water to the cyclotron heat exchangers stable to within ± 0.5 degrees Farenheit. This goal has been reached. Such temperature stability contributes to the long term stability of cyclotron operation.

There have been several failures of the new cooling tower in the last year as this new system is debugged. A chip in the computer-control system has failed three times when the building has had spontaneous power outages. This results in loss of automatic control and, therefore, no accurate temperature regulation. A control valve in the temperature regulation system jammed open on one occasion resulting in a low temperature excursion. Failure of an electrical component providing power to one of the tower pumps caused a dangerously high temperature excursion. Additional monitors and alarms of flow and pressure have been and are being installed to alert cyclotron operators more quickly to the potential for such temperature excursions.

There is cavitation at the suction side of the circulating pumps for this system which is worse for the north pump than for the south pump. Such cavitation causes vibration which is believed to have contributed to the failure of the motor-to-pump coupling on the north pump and the weakening of the coupling on the south pump. An engineering study of the cause of this cavitation is underway.

In preparation of the new cooling tower for use, it was necessary for IUCF personnel to carefully install leaf screens and covers enclosing the entire tower, clean the tower of mud and leaves, build a device for removal of large water filtration screens, clean these screens and provide inspection ports in the lid of the pump basin at the tower base. As a result of this work, the tower and screens have remained clean for more than four months and a valve bypassing flow from the tower to the sump was properly adjusted.

While there have been and continue to be problems with this tower, it has run for long periods (months) with better regulation than the previous tower. It is still under warranty and work continues to improve its reliability and ease of operation.

Stripper Loop Development - Dennis Friesel

The operation of the stripper loop, which began last year with an H_2^+ beam, continued this year with a newly developed H^- ion beam. The stripper loop, shown in Fig. 7, is a small isochronous storage ring for the DC beam from the 0.62 MeV ion source terminal and is used to vary the pulse structure of the beams from the cyclotrons over a wide range (1.5 to 10 μsec) while simultaneously increasing the beam brightness. The DC beam from the terminal is accumulated and stored in the ring so that beam bursts of high intensity can be pulse extracted from the device and injected into the cyclotrons for acceleration. In this way, beams with long off periods between bunches can have reasonably high average beam intensities. This capability is particularly useful for the intermediate energy neutron time-of-flight experiments at IUCF, and may also have application for the injection of cyclotron beams into the new cooler ring. A detailed description of the ring, its operating parameters, and the results of the initial tests with the H_2^+ ion beam were previously reported.[1,2,3] The results of the H^- beam studies with the stripper loop, which are discussed below, were also recently published.[4]

When an H_2^+ beam is injected into the stripper loop, as during the initial development work last year, the resulting circulating proton beam energy is half the injection energy. This limits the maximum energy to which the cyclotrons can further accelerate the beam to about 80 MeV. In the recent development runs, an H^- beam from ion source terminal B was injected into the stripper loop using both inflection magnets #1 and #2, and stripped to protons having the same energy. The duoplasmatron source in terminal B was modified to deliver a modest 25 μA of H^- with an emittance of about 3πmm-mr. Because of its small emittance, however, over

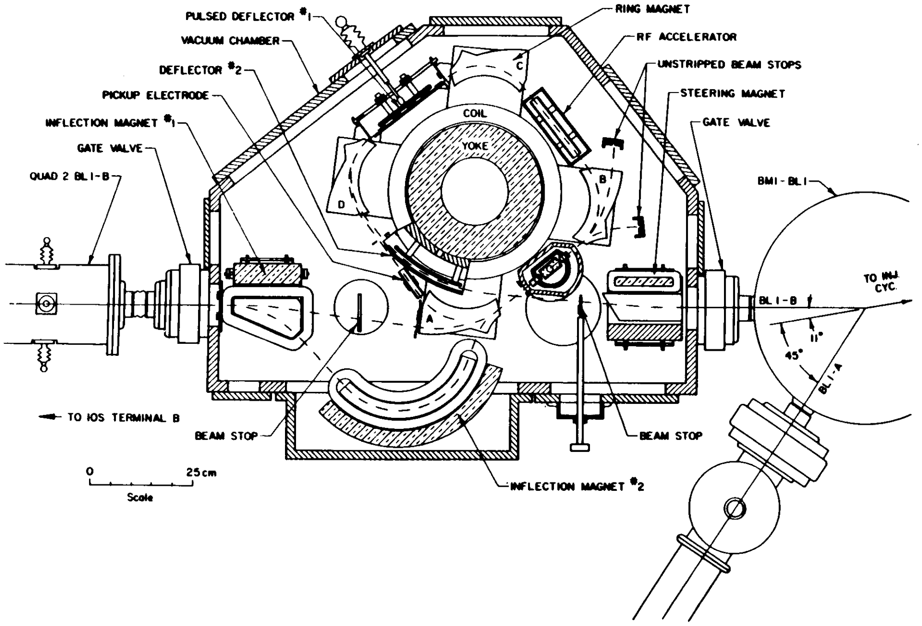

Figure 7. Plan view of the Stripper Loop

90% of this beam was transmitted from the source into the stripper loop. Also, the polarity of the normally positive 0.6 MV high voltage power supply for the terminal was temporarily reversed to accelerate the beam for injection. The resulting maximum circulating proton beam energy in the ring was 0.62 MeV, which permitted the acceleration of the beam extracted from the ring to 200 MeV.

An important parameter determining the brightness gain possible with the stripper loop is the H^- to H^+ stripping cross section. Hence, the fraction of the H^- beam converted to both H_0 and H^+ was measured as a function of the areal density of the vapor in the stripping canal located between magnet sectors A and B. From these data, which were obtained at incident H^- beam energies of 0.37, 0.56, and 0.62 MeV, the cross section for the conversion to any other charge state was determined to be about 1.3 times the measured conversion of the $H_2{}^+$ ions reported last year. This result is in reasonable agreement with the literature. The proton production rate from the stripping of the H^- beam, however, was observed to be larger than expected and somewhat independent of energy. Plots of the H^- beam are shown in Figure 8 and are nearly identical to similar plots obtained at the two lower energies. A possible explanation for the observed differences between these and other published measurements of this reaction is the nature of the stripping vapor used in our measurements. A commercially available long molecular fluorocarbon chain (C_7F_{14}) was used in the stripper loop. It may be that the probability of a direct conversion of an H^- ion to an H^+ ion during a single interaction with a large molecule is quite large. Nevertheless, the effective H^- to H^+ stripping

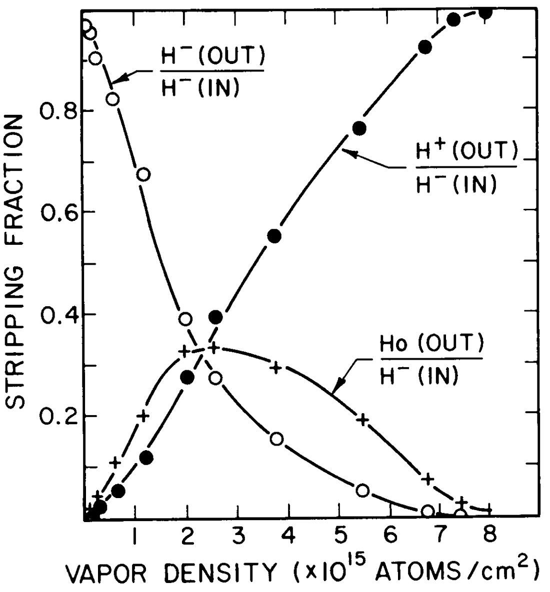

Figure 8. Stripping ratios versus vapor density.

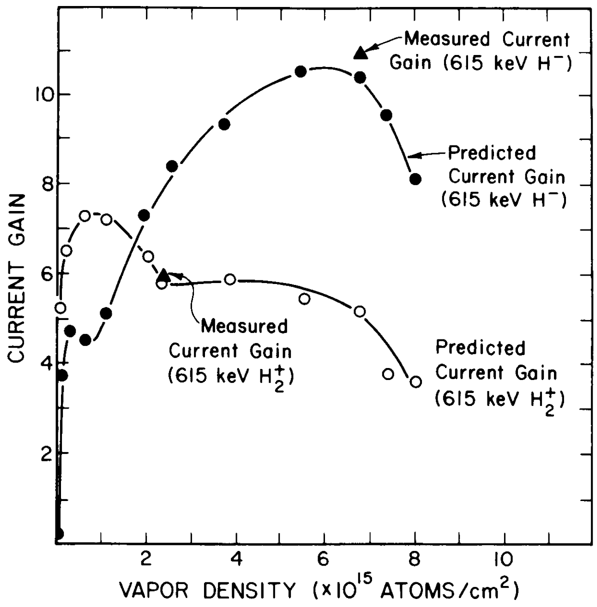

Figure 9. Predicted and measured intensity gain versus vapor density.

cross section was determined to be 1.6 x 10^{16} cm^2, which is the same as that measured for the conversion of an H_2^+ ion to a proton and a neutral hydrogen atom. The brightness gain of the stripper loop for an incident 0.62-MeV H^- beam was calculated from these measurements and is plotted in Figure 9 as a function of the density of the stripping vapor. Similar predictions for an incident H_2^+ beam of the same energy are also plotted in this figure for comparison.

Considerable effort was required to find the correct inflection trajectory necessary to obtain a circulating proton beam in the ring with the H^-beam. The strength of the ring magnet radial harmonic coils had to be increased and adjustments to the position of inflection magnet #2 were necessary before circulating 0.37-, 0.57- and 0.62-MeV proton beams were achieved. Because of the relatively low output of the H^- source, the maximum stored intensity in the ring was limited to about 0.4 mA. Attempts to increase the circulating beam intensity by increasing the accumulation time beyond 10 μsec were unsuccessful because the transverse beam instability observed previously at lower energies during the H_2^+ development work was encountered here as well. From our previous work, this instability is known not to be caused by a space charge depression of the ring tune. The cause of the instability, which is energy and intensity dependent, remains a mystery.

The beam pulse extracted from the stripper loop was bunched with a f/2 sub-harmonic buncher and injected into the cyclotrons for further acceleration. A plot of the intensity loss profile for a 180 MeV proton beam with a pulse period of 2.5 μsec using the stripper loop with H^- injection was shown in Fig. 5. The transmission of an 80 MeV proton beam with a pulse period of 2.4 μsec using the stripper loop injected with an H_2^+ beam is also shown for comparison. When intensity differences in the ion sources are taken into account, the maximum brightness gain obtained with the H^- beam was nearly 12, which agrees well with the predictions shown in Fig. 9. The measured variation of the brightness gain with the stripping vapor density was also found to be in reasonable agreement with the calculations. The transmission of the beams extracted from the stripper loop, however, is poorer than for the beams which are sub-harmonically pulse-selected using the chopper in beam line 1 to throw away the unwanted beam bursts. A profile for a 135-MeV proton beam pulse-selected 1:4 this way (0.13 μsec pulse period) was also plotted in Fig. 5 for comparison. Independent of the intensity limit imposed on the stripper loop for long accumulation times, a more practical limit to the brightness gains achieved at pulse periods useful for most experimenters (1 to 5 μsec) is the energy spread of the beam extracted from the ring caused by the repetitive passage of the circulating beam through the stripping vapor. The transmission of this beam through the cyclotrons is reduced to about 1% by the small velocity acceptance of the buncher sytem (0.1%) and the limited phase acceptance of the injector cyclotron. Nevertheless, peak beam intensities of over 12 μA were achieved with the stripper loop, which is about twice the maximum beam intensity transmitted through the cyclotrons with the natural pulse structure. Average beam intensities of over 100 nA are possible with pulse periods of about 2 μsec, which is a useful intensity for many experiments. The operation of the stripper loop for experiment has been demonstrated, as reported earlier.[5] While the development of the stripper loop will continue at a reduced pace to learn the cause of the transverse beam instability and increase the circulating beam intensity, it is considered an operational system available for general use.

1) 1984 IUCF Scientific and Technical Report, p. 196.

2) D.L. Friesel, R.E. Pollock, T. Ellison, and W.P. Jones, Proc. 10th Int'l. Conf. on Cyclotrons and Their Applications, IEEE No. 84CH1996-3, East Lansing, MI, p. 207 (1984).

3) D.L. Friesel, R.E. Pollock, T. Ellison, and W.P. Jones, Nucl. Instr. & Methods in Physics Research B10/B11, 864 (1985).

4) D.L. Friesel, R.E. Pollock, T. Ellison, and W.P. Jones, IEEE Trans. Nucl. Sci., NS-32, 2691 (1985).

5) 1985 IUCF Scientific and Technical Report, (Accelerator Performance), p. 103.

Ion Sources - H. Petri

The polarized ion source operated approximately 393 shifts in 1985. Polarized protons were run 74% of this time, polarized deuterons the remaining 26%. This is somewhat less running than in 1984 and is due to two six-week shutdowns which occurred in the latter part of the year. Some problems with tuning the ionizer were overcome this year. It was found that by lowering the E3 electrode in the electron gun .060 inches one could again tune the ionizer as we had in the past. Interaction between E2 and E3 no longer occurs. At times the source has been able to deliver 9 microamps of beam albeit the average intensity is still about 6 microamps. New filament leads a` la Texas A & M were made which brings the filament within .025 inches of the bottom of the E1 electrode. This also seems to have improved the tuning of the ionizer.

An improvement to the faraday cage was made with the replacement of the old floor. The new floor has all edges soldered over their entire length. This prevents leaking oil from getting under the floor which makes cleanup impossible. The new floor is very easy to keep clean.

Improvements which we will try to implement in 1986 are as follows. A new isolation valve in front of the ion pump will be installed. The old valve is beginning to malfunction and has already caused some downtime. A similar valve in front of the titanium sublimation pump will also be replaced. In addition the Ti-ball pump itself may be replaced with an 8-inch cryopump. This Ti-ball pump is not very useful and is troublesome. The cryopump will be pumping the electrostatic mirror region below the ionizer. This should enable us to eliminate a liquid nitrogen cold trap located in the beam line after the electrostatic mirror. Currently we must stop operation in order to fill this trap every 12 hours. If possible, we intend to replace the now aging and leaky belt drive mechanical pump which backs the diffusion pumps with a new direct drive pump.

Further improvements, if time permits, will include the redesign of the E1 and E2 electrodes and the replacement of the E1 and E3 power supply with commercial units. The E2 supply has already been replaced.

Dissociator bottle cooling was not attempted in 1985; perhaps in 1986.

The H^- beam from the duoplasmatron was used quite frequently during the early part of 1985 for stripper loop development. The construction of an off-line test facility was considered a possibility but was not necessary. Without too much difficulty the intensity was raised from 15 to 30 microamps. This was accomplished by increasing the size of the extraction aperture from .025 to .040 inches.

A device was constructed using a small hole aperture plate and a wire scanner in order to measure the phase space emittance of beams from the duoplasmatron. The H^+ beam measured 5π mm mrad $(\text{Mev})^{1/2}$ while the H^- beam measured 2.5π mm mrad $(\text{Mev})^{1/2}$. These numbers are in accord with the manufacturer's specifications.

During the second half of 1985 an unforeseen demand for beams from the hot filament PIG source developed. Reliability problems appeared and these problems were addressed. In particular, a set of vertical steerer plates located in the extraction box were shorting out because their insulators were being plated with copper during operation. Sometimes these insulators lasted only 24 hours. A careful analysis of the extracted beam trajectories showed that, while extracting doubly charged helium, the high intensity singly charged component of the beam was not being properly dumped. The singly charged beam was sputtering copper from a window frame through which the doubly charged beam was extracted. To remedy this problem a new beam dump was designed, the window was removed, and finally the vertical steerer was removed from the extraction box and installed about 4 inches downstream. Operation with the new system has been quite reliable and no further plating problems have occurred.

An attempt to produce high charge states of ^{14}N with the PIG source was made. The most intense beam we could produce was 0.5-1.0 microamp of charge +3. No higher charge states were observed. Clearly if we want these beams we will have to develop a cold cathode PIG source.

If possible, we would like to complete construction of a second spare hot filament PIG source in 1986.

Cyclotron Beam Diagnostics Development - T. Ellison

A. Beam Phase Probe:

A nondestructive beam-phase probe was installed and tested this year. This system provides an isolated rf signal phase-locked to the beam and an analog signal proportional to the beam current with a 100 Hz bandwidth. This system fucntions on the second harmonic of the cyclotron rf frequency, about 60 MHz, and uses a vector voltmeter as a phase detector. There are two important sources of error in this system:

1) Up to 30 nV of rf noise from the cyclotron rf systems is picked up on the wall gap monitor in beam line 3. This signal is equivelent in magnitude to the signal obtained from a 0.8 nA beam. The maximum possible error due to this coherent noise is shown in Figure 10 (solid curve).

2) The amplifier noise from the wall gap monitor causes a large amount of phase noise in the output rf signal for very low beam currents due to the relatively high IF bandwidth of the vector voltmeter. The peak-to-peak phase noise due to this incoherent noise is also shown in Figure 10 (open circles).

The error produced by these two noise sources is roughly equivalent and varies inversely with the beam current. In addition, there is a small amount of longterm drift, plotted with "X's" in Figure 10. This system is now being used by some experimentalists as a beam timing signal and for accelerator studies.

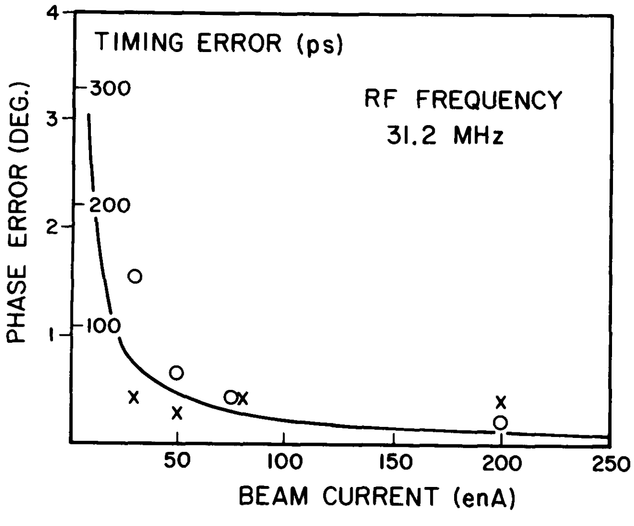

Figure 10. Measurement errors in the wall gap monitor versus beam intensity. The solid curve represents the error due to 30 nv of rf noise; the open circles represent the error due to noise from the wall gap monitor's amplifier; and the x's represent errors due to long term drift.

B. Studies of the Line Frequency-Related Beam Intensity Modulation:

Investigations into the cause of the line frequency-related beam intensity modulation were not able to pinpoint a specific device as the cause. However, all rf devices and many other devices in the cyclotrons have an influence on this intensity modulation. It may be that the modulation is a result of a small amount of noise on many different devices. Figure 11 shows a picture of the time-averaged beam current from the cyclotron with two slightly different settings of the buncher phase controller. As can be seen, a small change in the phase of this rf device results in a 180° phase change in the beam intensity

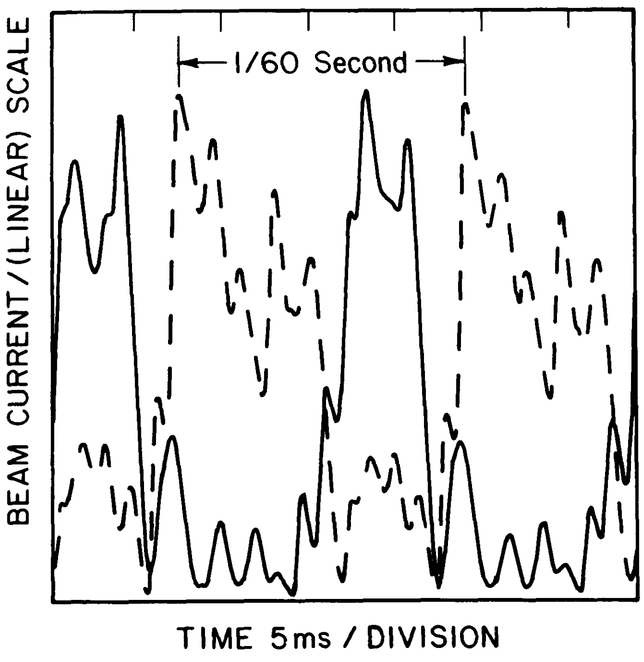

Figure 11. Time averaged beam current. The two curves are obtained with slightly different settings of the buncher's phase.

modulation with respect to the line voltage. An intermediate setting of the buncher phase control results in a modulation of twice the frequency. In the next year, a system for modulating the buncher phase at the line frequency will be implemented to see whether this system can cancel out the modulation and increase the average beam current.

Control System Software - J.C. Collins

After three years of preparation and four months of intensive testing, a PDP-11/44 has replaced the Xerox Data systems Sigma-2 as the cyclotron control computer. Software development on the 11/44 began in July, 1981, when the computer was first installed; summaries of development progress may be found in previous Annual Reports. In December, 1984, development had advanced sufficiently that hardware cound be switched from the Sigma-2 to the 11/44 at the beginning of every cyclotron shutdown period to test actual cyclotron operator stations and the DIO control bus. A switch back to the Sigma-2 then had to be made before cyclotron startup. By mid-February it was possible to switch the DIO and three operator stations between computers in less than one hour, an important number since it meant we could consider the Sigma-2 a "hot backup" for the 11/44. Also by then, readout and control on all cyclotron devices had been demonstrated. In early March the 11/44 was used as control computer for the first time in an energy change and a one-shift experimental run in the hot cell. In mid March, what proved to be the last computer switch occurred: the 11/44 has been the control computer ever since.

During the following months, a number of bugs and "undocumented features" in the operational characteristics of the new computer were found and corrected, changed or documented. Some bugs still remain; happily their frequency of occurrence is inversely proportional to the length of service of the 11/44. Of particular trouble were the SEEK programs designed to drive devices to predefined positions, because final tests required connection to real devices and insufficient time was scheduled for that purpose. With the 11/44 online and urgent bugs fixed, it was possible to finish some subsystems deferred earlier as not critical for operations, most notably, data logging. Some control algorithms were also reworked to make them more sophisticated. As of November, 1985, the functionality of the old Sigma-2 has become a true subset of that of the 11/44. IUCF Internal Report #85-8 presents many of the details of the new control system and its operation.

The cyclotron operators were able to use the new system from the beginning with no retraining necessary, thereby fulfilling one of the design goals of the system. It is safe to say that the new computer has yet to cause a delay to the operations schedule of more than an hour or so. After retaining the Sigma-2 for some months as a safety precaution, we sold that machine to a computer dealer. While the emptied space in the control room was rapidly filled with a desk and tape racks, the ambient control room noise level is noticeably lower (also helped by departure of the Harris A computer).

While the basic control system is complete and the original goals for the computer replacement have been met, further effort will be required to fully utilize the 11/44. Crude measurements show that the computer is about 85% idle with three operator displays running; comparable measurements on the Sigma-2 had shown only about 5% idle time. We are developing a better database from which to initialize the cyclotrons for particle and energy changes. Tuning algorithms may now be developed in those locations where computer accessible beam sensors are available. Because higher level languages are now supported, interested operators are beginning to write useful programs. DECNET runnning over Ethernet has been installed for communications with the laboratory VAXs, in principle, giving data acquisition programs access to all control functions. In practice, of course, such access will be limited to functions specifically requested by users. Users are welcome to submit any such requests. Remote spin flip control from VAXs will be available early in 1986.

EXPERIMENTAL FACILITIES DEVELOPMENT

Facilities in Operation - C. Foster

1. Existing Beamlines

Considerable effort was expended in 1985 on maintenance and improvement of existing beamlines. Leaking gate valves, slit assemblies and vacuum gauges were replaced or repaired in order to improve beamline vacuum. In addition, vacuum leaks in forelines, magnets and beamline hardware were found and fixed. Electrically operated air valves to actuators used on beam stops and viewers were replaced or repaired. Newly designed single-shaft actuators were installed in many locations on the beamlines. These actuators were designed, constructed and assembled in house. Solenoids were replaced on many beamline actuators to accommodate a change from 110 VAC to 24 VDC operation.

In beamline 7 to the polarized neutron facility, the beamline was reworked to accommodate the installation of a superconducting beam precession solenoid for use in the charge symmetry breaking experiment. Beamline modifications were accomplished on beamline 4 and the beamlines to the 64 inch scattering chamber and QDDM spectrometer to insert high energy beam polarimeters. One of these polarimeters was moved several times during the year to serve experiments in different facilities.

Two of the three Lambertson magnets necessary for beam splitting were installed in beamline 4 and the third was assembled for field studies. A hexapole magnet was moved upstream to a location just before the momentum analyzing magnet to provide space just downstream of that magnet for the RF portion of the splitter and for a superconducting beam precession solenoid. These latter devices were not installed in 1985. An additional beamline quadrupole magnet was installed in beamline 4 as required for proper transport of beam to the swinger, double spectrometer, or Cooler after the modifications described above and the installation of the 30 degree bending magnet, for the double spectrometer, in the beam swinger beamline.

2. New Beamlines

At the end of the year, installation of beamline 8, to the double spectrometer, was about two thirds complete. The old QDDM spectrometer was modified and moved into position as a bending magnet on beamline 8, the upstream bending magnet aligned, all quadrupole magnets, steerers and vacuum hardware had been installed on the beamline upstream of the penetration block but awaited power and controls, and the neutron shutter had been installed in the