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PROGRESS REPORT FOR OCTOBER 1947, PHYSICS SECTION

W. M. Brobeck, J.G. Hamilton, M.Martin
L.W.Alvarez, R.L.Thornton, R.Sorber, & B.J. Moyer

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UNIVERSITY OF CALIFORNIA RADIATION LABORATORY
PROGRESS REPORT FOR . OCTOBER 1947, PHYSICS SECTION

1. 184-Inch Cyclotron Program

W. M. Brobeck

Operation: Approximately 60 percent of the time during the month was spent on operation for physics and chemistry research, while about 22 percent was spent testing and improving the deflector system and ten percent on the correction of various troubles. The deflected beam current has been measured and found to be 2×10^{-9} amperes at the end of the "snout" port about one foot from the tank wall. 85 percent of the current appears to be concentrated in an area of about 7 sq. inches. This intensity and concentration is sufficient for much experimental work.

Troubles with the machine included a leak in the condenser rotor gaskets which is expected to be the last for it is hoped that this recurrent trouble is finally understood and corrected. A newly installed vacuum line was apparently the source of a considerable quantity of sand which got into the piping and required two days to clean out but caused no permanent damage.

Development: The permanent gas supply system for the ion source has been put into operation permitting the use of heavy water rather than the more expensive tank deuterium. Progress is being made on experimental work on the permanent deflector power supply. A magnet for re-focussing the deflected beam is being designed. Working drawings of the tanks for the proton conversion are complete and some other detail parts have been ordered. There are now six engineers and three or four draftsmen working on this job. The order has been placed to complete the concrete shielding wall around the cyclotron.

2. 60-inch Cyclotron Program

J. G. Hamilton

A number of difficulties were encountered during the month of October with the 60 inch cyclotron. In the main, they may be divided into two different categories. The first group of difficulties were associated with a number of improvements that were added at the time the burned out east dee stem liner was replaced in July. The changes were made in the hope of both making operation more efficient and reducing the radiation hazards. As things turned out, it could be said that we had to overcome the improvements. The most troublesome of these was the new deflector insulator system which made possible the changing of these insulators by means of remote control devices, since this is one of the most intensely radioactive areas of the entire instrument. In spite of many modifications of this system, the insulators failed with discouraging regularity and increasing frequency so that during this month the tank had to be let down to air to replace the deflector insulator on five occasions. We finally were forced to abandon this new and highly desirable arrangement from the point of view of radiation protection and revert, at least temporarily, back to our previous system so as to regain a reasonable operating efficiency. One of the other problems that arose was the setting of the grounding spiders at such a point as to permit the dees to be placed in an exactly central position within the vacuum chamber. Through some error in frequency determination, this was not done quite correctly with the result that the instrument was never quite in its most efficient adjustment. During this month, several days were taken off to very carefully set each dee at the proper frequency and then to retune the main oscillator for maximum efficiency. This was done successfully as evidenced by the regain of our former

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high alpha beam currents which had not been attainable since the shutdown in July.

The second consideration has been the ever increasing number of short bombardments using various specialized targets and attachments to the cyclotron as well as the necessity for using protons, deuterons, and alpha particles in rapid succession. The use of different types of particles necessitates the employment of a variety of ion sources and specific adjustments which are characteristic for the type of particles to be accelerated. These factors all contributed to interruption of operation. As a result of the many problems posed by the demands made upon us, we are gradually learning where the weak spots are and how to meet them.

To sum up our present situation as of the end of the month, most of the former efficiency of the instrument has been regained, the deflector difficulties, too, have been at least surmounted partially, and we have learned how to make rapid changes in the demand for different types of particle bombardments that are made upon us with ever increasing frequency.

The major bombardments for the month were deuteron bombardment of molybdenum, iron, and thulium and the proton bombardment of lithium for the Clinton Laboratories at Oak Ridge, the alpha particle bombardment of bismuth for Doctor Segrè, deuteron bombardment of lead for Doctor Seaborg, and the alpha particle bombardment of cadmium for Doctor Hamilton. There were a number of miscellaneous shorter bombardments which appear in the bombardment summary on the following page.

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Project Bombardments

Dr. G. T. Seaborg

Sc	+	d	0.5 hrs.
Y	+	d	3.0 hrs.
Pb	+	d	20.0 hrs.
La	+	d	1.5 hrs.
Au	+	α	7.0 hrs.

Dr. E. Segrè

Bi	+	α	10.0 hrs.
----	---	----------	-----------

Dr. J. G. Hamilton

Cd	+	α	14.5 hrs.
----	---	----------	-----------

Dr. B. Moyer

Ni ⁶⁴	+	Fast Neutrons(Be + d)	6.0 hrs.
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Clinton Laboratories

Mo	+	d	61.0 hrs.
Tm	+	d	1.0 hrs.
Li	+	P	143.0 hrs.

Non-Project Bombardments

Dr. G. T. Seaborg

Pt	+	d	0.5 hrs.
----	---	---	----------

Dr. J. G. Hamilton

Cholesterol	+	d	4.0 hrs.
-------------	---	---	----------

Dr. J. H. Lawrence

B ₂ O ₃	+	P	4.0 hrs.
B ₂ O ₃	+	d	3.0 hrs.
NaCl	+	d	4.5 hrs.

N. A. A.

21.5 hrs.

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3. Synchrotron Program

M. Martin

The cementing of the copper foil onto the plastic rings and the scribing to break up large eddy loops have been completed. The addition of holes for introduction of the r.f. tuning loops resulted in some added leaks through the plastic. The ring has been re-impregnated locally and these leaks eliminated. The re-impregnated area is now being cured by radiant heating. A vacuum of 0.2 microns was obtained with the plastic uncured and without the use of liquid air in the traps.

Additional magnet parts have been received during the past month. The following table summarizes the parts which are still needed to complete the magnet:

Slabs -	10
End Fillers -	4
Pole Base Wedges -	6
Flux Bars -	18

The percentage of completion of the various components follows:

Magnet Assembly	55%
Control Rack	80%
Transformer Yard	80%
Impregnation & Testing Wedges	95%
Magnet Excitation	85%

The entire job is believed to be about 90% complete.

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4. Linear Accelerator Program

L. W. Alvarez

Van de Graaff. The re-installation of the differential pumping system increased somewhat the available proton beam and decreased markedly the x-ray background from the machine. However, the proton beam current is still low, of the order of one microampere, due principally to over-focusing in the accelerating tube when the ion source is adjusted for maximum current input into the tube. Steps are being taken to correct this difficulty by increasing the range of adjustment of the ion source potentials. If necessary, a change of geometry will be made at the point where the beam enters the accelerating tube.

Installation of the ion source pulsing system is just being completed and when it is operating properly it will reduce by a factor of 200 the average load on the accelerating tube for a given injection current.

The new alumina drying system through which the nitrogen in the tank can be recirculated to take out moisture is nearing completion. When completed it will eliminate the long period of evacuation required at present for drying after the tank has been open for work inside.

40' Tank. On October 17, a beam of 32 Mev protons was obtained in the linear accelerator. The beam current was approximately 10^{-15} amperes average or approximately 100 protons per 200 microseconds. The proton energy, as measured by their range in aluminum, was greater than 31.5 Mev and less than 32.5 Mev. 90 percent grids were used and the cavity was excited by 21 Baker oscillators, with three modified SCR-268 oscillators for pre-excitation. On the 18th of October, the beam was again obtained, with approximately the same current.

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Since then, the linear accelerator has been opened in order to improve conditions before the next run. Silver-plated shims have been installed in the drift tube ends in an attempt to increase Q . Five more Baker oscillators have been installed so that the operating voltages of the oscillators will be lower and hence fewer tube failures should occur.

Sample 95 percent open slat grids have been manufactured here and have been tested at 70 kilovolts d.c. with 140 kilovolts per centimeter field. An optical bench is being modified to permit accurate measurements of the transmission of these grids. These grids are not yet installed in the accelerator.

Test Section. At the end of last month, the short test cavity was dismantled to study more carefully than before what produces the losses in a cavity with drift tubes. Many experiments have led to the conclusion that at least in the test cavity, the losses were due to the bad contact between the drift tube ends which are screwed on, and the drift tubes proper. The Q of the cavity with ends screwed on the drift tubes as tightly as possible was 28,000; with the ends soldered on Q increased to 41,000. The Q of the cavity without drift tubes, corrected to the proper frequency, was 53,000. Experiments also indicated that a good silver plating job on the brass stems decreased the losses. This effect was worth approximately 4,000 in Q , although there is some uncertainty in this estimate since it is within experimental error.

The test cavity was then put back in operation with soldered drift tube ends and we were gratified to read voltages in the cavity which were higher than any we have seen under similar conditions before. We are now proceeding to build up the voltage, which will enable us to test grids in high fields.

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Magnetron. With the development of plans for the Bevatron and the decision to place the Linear Accelerator on an unexpanded operating basis as quickly as possible, general agreement has been reached that the magnetron will not be required as a driving source for the 40 foot section. It is anticipated that the modified BC-677 transmitters will meet the r.f. demands for some time. With this in mind, all work on the magnetron project has been suspended, with the exception of job orders already in the Engineering Division or released to the shop. It was agreed in the conference with Professor E.O. Lawrence that work of this nature would be finished at the Radiation Laboratory in order to avoid loss of effort already applied.

The future of the magnetron project has developed as follows:

- (1) The Office of Naval Research has expressed a desire to continue the work on the coaxial magnetron, since this constitutes basic microwave tube research. The two graduate students working part-time on this research problem will be transferred to the Office of Naval Research payroll at the Microwave Laboratory, Division of Electrical Engineering, and the test setup will be moved to a new location as soon as satisfactory arrangements can be made.
- (2) The 200 megacycle power magnetron, now ready for final assembly, has been placed on a storage and maintenance basis. No additional work charged to the Radiation Laboratory will be done except that necessary to avoid loss or deterioration. The Army Air Forces have expressed an interest in this tube and discussions are under way toward an eventual transfer of this project to a contract under this sponsor.

The coaxial magnetron, at this stage of the investigation, seems promising. A cold test model has been achieved which tunes over a 10-15 percent frequency range by means of paddles in the coax section. Mode separation

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between the inductively coupled π mode and other modes appears to be good - well over 5 percent. The unloaded Q of the cold test model is approximately 6,000, with a loaded Q under matched conditions of approximately 90. It would appear that the design offers considerable promise for a magnetron tunable over a wide range with good load characteristics.

5. Experimental Physics

Experiments with the 184-inch Cyclotron

R. L. Thornton

Introduction. As is usual, additional experimental work involving the cyclotron is reported under operations, chemistry and health physics. During the month a large fraction of the available time was devoted to experimental work on deflecting the ion beam.

Excitation Curves For Charged Particle Reactions. Preliminary results have been obtained on reactions with Mg leading to the formation of Na^{24} and F^{18} . The observations are in agreement with those previously reported for such reactions; namely, a sharp peak in the neighborhood of the threshold, followed by a slowly increasing cross-section towards high energies after the minimum.

Absolute Cross Section Measurements. Experiments are underway towards the determination of absolute cross-sections for a number of charged particle reactions using the deflected beam. No results are available at this time.

Search for Mesotrons. Recent theoretical papers have indicated that there is a possibility of observing mesotrons from the cyclotron. It is expected that the most favorable conditions will be experienced when alpha particles are used in the ion beam, since the contribution to the available energy from the

-10-

internal motion of the nucleons in the projectile will be greater than for deuterons.

A search has been made using photographic emulsion techniques and looking for negative mesotrons from targets under 400 Mev alpha particle bombardment. Plates were placed so as to receive negative mesotrons of energies less than about 10 Mev. Search for higher energy mesotrons and experiments in which the neutron background is reduced will require more elaborate apparatus than has been used to date.

No indication of mesotron production has been observed; however the experiments have not yet been of sufficient refinement to observe the small production predicted by theory.

Neutron-Proton Scattering. A total of 205 knock-on proton tracks have been observed in the cloud chamber in a continuation of the experiments reported previously. The second hundred tracks were measured under better conditions than those previously reported and are believed free of discrimination against any set of angles. Figures 1 and 2 show the angular distribution of these scattered protons in both laboratory and center of mass systems. The cloud chamber data continues to suggest that non-exchange forces are somewhat stronger than exchange forces.

Plans are being made to study neutron-deuteron scattering by the same technique when the above experiment is completed.

Disintegration of Helium by Fast Neutrons. Cloud chamber pictures have been taken of an atmosphere containing helium, oxygen and water vapor. About a dozen examples have been observed of a disintegration involving the emission of two singly charged heavy particles and with no evidence of the recoil of a residual nucleus. These are interpreted as being due to the splitting of helium nuclei into protons and neutrons. There is some evidence to suggest that in

NEUTRON-PROTON SCATTERING

Laboratory System
Cloud Chamber Study
Oct. 23, 1947

Legend:

- 205 Cases with Probable Error
- First Group: 100 Cases
- Second Group: 105 Cases

All ordinates Scaled to 1000 for Comparison

Theoretical Curve for one half charge exchange

Number per unit solid angle

Figure I

Figure 2

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some cases a deuteron or triton is emitted - this is not yet definitely established.

Fast Neutron Scattering (Reported by B. J. Moyer)

Data from Pb and Cu scatters have been obtained in the range from 3° to 25° . The central peaks of scattered intensity for Pb and Cu are in the ratio of 4.05 ± 0.4 , after correction for neutron attenuation in the scatterer. Diffraction theory predicts this ratio to be 4.16, where an average neutron wave length appropriate to the neutron energy distribution is employed, and where the nuclear radii correspond to one-half the total cross sections measured in this neutron beam with the same detection method. The widths of the central maxima at 1/4 height are 6.5° , and 11° for Pb and Cu, respectively. Optical diffraction predicts values of 7° and 10° .

Measurements will proceed on other elements.

Neutron-Proton Scattering. Coincidence Counting Method. (Reported by H. York)

During the month observations have been made which have extended the n-p scattering curves to 65° in the laboratory system. A direct comparison of the protons at 25° and 65° (50° and 130° in the center of mass system) shows that the distribution curve is probably symmetrical in the center of mass system. The ratio of the intensities at these two angles is $1.05 \pm .03$, where the .03 is the error based on counting statistics only. Tubes with four counting wires in a single chamber have been used successfully with no evidence of signal propagation from wire to wire in the proportional region.

New Experimental Equipment. A long proportional counter has been constructed for the detection of high energy neutrons. The counter is filled with argon and carbon dioxide and makes use of a number of polyethylene disks. Preliminary tests have been quite satisfactory. The equipment for studying the angular

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distribution of n-p scattering has been tested with satisfactory results.

6. Theoretical Physics

R. Serber

Calculations on the excitation functions of several nuclear reactions are in progress. The calculations of star sizes are being re-examined to see if the observation that the mean number of particles does not increase with energy might not be due to higher energy protons being missed in the plates.

The measured angular distribution of the n-p scattering now seems to agree very closely with a theoretical curve calculated for half exchange - half ordinary force. This calculation was not very reliable however, and the attempt to improve it is continuing. It now appears that for the short range Yukawa wells we use, waves of high angular momentum are not very important - considerably less so than with a square well. This makes it fairly easy to calculate the scattering by a numerical integration, and it looks as though this may be even easier than the variation methods we have been investigating. Such numerical integrations are now under way. The interpretation of the total cross sections of nuclei for high energy neutrons is still in progress. Certain small discrepancies between measured and observed ranges for high energy deuterons are being investigated.

A number of papers were finished during the month. A paper by Serber entitled "Nuclear Reactions at High Energies" was sent to the Physical Review. Taylor collaborated with Chupp and Gardner on a paper on the energy distribution of the protons produced by stripping. Two letters were written for the Physical Review by Wolfe and Heckrotte, on the excitation functions of the reactions $C^{12}(p, pn)C^{11}$ and $C^{12}(n, 2n)C^{11}$. Two abstracts were submitted for the

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Los Angeles meeting, one by Serber on beam dynamics in the linear accelerator, and one by Horning on the distribution of star sizes.

7. Isotope Research Program

B. J. Moyer

A beta-gamma coincidence counting experiment was performed on Co^{60} in an effort to understand its decay scheme. The existence of beta-gamma coincidences in the 14-minute decay was demonstrated.

The Nier spectrometer has been applied this month to the analysis of deuterium concentration in connection with tracer experiments on photosynthesis under Dr. Calvin.

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