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PHYSICS DIVISION QUARTERLY REPORT

May, June, July, 1953

September 15, 1953

Berkeley, California

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PHYSICS DIVISION QUARTERLY REPORT

May, June, July, 1953

GENERAL PHYSICS RESEARCH

Cloud Chamber Program

Wilson M. Powell

Cosmic ray run. A run was made with the 4-by-8-foot diffusion chamber on the roof of Le Conte Hall to study the particles in extensive air showers from cosmic rays. The run began on May 27 and continued until June 24, 24 hours a day except for breakdowns and adjustments, which took approximately 25 percent of the total time. The observation time is estimated at 540 hours.

The flash tubes that illuminated the chamber were operated from a counter arrangement which allowed a picture to be taken only when a four-fold coincidence of counter trays under and around the chamber indicated that a shower occurred that would appear in the chamber. Approximately three pictures an hour were taken. Showers were present in about 120 pictures, and of these, 40 are considered to be of interest for the present study. These are the pictures which show either a particle-density gradient across the chamber or contain indications of groups or multiple cores.

Analysis of the showers is now under way. The original 1-1/4 x 1-1/4 inch negative of each half of the chamber is enlarged to 8-1/2 x 8-1/2 inches on Kodalith Ortho type 2 film. These transparencies show the tracks as voids in the positive print. They are then viewed by transmitted light and a pencil tracing is made on ordinary tracing paper of the shower particles only. Other tracks that appear in the negatives, caused by other cosmic-ray background and perhaps by the 60-inch cyclotron, are omitted, as are the portions of the chamber structure which appear in the pictures. Ozalid prints are then made from the tracings, and the prints can be marked in various ways for different kinds of analysis. Attempts to formulate a mathematical description of air showers are being made by obtaining track counts per unit area and utilizing these track counts to determine gradients and hence locate the core of the shower. Another approach has been to hunt for significant statistical deviations for an average number per unit area in an attempt to locate multiple cores.

Meson tracks. Analysis of pictures obtained in the run at the cyclotron with the 22-inch cloud chamber is proceeding. Approximately 200 pictures were obtained of the meson beam passing through a 1/8-inch lead plate. Each picture contained about 20 well defined meson tracks.

Temperature stabilization. In order to maintain the cloud chamber at a constant temperature a water jacket was designed and installed on both the top and bottom sections of the cloud chamber. This has resulted in improved picture quality as well as more stable operation, and a similar system has been installed on the 10-atmosphere cloud chamber.

Automatic developer. An automatic developer for use with expansion chambers has been built, and has been in use for the last several runs. It is designed to operate on a cycle time of from one to three minutes. When the developer is used, a continuous check can be made of the cloud chamber operation and appropriate corrections can be made. The developed film can be examined approximately ten minutes after it has been exposed.

The developer consists of five main sections built into a single unit. The first section receives film intermittently from the camera. The amount of film in the reservoir is controlled within close limits by a pair of microswitches. Too much film trips one switch and speeds up the developer motor drive, and the developer drive is stopped when all the film slack has been taken up. Second, the film goes into the developer and hypo tanks which were welded together to form one unit. The amount of film in each tank is contollable by a movable roller, which changes the path length. In this way the development time and the hypo time can be changed as the cycle time is altered. Third, the film is washed by sheets of fresh water from above and below for about one minute. Fourth, the film is dried in a rectangular tube by hot air. The top and bottom of this tube are made of lucite and a light is mounted below. This gives the first view of the developed film. The fifth section is the developer drive mechanism. Since the film used is unnotched, a friction drive rather than a sprocket drive must be used. A rubber-covered drive roller and a dural idler roller are used. The power is furnished by a D. C. Bodine gear reduction motor that is supplied from a chassis containing variable field and armature resistances to increase or decrease the motor speed. Warning devices and manually controlled switches are also incorporated in the chassis. An enlarged version of the automatic developer is being built and will soon be ready for testing. This will develop about two feet of film per minute. Owing to size limitations this will not be fastened to the camera, but will be installed in the darkroom. We are experimenting with a self-threading arrangement on this developer so that short lengths of film can be processes easily. This developer is to be used for the film from the 35-atmosphere diffusion chamber, as well as for the film from the magnetic measurements of the bevatron field.

An exploratory run was made with the 35-atmosphere chamber in the neutron beam. No results were obtained, owing to failure of an electrical circuit inside the chamber. This circuit has been redesigned and is being tested now. We expect to have a run within the next month.

Scattering of 32-Mev protons by helium. The film measurements are nearing completion and data reduction will begin soon.

Film Program

Walter H. Barkas

by Harry Heckman

Thesis submitted. During this report period, a thesis was submitted to the graduate division as partial fulfillment for the degree of Ph. D. by Robert W. Deutsch. The abstract of this research is given below.

"Analysis of Secondary Particles Resulting From High-Energy Nuclear Bombardment"

Thin foils of Be, Al, Ni, Ag, Au, and U have been bombarded by an internal beam of 375 Mev alphas, 332 Mev protons, and 187 Mev deuterons. Secondary particles emerging from the disintegration of the nucleus at 0^{o} to the incident beam direction are detected in nuclear emulsions located beneath the median plane of the 184-inch cyclotron. There are three specific positions for these emulsions corresponding to energies of the secondary protons and of alpha particles of approximately 6, 10, and 20 Mev. The angular distribution of secondary particles has also been measured for 240 Mev alpha bombardment of Be, Al, Ni, and Ag. Here, secondary particles emitted at 0^{o}, 45^{o}, and 135^{o} are detected in nuclear emulsions at positions for which the secondary proton and alpha energy is approximately 6 Mev. A secondary particle is identified by measurement of its radius of curvature upon entering the emulsion and its range and specific ionization in the emulsion. A considerable yield of hydrogen and helium isotopes as well as of particles of higher atomic number is found. The relative yields of the secondary protons and alpha particles for each element and for each bombardment are shown as a function of energy. The results are found to be consistent with the predictions of an evaporation model.

Articles prepared. The following articles have been submitted to the Physical Review for publication:

(1) "Large-Angle Scattering of Negative Pions in Aluminum, Copper, and Lead", Harry H. Heckman and L. Evan Bailey.

The total cross sections for backscattering of 32±10-Mev negative pions in Al, Cu, and Pb have been measured. A stripped emulsion was embedded in a semi-infinite absorber and exposed to an incident beam of π^{-} mesons. The positions and direction of mesons stopping in the emulsion were recorded. The cross sections are proportional to the ratio of the backward flux to incident flux, both of which are observed on the same strip of emulsion. The conclusions of this investigation are: (a) the scattering is consistent with energy independence in the region of 32±10 Mev; (b) the angular distribution has a maximum at 180^{o}; (c) the cross section for backscattering is proportional to the mass number A. The total nuclear backscattering cross sections (elastic and inelastic) for negative pions in Al, Cu, and Pb are 59.6±11 mb., 192±27 mb., and 577±80 mb., respectively.

(2) "Measurements of Meson Masses and Related Quantities", F. M. Smith, W. Birnbaum, and Walter H. Barkas.

A meson mass measurement program has been completed. The method has been partially described and preliminary results have been reported

at earlier stages of the work. As noted previously, it was discovered that stray mesons coming from points other than the target were interfering with the measurements. Attempts to reduce this effect have been successful, and little evidence of stray mesons remains.

To determine the pion masses, meson and proton ranges and momenta were measured in the same velocity interval. To measure the pion to muon mass ratio, similar comparisons were made between pions and muons. In one of the methods employed to find the momentum, p_o, of the muon which is emitted when the pion decays at rest, the muon range is compared with the ranges of pions of known momentum and of nearly the same velocity. The decay muons were also compared directly with muons coming from the target in a second type of experiment.

For each particle the quantity studied statistically is that function of the mass in which the range appears linearly. The dominant term in the variance of this quantity is the range straggling; consequently, it as well as other sources of variance has been examined closely, and the shapes of the measured distribution functions are now understood theoretically.

The stray mesons mentioned above introduced a systematic error of about one percent in the mass values quoted previously. The known systematic effects are now believed to be eliminated, and the statistical errors also have been considerably reduced. Our final results are contained in Table I.

Complete reports of the theoretical and experimental details are being prepared for publication.

The generous assistance of many individuals in the Radiation Laboratory is acknowledged with appreciation.

Table I

Values for Meson Masses and Related Quantities

The errors quoted are statistical probable errors. The uncertainties in the various quantities are not independent.

The mass assumed for the proton is 1836.1 electron masses.

The bracketted numbers are absolute mass determinations in the derivation of which no use is made of information obtained from the direct comparison of masses with that of the proton, but it is assumed that a neutrino of zero rest mass is emitted in a two body decay of the pion.

Fundamental Mass Ratios

π^+/Proton	π^-/Proton	π^+/μ^+
0.14888 ± 0.00011	0.14840 ± 0.00017	1.321 ± 0.002

Absolute Decay Momentum of Positive Muon

p_o = 29.80 ± 0.04 Mev/c

Derived Masses in Units of the Electron Mass

π^+	π^-	μ^+
273.4 ± 0.2	272.5 ± 0.3	207.0 ± 0.4

Absolute Mass Measurements in Units of the Electron Mass

π^+	μ^+	$\pi^+ - \mu^+$
(273.5 ± 1.2)	(207.1 ± 1.1)	(66.41 ± 0.07)

Results evaluated. Several of the researches previously reported have led to definite conclusions. The energy spectra for He^4 and He^3 for all angles up to 60° in the laboratory have been obtained from the bombardment of Ni by 340-Mev protons. The integrated ratio of the He^3 to He^4 production in this angular interval is 0.115±0.01. The He^3/He^4 production ratio above 25 Mev is about 0.30. No reliable estimate of the H^3/He^4 ratio can be obtained from the data.

The study of the range distributions in emulsion of the alpha particles from the following two reactions has been concluded.

(1) $Li^8 \rightarrow \beta^- + B\tilde{e}^{*8}$)
) $B\tilde{e}^{*8} \rightarrow 2\ He^4$
(2) $B^8 \rightarrow \beta^+ + B\tilde{e}^{*8}$)

Two hundred and fifty-seven Li^8 decays were measured and the resulting distribution was found to be in agreement with those of previous investigations. One hundred B^8 decays were measured and no significant difference was found from the Li^8 distribution. The combined 357 events were found to fit a single resonance theory with E_o = 2.9 Mev, Γ = 1.2 Mev, and J, the spin of the excited state in Be^8, = 2. However, the longer-range alphas, 15 to 25 microns, are not included by this resonance and must be attributed to higher and broader levels in the Be^8 nucleus.

Projects continuing. Work has continued in the following projects: (a) γ-ray spectrum from Pb when bombarded by the 320-Mev bremsstrahlung beam (b) momentum and angular distributions of spallation products from various targets under proton, deuteron and alpha bombardment; (c) high-energy β-ray spectra; (d) γ-ray spectrum from a 330-Mev proton bombarded target (in this program, the energies of about 150 electron-positron pairs in emulsion have been measured and the experimental data are now being analyzed.); (e) interactions of 386-Mev alpha particles in G5 nuclear emulsion; and (f) meson production from p - C^{12} collisions.

Under the direction of R. Sagane, a program has been undertaken to develop a 20 to 26-Mev meson beam using a modified spiral-orbit spectrometer. The general program of meson spiral-orbit spectrometer development has continued and an extensive research program employing these instruments has been outlined.

Theoretical Group

David L. Judd

Nuclear Physics

1. A calculation of the stopping power of liquid deuterium for He^3 and H^3 nuclei, and of the multiple scattering, is under consideration; and the results would be useful in connection with experiments planned to test the charge-independence hypothesis by use of the reactions $p + d \rightarrow He^3 + \pi^o$ and $p + d \rightarrow H^3 + \pi^+$. (Judd)

2. The low-energy (15-Mev) photo-neutron resonance is being studied by means of a perturbation method that takes into account correlations between nuclear particles. It is hoped in this way to calculate the shape of the excitation function for photo-neutron emission. (Heckrotte and Lepore)

3. An investigation of the proton-deuteron scattering problem has been undertaken with particular interest in the associated polarization effects. (Tamor)

4. The inelastic scattering of medium-energy protons by nuclei has been reexamined in an attempt to improve previous calculations, which correlated the angular distribution with the change in the angular momentum between the initial and final nuclear states. The agreement with experiment is still unsatisfactory. (Heckrotte)

Electromagnetic Problems

1. Calculations of the target-thickness corrections to the bremsstrahlung spectrum from bombardment of high-energy electrons on copper have been carried out. The work is to be extended to heavier elements. (Tamor)

2. The phase variations of particles in a cyclotron operated with two 90° dees driven in phase have been studied in connection with projected modifications of the 60-inch cyclotron. The proposed use of an approximately square rf wave form is equivalent to an increase of $\pi/2$ in dee voltage. (Judd and Bludman)

3. The azimuthal density distribution of the particle bunch in an FM cyclotron has been measured and found to be sufficiently large to be consistent with a theoretical estimate that little if any phase oscillation damping should occur. Calculations are in progress to determine to what extent this observed distribution reflects the phase dependence of catching efficiency near the center. (Smith)

Meson Physics; Field Theory

1. Very high-energy nuclear processes are being studied by using the statistical model, which for such processes may be regarded as an opposite extreme from perturbation theory. A method is being devised to evaluate the fundamental phase space integrals. Results will be compared with the formulae based on the limiting cases of nonrelativistic nucleons and extremely relativistic mesons. (Lepore)

2. The Feynman-Schwinger Green's function technique hitherto employed to formulate bound state and scattering problems independently of perturbation theory has been extended to cover nonstationary processes involving the creation and annihilation of particles. It was shown that the transition amplitude of this type may be expressed in terms of a Green's function. The equations for the Green's function derived by this technique, unlike those conventionally employed, are nonlinear even in the lowest approximation, thus allowing perhaps for the possibility of radiative transitions, which is absent in the Bethe-Salpeter equations. This method has been applied to an interacting system of nucleons, mesons, and photons. The amplitude for photomeson production was shown to be simply related to the variational derivatives of the propagation function of the nucleon-photon and nucleon-meson systems with respect to the meson and photon sources respectively. With this expression it should be possible to trace the effect of an isobar in the nucleon-meson system on photomeson production. The possibility of this kind of phenomenological approach on a field theoretical level is being currently investigated. (Neuman)

3. A detailed investigation is being made of the relation of the Tomonaga intermediate-coupling approximation in the strong-coupling limit to the conventional strong-coupling theory of Wentzel et al. The primary emphasis is upon the application of these results to the problem of meson-nucleon scattering. (Riddell and Fried)

4. A pair of coupled nonlinear differential equations describing all electrodynamic self-energy effects (excluding overlapping and vacuum polarization graphs) has been derived using the integral equation formalism of Schwinger. (Arnowitt and Gasiorowicz)

5. Work has continued on the meson-nucleon wave equation in the adiabatic limit. The low-energy total cross section for π^+ - p scattering has been calculated. At 37 Mev the result is 19.5 mb., in good agreement with the experimental value of 20.8 ± 1 mb. reported by Angell and Perry (Rochester) but not with the value of 7.9 ± 2 mb. at 33 Mev obtained by Leonard and Stork here. (Arnowitt)

6. π^- meson production in n-d collisions is being investigated for the special case in which a final deuteron is formed. The R-matrix for this reaction has been chosen to agree with experimental data for the reaction $p + p \rightarrow \pi^+ + d$. (Huddlestone, Macdonald, and Stuart)

7. The effect of the meson-nucleon interaction in the final state of the reactions $p + p \rightarrow \pi^+ + n + p$ has been investigated. The proton energy distribution has been found to be much more sensitive to the interaction than that of the meson. (Tamor)

Synchrotron Studies

A. C. Helmholz

During the months of May, June, and July there were a number of long runs on the synchrotron. One experiment, that of R. Kenney, was finished, and the runs for R. Sagane and W. Dudziak were completed for the present series. They employed the spiral-orbit spectrometer to study the low-energy photomesons produced in carbon and hydrocarbon. They also exposed plates to mesons coming in both directions at the edge of the spectrometer so that the yields of π^+ and π^- from carbon can be obtained. The subtraction will of course give the hydrogen yield of π^+. The main difficulty was to shield the synchrotron from the strong stray field of the spectrometer, and this required a good deal of time. The emulsions exposed to the mesons are being examined and results should soon be available. Further runs are planned with the bigger, new spiral-orbit spectrometer.

R. Kenney, assisted by C. McDonald and J. Dudley, completed the runs to determine the nonpair contribution to the cross section of Be for high-energy γ-rays. The data are being worked up. In order to monitor the beam, use was made of a NaI crystal and photomultiplier tube to count high-energy electrons bent in an auxiliary magnetic field. The purpose was to monitor the high-energy quanta rather than the total beam energy, and it was accomplished by setting the crystal, magnetic field, and collimating channel so that only electrons from high-energy quanta could enter the crystal. This, with the vacuum chamber for the pair spectrometer, provided the desired accuracy. The results should be written up in the near future.

In this connection, work on the calibration has progressed. Chambers identical to those used at Illinois and Cornell have been built and operated. More runs will be made, but the initial run indicates agreement of the Cornell chamber, Victoreen thimble chambers, and the Blocker and Kenney calibration. Discrepancies in the calibrations at different beam levels will of course be investigated.

F. Coensgen has made runs to measure the angular variation of the Compton effect at high energies. He is measuring the momentum of the electron in the pair spectrometer magnet and the scattered γ-ray coincidence with a CsF crystal. The runs will probably be completed in the next month and a half, and the results will be written up in Coensgen's thesis.

R. F. Post and C. McDonald plan to do their measurement of the triplet cross section in hydrogen with a setup similar to that used by Kenney; that is, they will use the pair spectrometer to measure the number of quanta, then measure the absorption coefficient of C_6H_6, C_6H_{12} with the background. The subtraction gives the H cross section. H. Heckman has made a further run to measure the scattered γ-rays from different substances.

Resonance Excitation of Delayed Heavy Particle Emitters

S. W. Kitchen

Another bombardment of Mg^{24} verified the presence of the resonance peak, but the Na^{20} integrating counter was not reliable enough for accurate measurements. A new integrating counter with cylindrical geometry was built in order to get better discrimination between the alphas and betas. This counter was filled with 5 cm of Ne and 2 atmospheres of helium in order to avoid the limited-lifetime characteristics of CO_2. The linearity of the calibrating Faraday cup was checked by counting C^{11} after bombardment in the cup. The cup was found to be linear with current up to 8×10^{-8} amps. to within ± 2 percent, the accuracy of the measurement. Several characteristics of proportional counters made the linearity of the integrating counter sensitive to the scalar discriminator setting, but the counter could be made to operate satisfactorily.

Neon 18

L. W. Alvarez and J. D. Gow

By the use of the internal target beta-ray spectrometer built by Roger Wallace, we have completed the investigation of the radioactive nucleus Ne^{18}. The characteristics of the decay are very similar to those of the other known (4n + 2) triads. The beta-ray energy was determined by direct comparison with the He^6 activity, which could be produced in the same LiF target used for Ne^{18} production. The positrons have an upper limit of 3.2 ± 0.2 Mev. The half-life of the activity is 1.6 seconds. Using these values, the decay has a log (ft) of 2.9 ± 0.2, essentially the same value as found for He^6. The value of beta-ray energy found agrees very well with the expected value given by a Coulomb energy difference calculation based on replacing the last two neutrons of O^{18} with protons.

Time-of-Flight Neutron Spectroscopy

W. Linlor and B. Ragent

Runs have been made with the time-of-flight instrumentation to determine the variation in total neutron cross section with energy for antimony, tantalum, and bismuth. Carbon was run as a check.

The results for bismuth show the same general variation with energy as the data of Taylor and Wood for lead. Bismuth has a dip in cross section to 4.14 ± 0.14 barns at 62 Mev, followed by a rise to 4.92 ± 0.12 barns at 70 Mev.

The results for carbon agree well with values published by others, indicating that the instrumentation had been working properly.

Data for antimony and tantalum are being analyzed.

As a part of the data, the direct beam neutron spectrum has been obtained. It agrees with the Serber "opaque-nucleus, all angles" model for 195-Mev deuterons stripped on a thin target. Inasmuch as the data were taken in the extreme forward direction, with a copper probe 1-1/4 inches long, one would not expect agreement with the theoretical curve just described.

Calculations are in progress to try to explain the spectrum shape. Spectra from beryllium and lead targets are to be examined also, to see if multiple-scattering effects can produce a thin-target spectrum from a physically thick target.

Ether Bubble Chamber

F. S. Crawford, Jr., L. W. Alvarez, M. L. Stevenson

An ether bubble chamber similar to the one described by Donald Glaser (Phys. Rev. 87, 665 (1952); Bull. Am. Phys. Soc. 28, 72 (1953)), has been constructed and operated with moderate success. Bubbles have been shown to be formed by ionizing particles. At present, attempts are being made to obtain photographs of charged-particle tracks in the chamber.

The liquid in the chamber is maintained at a constant temperature, T, by means of a heat reservoir. This temperature (approx. 120°C) is 88° higher than the boiling point at atmospheric pressure. The chamber is maintained in a liquid state by about 20 atmospheres pressure. The chamber is then expanded to a final pressure of one atmosphere, when it is a pure liquid in a superheated state.

The surface tension of the liquid suppresses formation of vapor bubbles. If there were no impurities and no ionization, the system would remain in the superheated state indefinitely. The effect of ionization is to give clusters of electric charge that compensate the effect of surface tension and hence allows bubbles to form. With bubble formation, the pressure rises to the vapor pressure at the temperature T.

Work is in progress to construct a chamber that will operate first with liquid nitrogen and later with liquid hydrogen.

Beta-Ray Spectrometer

R. Cence and R. Wallace

The new power supply for the beta-ray spectrometer was completed by A. Schwemin and D. Parmentier. Two additional counting tubes were added to the beta spectrometer to intersect the trajectories of all of the particles coming through the exit slit. This change was found to be necessary during the previous runs on the linear accelerator.

Design work was started on new counters for a double scattering experiment using DuMont 6292 photomultipliers and plastic scintillators. Work was also started on a faster coincidence circuit for this experiment to make 10^{-8}-sec coincidences rather than the 10^{-6}-sec coincidences that were used in the previous run. This change is being made to reduce the accidental counting rate.

Operation of the Van de Graaff Beam "Chopper"

H. Bradner, G. Hecht, W. Pon

The Van de Graaff proton beam "chopper" was tested on July 6, 1953. The chopper consists of an rf oscillator operating at about 487 kc and producing up to 30 kilovolts across pairs of plates 1 meter long separated by 1 cm, between which the proton beam from the Van de Graaff passes. Two pairs of slits were built to act as adjustable collimation before the beam entered the region of the plates, and it was found that by proper collimation the beam could be successfully deflected so that its duration across the entrance port of the linear accelerator was less than 10^{-8} sec and with a separation of about 1 μs. Bias voltage between plates and ground to remove secondary electrons was not found particularly helpful; it was not employed.

Operation of the chopper was observed by monitoring the linear accelerator beam with a stilbene crystal counter and displaying the pulses on the sweep of a fast scope. Ratio of intensities of the beam with and without the chopper on, as measured with a Faraday cage, appeared to be in the neighborhood of 1:200, which is expected; but the determination will be repeated, as there was insufficient time to measure the ratio carefully.

It is hoped to produce pulses of about 5×10^{-9} sec duration with the chopper, corresponding to the period of the linear accelerator rf, and consequently, because of the phase-bunching property of the linear accelerator, to produce output pulses of less than 10^{-10} sec duration with 1 μs spacing, which will then be used in fast time-of-flight experiments.

Nuclear Scattering of 2.8-Mev Gamma Rays

L. Alvarez, F. Crawford, Jr., L. Stevenson

Work is continuing on the measurement of the elastic scattering of gamma rays of light nuclei. The measured cross section for 2.8-Mev gamma rays on carbon is 6 ± 1 times the classical Thomson cross section at 80°-90°. It is improbable that the increase is due to Rayleigh scattering from the "bound electrons," but this possibility must be investigated by varying the scattering angle. It is more probable that the increased cross section is due to scattering from the meson cloud.

Fast Deuterons from 340-Mev Protons on Nuclei

Wilmot Hess and John Wilcox

Differential cross sections for deuteron production at 40° to the beam resulting from proton bombardment of various elements have been measured and are reported in the table below. These cross sections were obtained using the magnetic particle spectrometer with wedge-shaped absorbers of thickness of 0.6, 1.2 and 2.0 deuteron ranges placed in front of the 35 channel counters. Deuteron-production cross sections can be determined from the change in counting rate in going from an $0.6R_D$ absorber to a $1.2R_D$ absorber. The cross section of alpha + triton production can be determined from the change in counting rate from $0R_D$ absorber to $0.6R_D$. Also, the effect of proton nuclear attenuation in the absorbers can be measured. Proton-production cross sections were also determined from these same data and are listed in the table.

Target	$\frac{d\sigma}{d\Omega}$(proton)	$\frac{d\sigma}{d\Omega}$(deuteron)	$\frac{d\sigma}{d\Omega}$(α-t)
Li	33.6±0.10	0.57±0.72	
C	49.0±0.21	1.33±0.21	0. ±0.50
Al	85.5±0.27	4.92±1.00	0.59±1.13
Cu	151.0±0.43	11.55±3.14	
Pb	266.0±1.10	14.37±8.76	

Differential Cross Sections for Production of Various Charged Particles at 40° to the Proton Beam (in millibarns/steradian).

These cross sections were put on an absolute scale by normalizing to the differential p - p cross section. This was done by determining the counting rate from hydrogen using a CH_2 - C target difference. The deuteron cross sections reported are lower limits, because the spectrometer will not count deuterons of energy less than 52 Mev. The energy spectrum of the deuterons is essentially zero above E_D = 110 Mev, and rises as the deuteron energy falls. The spectrum is at a maximum at 52 Mev, indicating that there are deuterons of lower energy present that are not detected.

The cross section for proton production fits well to a curve of the form

$$\sigma_p = 13.2 Z^{.71} \text{ millibarns/steradian}$$

The exponent 0.71 says that the proton production is predominantly a surface effect, which is to be expected from other high-energy inelastic cross section data.

The cross section for deuteron production fits well to a curve of the form

$$\sigma_d = 0.035 A^{1.48}$$

This is very interesting in that it indicates that the production goes up faster than A. This can be explained by assuming the process is the indirect pickup process described by Bransden (Proc. Phys. Soc., Sept. 1952).

It is proposed to determine the angular dependence of the differential cross section for one element to aid in identifying the formation mechanism.

The Photoproduction of Negative Pions from Deuterium

Kenneth C. Bandtel, Wilson J. Frank, Richard Madey

The details and results of this experiment are to be reported in a forthcoming UCRL Report.

Range - Energy Program

Marvin Rich, Richard Madey

Work is now in progress, and about forty percent complete, on a new set of range-energy information which will be more complete than any previously turned out. The original data involved have come from the theoretical range-energy tables in the Report AECU-663 by Aron, Hoffman, and Williams. Using these results, calculations are being made to extend the range-energy information so that the final work will cover pions, protons, deuterons, H^3 and He^3 in such materials as Be, C, Al, Cu, Pb, air, H_2O, D_2O, H_2, D_2, CH_2, CD_2, trans-stilbene, and phenyl-cyclohexane. The new booklet, when complete, will be arranged in four parts as follows:

(1) Tables of range and stopping power versus kinetic energy.

(2) Curves of range versus kinetic energy for energies from 1 Mev to about 10^4 Mev.

(3) Curves of stopping power versus kinetic energy over the above-mentioned energy range.

(4) Tables of range-energy spproximation equations of the form

$$R = K T^n$$

High-Energy Gamma-Ray Telescope

Nils Wickner, Richard Madey

Preliminary tests of a high-energy γ-ray telescope were made at the 184-inch cyclotron in conjuction with other instrumentation investigations. The telescope was composed of two counters, connected in coincidence, each having a Dumont 6292 photomultiplier viewing Cerenkov radiation in water. The telescope was situated at 90^o with the incident proton beam. Converters of Pb and C having equivalent stopping power for heavy charged particles were alternately placed in front of the telescope. (A six-inch beryllium block was placed between the target and the converters to stop charged particles directed toward the channel.) The difference in the coincidence counting rates from Pb and C converters represented the gamma-ray yield.

The coincidence counting rate per unit integrated beam showed a target-in to target-out ratio of about eight. The fact that the coincidence counting rate vanished when the beam was turned off eliminated the possibility that the target-out counts resulted from the noise pulses in the photomultiplier tubes. Removing the water from one of the counters gave a coincidence counting rate from the target about the same as the target-out rate when both counters were filled with water. Since the counter telescope was well shielded with lead, these latter two results indicate that the target-out counts are probably caused by neutron bombardment of the photocathodes of the two photomultipliers.

The singles counting rate as a function of photomultiplier high voltage showed that the first counter of the telescope is less efficient than the second. This result is to be expected from the construction of the two

counters forming the telescope. A water container forms a part of each counter. The container for the first counter is a two-inch cube at the end of a cylinder of height four inches and diameter two inches. The second water container is a cylinder of the same dimensions as that forming a part of the first container. To form the telescope the first counter is placed at 90° to the second and converted electrons pass through the cube of the first and down the cylinder of the second. This geometry is responsible for the inefficiency of the first counter.

The following table shows that under various conditions a difference exists in the coincidence counting rate for Pb and C converts. Since the converted electrons must have enough energy to pass through at least two inches of water, a lower limit is placed on the energy of the detected gamma rays.

Target	Beam Channel Meter Reading	Converter	Doubles	Integrator Volts	Photomultiplier High Voltage		Counts per .01 Integrator Volt
					C-1,	C-2	
3"Be	$.4\times10^{-9}$	.27 Pb	33± 8	0.04	1.7 kv	1.4 kv	8 ±2
3" Be	$.4\times10^{-9}$	$\frac{11"}{8}$ C	1±1	0.01	1.7 kv	1.4 kv	1 ±1
					Difference		7 ±2
3" Be	$.2\times10^{-8}$	.27 Pb	76±9	0.3	1.6 kv	1.4 kv	2.53±0.30
3" Be	$.2\times10^{-8}$	$\frac{11"}{8}$ C	37±6	0.3	1.6 kv	1.4 kv	1.23±0.20
					Difference		1.30±0.36
$\frac{5"}{16}$ C	$.6\times10^{-8}$	.135 Pb	159±13	1.0	1.5 kv	1.5 kv	1.59±0.13
$\frac{5"}{16}$ C	$.6\times10^{-8}$	$\frac{5"}{16}$ C	113±11	1.0	1.5 kv	1.5 kv	1.13±0.11
					Difference		0.46±0.17

The electronics arrangement for this run can be described briefly as follows. The negative signal from each counter of the telescope was passed through two Hewlett-Packard 460A wideband amplifiers. The signal then passed through a 6BQ7 limiter-inverter stage (without delay line clippers) to a crystal-diode double-coincidence circuit. The output from the coincidence circuit went to a three-stage EFP-60 pulse-lengthening amplifier with a 6AQ5 pentode output tube. This amplifier could deliver as much as a 45-volt output signal in the microsecond range; however, since the linear range was only about 20 volts the discriminator bias on the scaler was calibrated and set at 15 x 0.9 volts. This EFP amplifier delivered the signal to the scaler directly. The singles counts from each counter were recorded on separate scalers; in addition, a scope viewed the signal from the monitor output of the EFP amplifier.

High-Energy Gamma-Ray Spectroscopy

David Cohen, Harlan Shaw, and Charles Waddell

Two runs were made during this period: a Van de Graaff and a synchrocyclotron run.

The Van de Graaff run was essentially an instrumentation run. Four-hundred-and-forty-Kev protons on Li^7 yielded the gamma line spectrum from Be^8, and the 17.6-Mev line was used as a final check on the energy calibration of the spectrometer. This calibration was in agreement with the floating-wire technique and Magnetic Testing Group measurements. Unfortunately the counting rate was too low to obtain a good line shape determination.

At the synchrocyclotron, the pair spectrometer was set at the 90° position to the beam. The following phenomena were dealt with:

1. Shape of the π^o Spectrum (340-Mev protons on thick carbon target)

Although the data are still being evaluated, preliminary results seem to indicate a good, clean spectrum with good statistics. The maximum is close to 50 Mev for this 90° angle of view, which is in accord with expectations.

2. Bremsstrahlung (140-Mev protons on thin beryllium target)

In spite of low counting rates, a rough spectrum was obtained in the region of 20- to 150-Mev gamma rays. The shape is not too inconsistent with a $\sqrt{(E_o/2) - h\nu}\ d\nu/\nu$ type of spectrum.

Theoretical Predictions in Brief

Theory	Shape for Yield vs. $h\nu$
Phenomenological	$\sqrt{(E_o/2) - h\nu} \cdot d\nu/\nu$
Scaler Meson Theory	$\sqrt{(E_o/2) - h\nu} \cdot d\nu/\nu$
Pseudoscaler Theory	$\sqrt{(E_o/2) - h\nu} \cdot \nu d\nu$

3. Sharp Gamma Lines (140-Mev Protons on Thick Be, B, Melamine, Al_2O_3, and Al Targets)

Short runs on these targets indicate that there are no intense lines in the 12- to 50-Mev gamma region. This is in contrast to the previously seen and reported intense line (15.2 Mev) from a carbon target under the same bombardment conditions. This line from carbon was again obtained in this run.

4. Instrumentation

(1) To increase accuracy in determining spectrum shape, it was found necessary to change the 23-channel spectrometer to 19 channels.

(2) A workable thermocouple system was successfully used to monitor beam current through the various targets. A circuit will soon be put into operation that will greatly shorten the very long time constants involved in the heat-transfer phenomena.

Nuclear Internal Momentum Distributions

John Wilcox, Wilmot Hess

Hydrogen, lithium, beryllium, and boron have been observed. Preliminary results suggest qualitative differences among these elements. The values of the various energy widths necessary to determine the resolution of the equipment are being computed. A new gate generator will be tried out, which we hope will reduce the background counts in the spectrometer. It appears that the spectra will have to be gathered at a rate of two or three counts a minute, owing to background problems.

Cerenkov Radiation Detector

Robert Squire and John Osher

A Cerenkov counter has been constructed according to Professor Moyer's design, which is intended for use in the detection of high-energy electrons.

The preliminary form is a 12-inch lucite radiator branching to two arms which are connected to two Dumont 6292 phototubes operated in coincidence.

The Neher coincidence bridge was checked for this application and is being used.

Early tests on cosmic rays and gamma source indicate that successful operation can be achieved.

Further work will be done in checking for lucite scintillation, and with refrigeration of the phototubes to lower thermal noise background.

Production of H^3 and He^3 in Deuteron-Deuteron Collisions

Charles Godfrey, Kenneth C. Bandtel, Wilson J. Frank, Richard Madey

A run was conducted to compare yields for the reaction $D + D \rightarrow \begin{matrix} H^3 + p \\ He^3 + n \end{matrix}$ A magnetic channel and pulse height were used to separate and identify particles. A CD_2 target was used. It was found, however, that for every valid triton from deuterium there were 36 tritons from carbon of the proper momentum to traverse the channel. Since this represents too high a background, the next run will use a liquid deuterium target with thin windows to minimize this background.

A one-day run was conducted to finish the cross section angular distribution of the $D + D \rightarrow H^3 + p$ reaction. The anomalously low cross section previously found at 90^o center-of-mass was found to be in error, and the entire curve now follows a straight line on semi-log paper. At the end

of the run, a beam-gating device developed by Vern Ogren was tried out to see whether time-of-flight techniques could be used to debunch the background and eliminate the necessity for the magnet. The gate worked satisfactorily, but the width of the fine-structure pulses of deuterons was found to be about 2×10^{-8} sec. Since the difference in time of flight between the desired particles and the background is only about 1×10^{-8} sec., it seems that time-of-flight techniques will not be very useful.

The Angular Distribution and Yield of the Process $p + d \rightarrow t + \pi^+$

Wilson J. Frank, Kenneth C. Bandtel, Richard Madey

The details and results of this experiment have been described for the forthcoming UCRL Report no. 2292.

Excitation Function for $p + C \rightarrow \pi^+$

D. Hamlin and J. Merritt

Experimental work on the excitation function for positive pions produced at 90° in proton carbon collisions is being continued. During two additional cyclotron runs data were obtained at various meson energies for the proton energy interval 240 - 340 Mev. Analysis of the data is in progress.

Total Cross Sections for Positive Pions in Hydrogen

D. Stork and S. Leonard

Work on this experiment has been completed. The measured cross sections are:

Pion Kinetic Energy	Total Cross Section (mb)
33 ± 4.5	6.4 ± 2.1
44 ± 4	9.8 ± 1.5
56 ± 4	17.6 ± 2.2
70 ± 5	19.0 ± 2.6

A complete report of the experiment is being prepared for submission to the Physical Review.

Total Positive Pion Cross Sections in Complex Nuclei

D. Stork

Measured attenuation and scattering cross sections for positive pions in complex nuclei have been analyzed in terms of the optical model. The mean free path for interaction of pions in nuclear matter, λ_a, was calculated for pion energies 33, 46, and 68 Mev. The resulting energy dependence of the mean free path was compared to that given by

$$\lambda_a = [\, 2b(k\, r_o)^4/\gamma^2 \,]^{-1}$$

where k is the pion wave number, r_o is the pion compton wave length, and γ is the total pion energy divided by its rest energy. This equation is based upon the assumption that the energy dependence for the bound-nucleon cross section is the same as that for free nucleons, where the free-nucleon energy dependence is taken to be that derived from lowest-order gradient coupling theory.

Satisfactory agreement was found with the constant, b, determined to be $0.21 \pm {}^{0.04}_{0.03}$. Published interaction cross sections from other experiments were analyzed by means of the optical model to provide additional determinations of the mean free path, and again agreement was found with the above energy dependence. The combined results from our experiment and from other experiments determine b to be 0.26 ± 0.02 by means of a least-squares fit. The final result was also compared to mean free paths derived by means of multiple-scattering theory from the scattering amplitudes for the interaction of pions with free nucleons.

A detailed report of the measurements and analysis will be presented in UCRL-2288.

Nuclear Emulsion Program

D. Stork and S. Whetstone

The new darkroom, designed for the processing of thick electron-sensitive nuclear emulsions, has been completed.

Grain-density measurements of several types have been made on tracks produced by protons, deuterons, and electrons of several energies. The subjective influence of the observers is being studied.

Plates exposed to normally incident 340-Mev protons have been used to obtain a measure of the distortions present in the processed emulsions.

Controlled variations of the eradication and processing procedures have been evaluated with respect to the resulting sensitivity, random background, and distortion. These experiments are continuing. The processing of "pellicle stacks" is being investigated.

The Elastic and Inelastic Scattering of Neutrons by Deuterons

L. T. Kerth and B. L. Youtz

(See UCRL-2307)

The differential cross sections were measured for the elastic and the n-p type of inelastic scattering of 90-Mev neutrons by deuterons. Neutrons produced in the stripping of 190-Mev deuterons by a beryllium target in the Berkeley 184-inch synchrocyclotron have an energy distribution centered at 90 Mev with a spread of 30 Mev full width at half-maximum. Normalization of the cross sections was made by comparison to the n-p scattering cross sections of Hadley, et al. The angular range between five degrees and forty degrees in the laboratory was covered for both the elastic and inelastic reactions with $\pm$ 2-1/2° angular resolution.

The experimental data are compared with the theory of Chew, which uses the impulse approximation with central forces only, and with the theory of Horie, Tamura and Yoshida, which is based on the Born approximation but includes both central and tensor forces. Furthermore, the data for elastic scattering are shown to be in satisfactory agreement, over the angular range covered here, with the results of Stern for 190-Mev deuteron-proton scattering, thus lending further support to the idea of charge independence of nuclear forces at moderately high energies.

ACCELERATOR OPERATION AND DEVELOPMENT

184-inch Cyclotron

Operation James Vale

The cyclotron was in operation approximately 96 percent of the time that the crew was on duty during this period.

Pump-downs of the vacuum tank after it has been opened are gradually becoming longer. This can be caused by the magnet oil leak in the vacuum chamber becoming worse, and it also can be caused by the outgassing of the increased amount of experimental equipment that is now located in the vacuum tank.

Modification Marvin Martin

Magnet. Force measurements on the model magnet coils have been completed with various combinations of current in the separate coils and the data from these tests have been incorporated in the structural design of the coils and coil supports. The forces involved in support of coils and poles are large and an adequate design appears to be difficult. It is currently believed, however, that the use of heat-treated alloy steels for the through bolts will permit these forces to be withstood without basic redesign of the pole structure.

The auxiliary coil tanks have been fabricated during the past quarter and the machining is in process at Mare Island. The coil-winding order has been awarded to the Westinghouse Corporation. The copper has been delivered to them and the orders for coil insulation have been placed.

Radiofrequency Design. The half-scale rf model has been completed and measurements are in process. The resonant frequencies correspond closely to those predicted by calculations. Certain parasitic modes of oscillation remain and experimental work must be done to suppress these modes. The design of the dee is nearly complete, ready for detailing, and the oscillator design is under way.

Fabricating condenser. A supplier for the vibrating-blade forgings has been located and an order is being negotiated with him. A suitable source has been found for the heat treatment of the blades and inquiries are out for the machining contract. The 30-cycle power supply and driving magnet are being studied jointly by the Mechanical and Electrical Engineering Departments and a satisfactory solution is expected soon.

Deflector. Orbit plots have been made, taking into account the field fall-off outside the maximum orbit radius and the measured magnetic field produced by the pulsed magnetic deflector. These plots indicate that a satisfactory deflector of this type can be installed in the cyclotron and the design is being started.

Experimental facilities. Other experimental facilities such as the proton probe, meson cave, and electrostatic deflector are being postponed except for basic design study. It has been decided to incorporate these facilities at a future

shutdown instead of next spring. The scheduled shutdown date of March 1, 1954, appears to be possible provided unforeseen troubles do not arise and provided the Laboratory program permits the present amount of manpower to be placed on the 184 in. modification.

60-inch Cyclotron

William B. Jones

Operation

The operations of the 60-inch cyclotron during this quarterly period were as follows:

Alpha bombardments		182.0 hrs
Deuteron bombardments		260.0 hrs
Proton bombardments		231.0 hrs
Carbon bombardments		127.5 hrs
Development and Experimental		142.0 hrs
	Total	942.5 hrs
Outage		233.5 hrs
	Total	1176.0 hrs
Shutdown		1000.0 hrs
Holidays		32.0 hrs
		2208.0 hrs

Operating efficiency: 80 percent

New techniques. A method of bombarding gaseous targets was developed in this laboratory and described in Physical Review, Vol. 75, No. 2, 231(1949). This method has certain difficulties: (1) The gas must be continuously flowed at a slow rate. The rate changes as the beam varies in intensity, since the gas pressure varies as a function of beam intensity. The pressure changes make a continuous flow difficult since they range from positive to negative. (2) The amount of gas used becomes very large for a run of long duration. (3) The apparatus is large and awkward to handle for the recovery of the radioisotope is effected by washing the jar with a solvent.

A modified gas bell jar has been developed to overcome these difficulties; it contains the gas under a pressure of 20 to 25 pounds per square inch in a sealed container. Pressure rises due to the beam were not found to be large, varying from 25 pounds per square inch to approximately 28 pounds per square inch at a beam level of 5 microamperes, and to approximately 32 pounds per square inch at a beam level of 10 microamperes. The volume of the modified jar was one-sixth that of the original, which also produced a corresponding change in mass and greatly facilitated handling. This decrease in size was made possible because of the increased gas pressure, from atmospheric to approximately 25 pounds per square inch above atmospheric pressure. The pressure was raised by a factor of 2-2/3, thus the range of the particles was cut by a factor of two.

The 1-mil aluminum foils used to separate the bell jar from the cyclotron vacuum have been reduced in size to withstand the higher operating pressures. These foils are flat and not curved as in the original bell jar which further reduced the mass of the window assembly a factor of four. The water-cooling lines are directly welded to the chamber, eliminating the weight of ribbing.

Since the fall of 1948, ion sources of type no. 15 (see Fig. 1) have been used at this laboratory. The ion-extraction orifice is 3/4 in. x 1/8 in., representing a size compatible with good operational characteristics. Continued use of this cone has shown that a beam decrease occurs after approximately 250 hours of operation. A marked erosion occurs, which greatly enlarges the orifice in the direction of ion extraction. The erosion is evident in Cone no. 13, Fig. 1. As this section is fairly well cooled, the erosion appears to be due to a sputtering of the copper, rather than to a heating phenomenon. To combat the erosion effect, a molybdenum section was silver-soldered into the cone in the orifice region. After 550 hours of operation, no appreciable erosion or decrease in beam intensity has been noted. This modified cone is shown in Fig. 2.

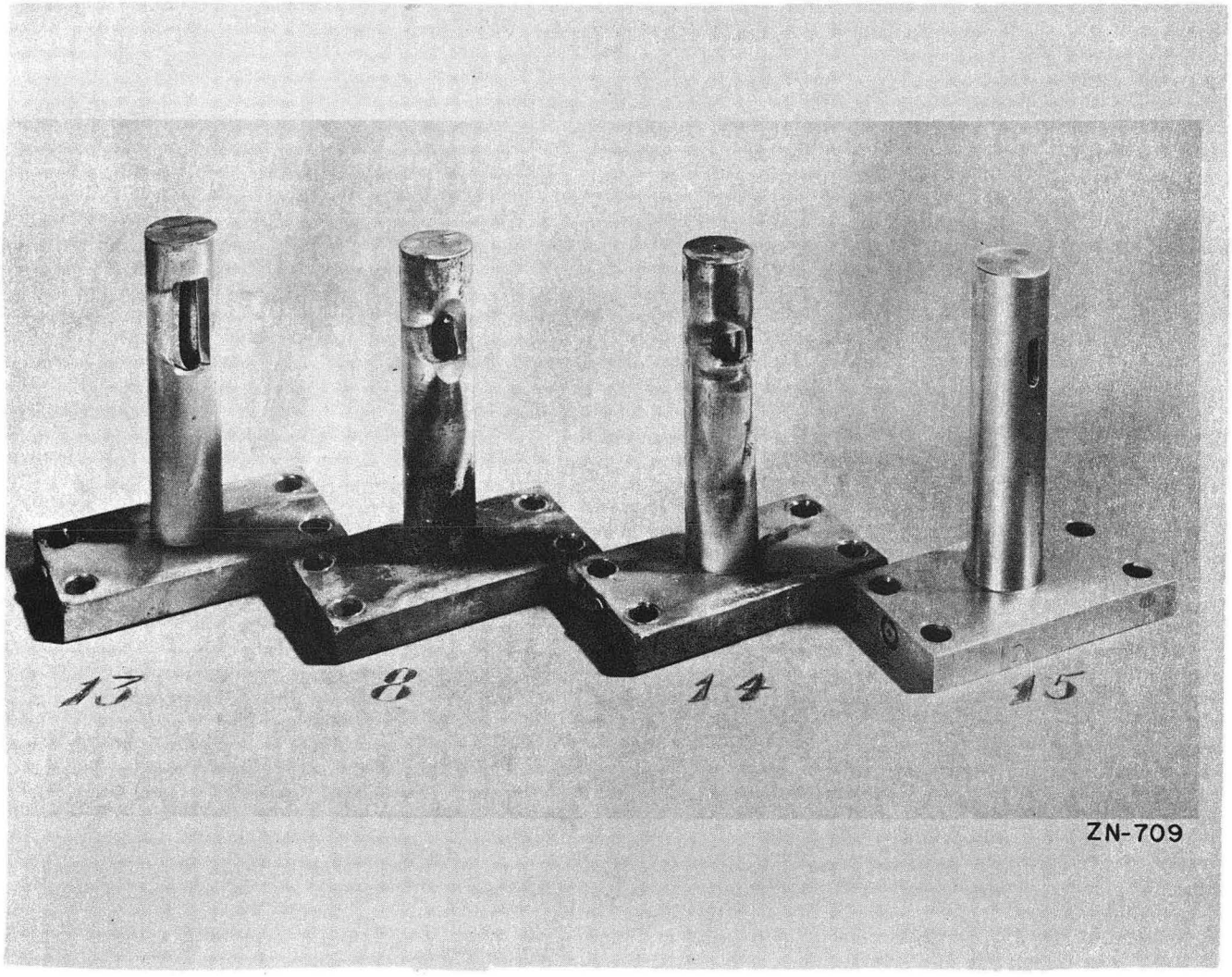

Fig. 1

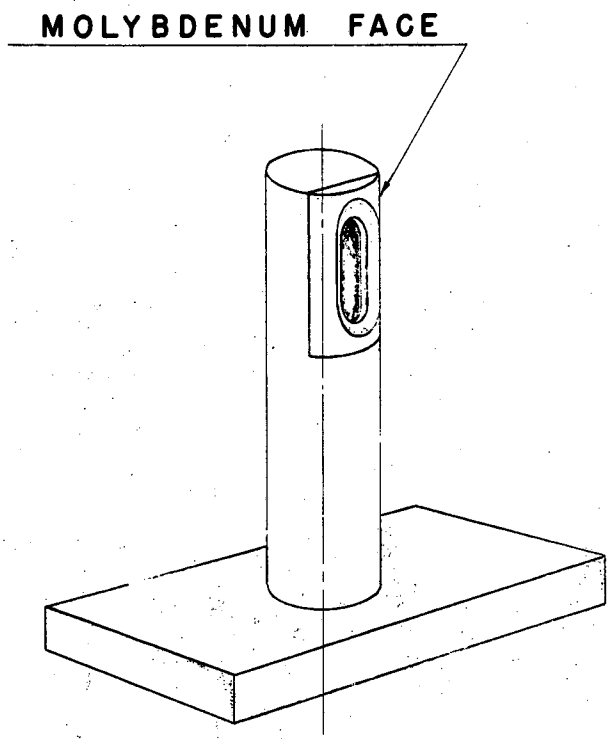

Fig. 2 Standard cone showing molybdenum insert in orifice region.

Electrical Design and Maintenance Kenneth D. Jenkins

Control-circuit modification. The control circuits of the 60-inch cyclotron were installed in 1944. Since that time many changes have been made in the operational equipment of the cyclotron. The usual procedure has been to alter the affected circuits to accommodate these changes. As a net result, there is a great amount of relay duplication and interconnecting wire loops. Approximately 20 percent of the relays and 10 percent of the interconnecting wires are to be removed. In addition, all the circuits are to be converted to one common system. All power except the control power is to be removed from the control room so that, when the control power is turned off, all circuits and wires in the control room will be dead. The magnet system is being revamped so that the auxiliary generator can be operated in series with the main magnet generator from one set of controls.

Arc power supply. Work is being done to determine a better type of power supply to operate the ion-source arc for multiple ion use. With protons and deuterons, almost any type of supply will do. There is still considerable doubt as to the best type of supply for heavier ions, such as alphas and carbons. The only rigid requirements on the power supply are that the arc be maintained at the approximate condition as set by the operator and that the arc supply and the ion source should be protected from surges and shorts. The power supply that has been in use for the past four years is a current-regulated supply using a hard tube series regulator. A voltage-limiting control is used to hold the voltage down when the arc goes out. A variac is used to reduce the primary power for low-power arcs.

In May, 1953, the arc power supply was moved from the previous location in the control room to a new location in the cyclotron room. During the changeover, a simplified supply was used which had the same voltage current characteristics as the regular supply, but with a primary thyrotron control instead of the hard tube series regulator. This new supply caused various breakdowns, mostly because of surges of voltage and current, even when the arc had a 20-ohm limiting resistor in series. A modification of our previous supply (more current-carrying capacity) was put back in and the arc source troubles were reduced back to normal. A careful check on the operating procedure with an alpha arc showed that, for the best beam, the current regulator was saturated so that the arc was running essentially with a series load resistor. The only function of the regulator was to prevent voltage and current surges, as it had both an upper voltage and current limit. Both limits could be close to the operating voltage and current of the arc. Further studies are being made to determine the best all-round arc supply for all types of particles.

Dee Voltage Wave Shape G. Bernard Rossi

A proposal has been considered for some time for changing the rf dee-voltage wave shape of the 60-inch cyclotron. This is based on the fact that specific benefits would be derived from the dee voltage shape's being square rather than sinusoidal. Specifically, with such a wave shape fewer revolutions would be required to accelerate an ion to peak energy; a greater ion acceptance angle would be achieved; an increased phase stability would be expected. In general, larger beams with less energy spread and reduced starting centers should be obtained with decreased dee voltages.

The difficulty of obtaining a square wave with attendant rf circuit Q's of 3000-5000 is met by designing the rf system so that a mixing of the fundamental sinusoidal frequency (11.6 megacycles) and the third harmonic (34.8 megacycles) can be effected. Along the dee, this mixing must be 180 degrees out of phase so that an approach to a square wave can be realized as shown in Fig. 1. By varying the amplitude of the third harmonic with respect to the fundamental, one can closely approach a flat-top wave with sloped leading edges.

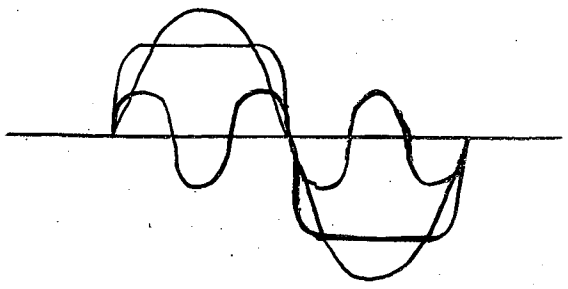

Fig. 1

Recent checks have been made on the 60-inch cyclotron rf circuit to study the feasibility of such mixing, with the finding that little disturbance of the fundamental conditions results from added components necessary to resonate the third harmonic. During the tests the geometry shown in Fig. 2 was used.

The distance, A, was varied over a wide range and the stub resonant frequency was measured. Figure 4 indicates the resulting fundamental frequency change for various lengths of A and the resonant frequency of the stub for these lengths. Schematically, Fig. 3 shows the electrical equivalents of the rf sections involved.

The results of this initial check indicate that such a mixing can be easily accomplished and that the required powers can be realized. The Q's of both the dee-stem circuits and the stub lines were measured and indicate values of $Q_{dee} = 3500$ and $Q_{stub} = 10,500$.

To further check this proposal with minimum disturbance to present operating conditions, plans have been made to install two stub lines similar to those used in the initial checks. One stub member can be driven with a separate oscillator whose excitation is derived from the fundamental oscillator as shown in Fig. 5.

Other proposals are under consideration for a more permanent installation that would eliminate the need for additional stubs and a separate third-harmonic oscillator. This type of installation would require greater changes in the present equipment than is planned for a preliminary test.

The preliminary checks on this proposal were made under the supervision of K. D. Jenkins, W. B. Jones and C. A. Corum of the 60-inch cyclotron staff; a theoretical review was made by the 184-inch Theoretical Group under Dr. David Judd.

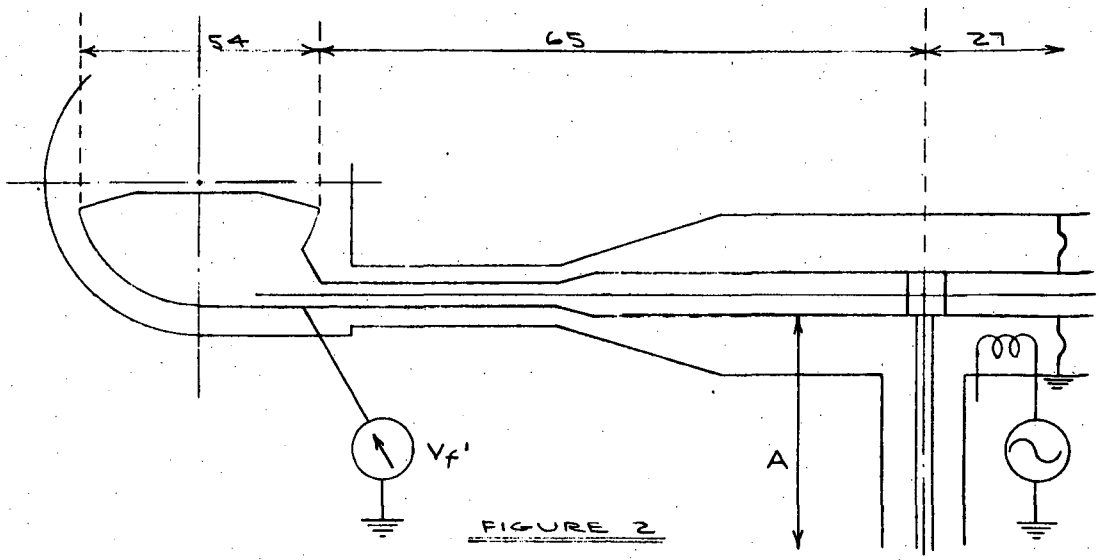

FIGURE 2

MU-6152

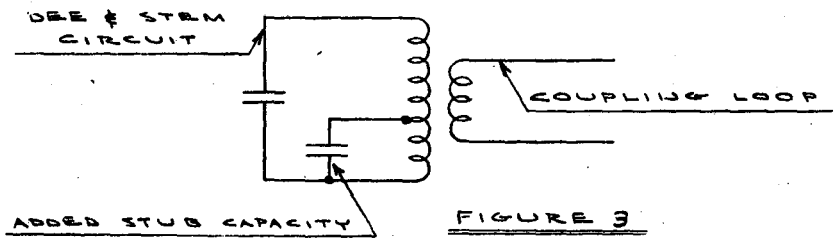

FIGURE 3

MU-6153

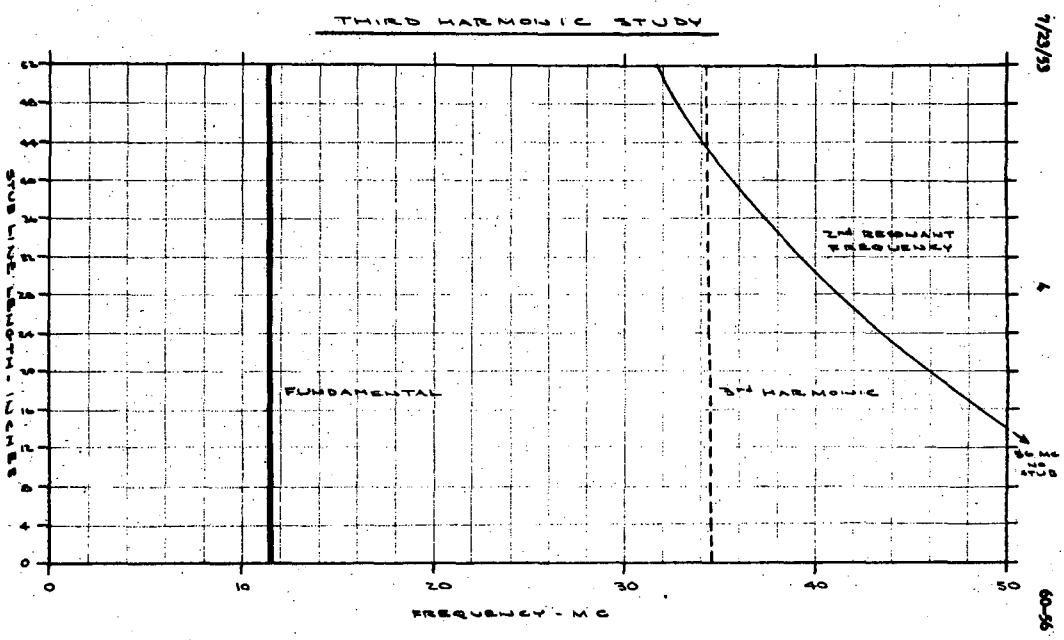

FIGURE 4

MU-6154

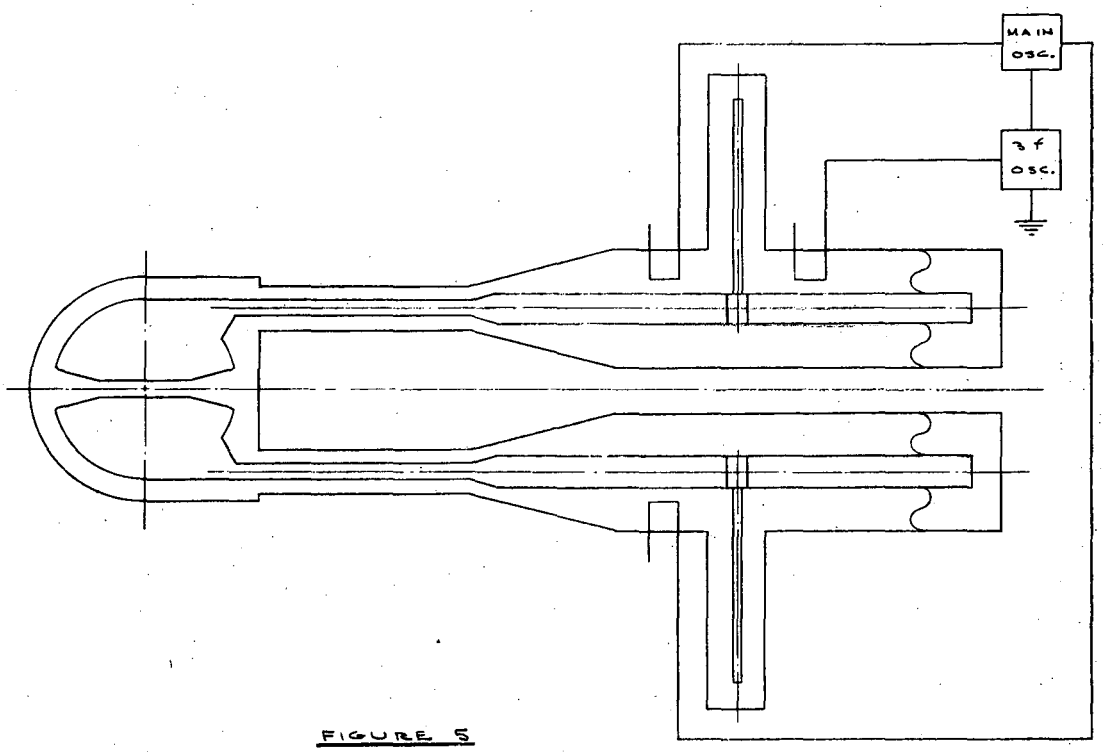

FIGURE 5

Proposed Third Harmonic Test Circuit

MU-6197

Synchrotron

George McFarland

The synchrotron accelerator and the electron linear accelerator have both operated satisfactorily during this report period. No modifications of the accelerators took place. This group's major effort has been devoted to design, mockups, and tests of the electron linear accelerator for Livermore.

Linear Accelerator and Van de Graaff

J. D. Gow

Modification R. D. Watt

The linear accelerator and Van de Graaff operated on a normal schedule during this period until July 6. On the night of July 6, trouble developed with the Van de Graaff. Upon opening the machine, it was discovered that all six textolite supports had failed mechanically. These members had broken about one inch inside the aluminum sleeves that fasten them into the high-voltage terminal. There was evidence on further disassembly that at least two and possibly more of the supports had been cracked for some time. Since a complete set of textolite tubes of the required size was on hand, the work of rebuilding the machine was started immediately. During this shutdown, the control system, which used 28 volt motors and a selector system operated by two strings, is being replaced by a system of eleven strings. These will directly actuate the desired controls in the high-voltage terminal. It is expected that the machine will be returned to operation during the first week in August.

It is planned to install a set of diagonal braces in the upper half of the machine at a later date. These should relieve the bending moment at the point of entrance of the textolite into the high-voltage terminal, thereby preventing future mechanical failures of the type experienced.

The new control system, mentioned above, replaces 40 relays, 22 microswitches, and 12 motors with a string control system which is mechanical in nature throughout its entire scope. Individual control over eight variacs has been obtained by spring loading these variacs so they tend to return to zero voltage and can be set to any desired voltage by pulling on a string that stretches from the high-voltage end to the ground end of the machine. At the ground end, the string winds around a pulley that is controlled by a shaft feeding through the side of the pressure tank to a handle outside. Eight variacs are controlled in this manner, as well as one 10-point metering switch and a 4-point switch that changes ion pulser channels from a normal channel to a spare channel.

STATISTICS:	Running time	69%
	Repair	29%
	Maintenance	2%

Bevatron

W. M. Brobeck

Construction Progress Ralph Peters

The schedule calls for over all pump-down of the vacuum system on August 24 and for magnet tests to start on September 28.

Magnet. All pole components have been assembled and by August 1 all lower pole bases and about half the pole tips were in place in the machine. About 10 percent of the pole face windings have been pulled into their conduit. The permanent terminals to the pole-face windings will not be installed, however, until after the completion of the vacuum and magnet tests. Temporary wooden air shrouding is being designed to be installed in time for cooling during the magnet tests.

Vacuum system. All tangent, transition, and curve tanks have been installed. Refrigerated baffles are being installed. All vacuum pumps and piping are in. After all pole tips are installed the curve tank tops can be replaced and the vacuum system can be pumped down.

Injector. The linear accelerator is operating satisfactorily with a beam of 9.6 Mev. Physics experiments are being done with this beam during the wait for completion of the rest of the Bevatron.

Ninety percent of the parts of the inflector are in procurement. The remainder are being designed.

Accelerating System. The accelerating electrode with its immediate power supply and plumbing is essentially all installed.

Design of components and their temperature control for the shunt house is being carried on.

Controls. The controls for the main M-G sets were moved down to the sub-switch gear room during this period. Work is proceeding on the installation of the operating and counting area controls.

Shielding. Shielding should be designed and ready for procurement by August 24.