AS-3

[redacted]

BNL-39

Progress Report

July 1 through December 31, 1949

BROOKHAVEN NATIONAL LABORATORY

Upton, N.Y.

Copies available at 45 cents
from the
TECHNICAL INFORMATION DIVISION, ORE
UNITED STATES ATOMIC ENERGY COMMISSION
OAK RIDGE, TENNESSEE

AEC, Oak Ridge, Tenn.-4-7-50--475-A18192

Progress Report

July 1 through December 31, 1949

BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York

This report, submitted under the terms of Contract #AT-30-2-GEN-16, between Associated Universities, Inc. and the Atomic Energy Commission, covers the interval June 30 - December 31, 1949. It contains a summary of research in progress at the Brookhaven National Laboratory and outlines the Laboratory's future program. The next issue will be an annual report covering the calendar year 1950.

Printed at Upton, New York, for distribution to persons and organizations associated with the national atomic energy program.

January 1, 1950 1500 copies

Cosmotron magnet section from test block

CONTENTS

Part I - Report of Associated Universities, Inc. 1

Part II - Report of Brookhaven National Laboratory

Introduction 8

Physical Sciences and Engineering

Physics 13
Electronics and instrumentation 34
Accelerator development and construction 39
Chemistry 47
Reactor science and engineering 62

Life Sciences

Biology 73
Medicine 83

Radiation Protection

Health physics 89
Meteorology 91
Geological studies 95

Direct Services

Information and publications 96
Photography and graphic arts 97
Drafting 98
Shops 99

Administration and Maintenance

Architectural planning and plant maintenance 100
Business management 102
Personnel 105
Security and plant protection 106

Appendix - A. Unclassified publications, July 1 - December 31, 1949 108

B. Officers and scientific staff 118

PART ONE

ASSOCIATED UNIVERSITIES, INC.

Organization and Personnel

At the July meeting of the Board of Trustees, Dr. Eugene P. Wigner of Princeton University was elected a Trustee to represent that institution in place of Dr. Henry DeWolf Smyth. At the annual meeting in October, four new Trustees, nominated by their respective universities to take the places of retiring members of the Board, were elected as follows:

H. Keffer Hartline, Chairman, Department of Physiology, Johns Hopkins University, to replace Robert D. Fowler, Professor of Chemistry,
C.N. Hugh Long, Dean, School of Medicine, Yale University, to replace Edmund W. Sinnott, Chairman, Division of Sciences,
Foster C. Nix, Professor of Physics, University of Pennsylvania, to replace W.E. Stephens, Professor of Physics,
Donald W. Gilbert, Provost, University of Rochester, to replace Raymond L. Thompson, Treasurer.

The members of the Board of Trustees are now as follows:

Frank D. Fackenthal, President

Columbia University

George B. Pegram, Vice President of the University
I.I. Rabi, Professor of Physics

Cornell University

Franklin A. Long, Professor of Chemistry
Theodore P. Wright, Vice President for Research

Harvard University

A. Baird Hastings, Professor of Biological Chemistry, School of Medicine
Edward Reynolds, Administrative Vice President

Massachusetts Institute of Technology

Thomas K. Sherwood, Dean of Engineering
Jerrold R. Zacharias, Director of the Laboratory for Nuclear Science and Engineering

University of Pennsylvania

William H. DuBarry, Executive Vice President
Foster C. Nix, Professor of Physics

Johns Hopkins University

H. Keffer Hartline, Chairman, Department of Physiology
P. Stewart Macaulay, Provost

Princeton University

George A. Brakeley, Vice President and Treasurer
Eugene P. Wigner, Professor of Mathematical Physics

University of Rochester

George B. Collins, Chairman, Department of Physics
Donald W. Gilbert, Provost

Yale University

C.N. Hugh Long, Dean, School of Medicine
William W. Watson, Chairman, Department of Physics

Officers of the Corporation were reelected:*

Frank D. Fackenthal, President

Eldon C. Shoup, Executive Vice President (resident)

James S. Alexander, Treasurer (Guaranty Trust Co. of N.Y.)

Leland J. Haworth, Director of Brookhaven National Laboratory (resident)

Joseph McDonough, Asst. Treasurer (Guaranty Trust Co. of N.Y.)

Charles F. Dunbar, Secretary and Asst. Treasurer (resident)

John D. Jameson, Asst. Treasurer and Asst. Secretary (resident)

Advisory and Visiting Committees

The Engineering Advisory Committee met on July 11 and, having reviewed the status of the nuclear reactor in detail, endorsed the general plans for appraisal and cure of its known inadequacies, and recommended that the study of other principal features of the reactor structure itself, which had already started, be both broad and intensive.

The Advisory Committee for Biology and Medicine met on July 13. It reviewed the staffs and activities of the Biology and Medical Departments and expressed satisfaction with their plans and progress.

Following the decision in April to review the system of advisory committees serving the Board of Trustees, a subcommittee of the Board recommended in July

*See end of report for full list of the officers and scientific staff.

that the advisory committees be discontinued and that, in their place, five visiting committees be established. This plan was ratified in October, and the committees have been appointed as follows:

For the Biology Department:

Chairman, Edmund W. Sinnott, Chairman, Division of Sciences, Yale University
Richard Bradfield, Head, Department of Agronomy, Cornell University
J. Walter Wilson, Chairman, Department of Biology, Brown University
H.G. Wood, Chairman, Department of Biochemistry, Western Reserve University
J.R. Loofbourow, Executive Officer, Department of Biology, Massachusetts Institute of Technology

For the Chemistry Department:

Chairman, George B. Kistiakowsky, Professor of Chemistry, Harvard University
David Harker, Research Laboratory, General Electric Company
Ralph Connor, Vice President, Rohm and Haas Company
Louis P. Hammett, Professor of Chemistry, Columbia University
Joseph W. Kennedy, Professor of Chemistry, Washington University, St. Louis

For the Medical Department:

Chairman, I.S. Ravdin, Professor of Surgery, University of Pennsylvania
Herrman L. Blumgart, Professor of Medicine, School of Medicine, Harvard University
Wallace O. Fenn, Associate Dean, School of Medicine and Dentistry, University of Rochester
Colin M. MacLeod, Chairman, Department of Microbiology, New York University
G. Failla, Director, Radiological Research Laboratory, Columbia University

For the Physics Department:

Chairman, Jerrold R. Zacharias, Director of the Laboratory for Nuclear Science and Engineering, Massachusetts Institute of Technology
Charles H. Townes, Associate Professor of Physics, Columbia University
C.G. Montgomery, Associate Professor of Physics, Yale University
Hans A. Bethe, Professor of Physics, Cornell University
Victor F. Weisskopf, Professor of Physics, Massachusetts Institute of Technology

For the Reactor Science and Engineering Department:

Chairman, Thomas B. Drew, Executive Officer, Department of Chemical Engineering, Columbia University
Manson Benedict, Director of Process Development, Hydrocarbon Research, Inc.

W.G. Whitman, Professor of Chemical Engineering, in charge of the Department, Massachusetts Institute of Technology
Harvey Brooks, Associate Division Head, Research Laboratory, General Electric Company
Eugene P. Wigner, Professor of Mathematical Physics, Princeton University
John Chipman, Professor of Metallurgy, in charge of the Department, Massachusetts Institute of Technology
Augustus B. Kinzel, President, Union Carbide and Carbon Research Laboratories, Inc.

The initial steps have been taken in the establishment of the Brookhaven National Laboratory program. Major facilities are nearing completion. Research projects are under way, and will be extended as the facilities themselves are ready for use. The new visiting committees, like those often utilized by universities, will advise the Trustees about the plans and progress of specific departments, and will more nearly suit the Laboratory's present circumstances and the Trustees' needs than the earlier advisory committees, which reflected the division between major scientific disciplines. The committees have been appointed for an initial one-year term, but it is intended to eventually make appointments on a staggered rotation basis. This will spread the influence of the Laboratory and bring directly into her councils a continuing stream of scientists from outside, as well as from inside, the Associated Universities family. Of the present 27 visiting committee members, 18 are from the staffs of the Associated Universities, while 9 are from other universities and industrial companies.

It is expected that the visiting committees will serve two principal purposes: For the benefit of the Trustees and Officers, they will make an objective appraisal of the staff, work, and progress of the Laboratory departments, and they will be available to the Director for consultation. In addition, of course, they will be a source of informal advice and consultation for the chairmen and staffs of the departments themselves. It is expected that each committee will render an annual report to the Trustees concerning the department to which it is attached, based as far as possible upon personal visits, as well as upon discussions of Laboratory problems in committee.

Trustees Report

Acting upon recommendations of the Trustees in April, the officers prepared for consideration in July an outline of a report of contractor's operating experience under the contract with the Atomic Energy Commission. In July, a subcommittee of the Board of Trustees was appointed to prepare this report in final form for submission to the Board during 1950. An advanced, but not final, version will be considered by the Board at its meeting in January.

Housing Procurement

Delay in completion of the Laboratory's major facilities has resulted in a slower increase of visiting scientific staff than previously expected. The shortage of rental

housing nearby is, therefore, a less pressing problem than it was. It requires an eventual solution, however, if the Laboratory is to attract the quality and numbers of on-leave scientific staff members it will need. Plans have been submitted for approval by the Commission to construct about twenty houses in a neighboring village on land acquired for the purpose. It is planned to rent these units at rates comparable to the going rates in the area, and to reserve them for the use of on-leave scientific staff. Except for this group and the short term visitors, most staff members have found homes of generally suitable description in villages within twenty-five miles of the Laboratory. This result is in accordance with the Laboratory's original policy of encouraging individuals to find their homes in the settled communities.

Fiscal

Fiscal matters of interest during the period included the following:

1. At the Commission's request there was adopted, in July, a modified form of accrual accounting involving capitalization of assets and establishment of depreciation records. The balance sheet and operating accounts submitted as of July 31 gave effect of these changes. Assets were capitalized on the basis of appraisals and calculations carefully made by Laboratory engineers and fiscal officers of the useful life and accrued depreciation applying to the several categories of durable property. By agreement with the Commission, depreciation is accumulated on a Laboratory-wide basis for each category of property, and is not distributed departmentally.

2. In December, also at the request of the Commission, the Laboratory's budgets and accounts were shifted from an expenditure and commitment basis to one reflecting incurred costs. This change was made necessary by the Commission's agreement with the Bureau of the Budget and the committees of Congress to adjust its accounting, budgeting, and reporting methods, so that its financial reports will more nearly resemble those of the large production enterprises of American industry and give information of more use to the Congress and to the people in judging the efficacy of the Commission's efforts. In making these changes, it was necessary to rework the Laboratory's reports of expenditures for the 1949 fiscal year and to recalculate budgets for the fiscal year 1950. Reports on the new basis were submitted during the month of December.

3. With the Commission's approval, negotiations have been undertaken with Liberty Mutual Insurance Company to increase the limits of insurance coverage against claims arising from occupational disease, public liability, and property damage. The new limits reflect more accurately the probable amount of claims in case accidents occur during normal operations. It is expected that these negotiations will be completed during 1950.

4. On October 17, 1949, Messrs. Haskins and Sells, the corporation's auditors, submitted their report of their full audit of the Corporation's accounts as of June 30, 1949, accompanied by an unqualified certificate.

Conference with Representatives of Other University Contractors

In October, at Los Alamos, was held the second of what is hoped to be a regular series of meetings of the representatives of the principal university contractors having responsibility for major installations sponsored by the Atomic Energy Commission. During two days as guests of the Los Alamos Scientific Laboratory, representatives from the Radiation Laboratory at Berkeley, University of California, Argonne National Laboratory, University of Chicago, Brookhaven National Laboratory, and Associated Universities, Inc. discussed a wide range of administrative subjects concerning which they have common problems. The results of these conferences are valuable in at least two respects: They assist each contractor to improve its operations through utilization of the experience of others in similar circumstances; also, frank discussions of operations under Commission contracts improve a contractor's ability to assist the Commission to obtain the best results from the scheme of contract operations.

Public Education

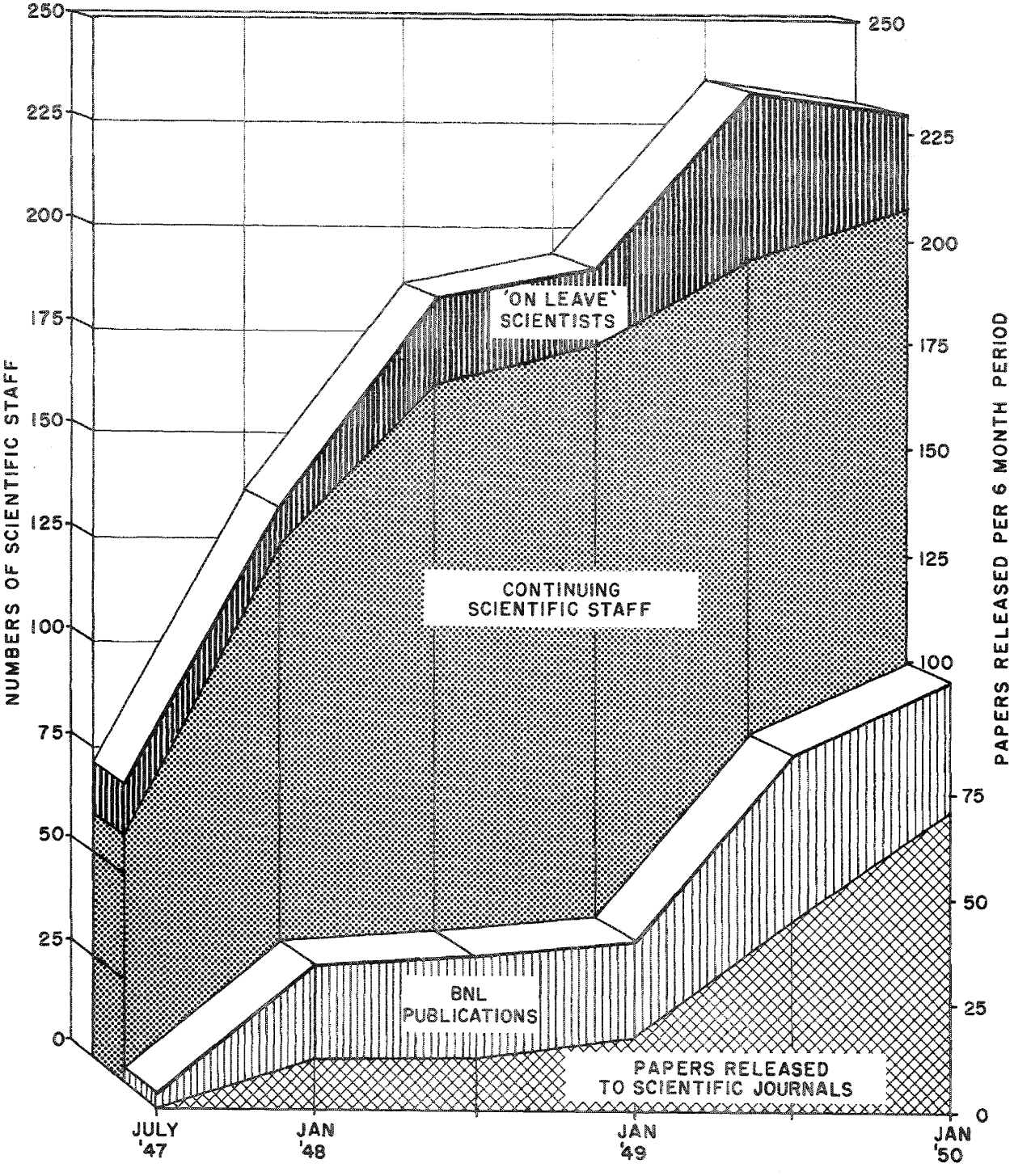
A full report of the public education program was made to the Trustees at their meeting in July. The Trustees reaffirmed their interest in the general objectives of the program and their belief that certain limitations upon the means by which they should be sought were appropriate.

Associated Universities, Inc. is the means by which the universities and colleges of the northeast cooperate with the Atomic Energy Commission for the successful prosecution of a program of nuclear research and development. Since its financial support comes entirely from the taxpayers of the United States, it has a primary obligation to make factual reports of its plans, progress, and accomplishments. It has a further duty to explain its operations sufficiently well to its neighbors, so that they will value it as an asset rather than a liability. These are the principal purposes of the public education program. In addition, however, as a member of the family of Atomic Energy Commission contractors, Associated Universities, Inc. has the duty and opportunity to contribute to general enlightenment of the people about the atomic energy development in the broadest sense. This contribution must be made within well-defined limits of policy. Public funds must not be used directly or indirectly to influence legislation. Crusading and propagandizing on controversial matters must be avoided. Also, it is inappropriate for federal agencies or their contractors to duplicate the efforts of the established education system. It is the function of the existing educational establishments to organize or prepare material for the promotion of particular educational objectives.

Within these limits, however, the Trustees believe it to be the duty of Associated Universities, Inc. to explore possibilities for educational activities by others, to suggest profitable ways by which existing institutions may undertake educational programs in the atomic energy field, to serve as a clearing house for information among such institutions, and, in general, to do what is possible and appropriate to accelerate the natural evolution of educational philosophy and practice with respect to atomic energy.

In practice, the prosecution of this program since July 1 has been sharply restricted by temporary depletion of the small staff available. Furthermore, it was necessary to retire the Nuclear Energy Exhibit for the time being until certain decisions essential to its continued operations were made. However, a number of interesting possibilities for stimulating the educational activity of others have been explored. Some of them are expected to bear fruit in 1950. Most promising are those which emphasize the development of materials and other opportunities by which teachers, especially in the social sciences, will be enabled to increase their attention to atomic energy subject matter in the classroom.

Relations between the Laboratory and its Long Island neighbors continue good.



BROOKHAVEN NATIONAL LABORATORY
SCIENTIFIC STAFF and PUBLICATIONS

Publications do not include abstracts of papers presented at meetings.

PART TWO

REPORT OF BROOKHAVEN NATIONAL LABORATORY

INTRODUCTION

The Brookhaven National Laboratory is approaching the end of its third year of operation, with a total, as of December 31, 1949, of 1447 employees. It has assembled a competent scientific staff of 230 scientists and engineers, of whom approximately 145 (including 24 visitors) are actively engaged in direct research. Although the incentive of the special facilities is not yet present, a substantial beginning has been made with respect to participation on the Laboratory staff of scientists from other institutions. Approximately 140 visitors (not including guests and consultants) from about 48 scientific institutions have participated in the work of the Laboratory since its founding. Consulting scientists and engineers, during this period, numbered 152.

Scientific activity has kept pace with the growth of the staff. During the past six months, there has been a gradual transition from intensive design and construction of major facilities with their accompanying buildings and laboratories to a condition in which research is the predominating activity. Comprehensive research programs are well under way in physics, chemistry, and biology; and other programs have been more recently established in medicine, chemical engineering, metallurgy, and various fields of applied physics, chemistry, and engineering.

The acceleration in the pace of the research program in recent months is best illustrated by the accompanying chart of scientific staff and publications. Since the beginning of the Laboratory, members of the staff have published 182 scientific papers, exclusive of abstracts, of which approximately 45% were completed in the past six months. The rate of acceleration is expected to increase still further as new research programs, already planned and equipped and now awaiting use of the nearly completed facilities, get under way within the next few months.

Several changes have taken place during the past six months in the organization of the Laboratory. On September 1, the Business Manager temporarily relinquished his functions to serve as coordinator of all work remaining to be done on the reactor complex and hot laboratory, and to act as a channel of formal communication with the firm in charge of construction. His regular duties are being discharged by the Budget Officer.

On April 1, Dr. George B. Collins, now Chairman of the Physics Department at the University of Rochester, will succeed Dr. Milton G. White as Head of the Accelerator Project. Dr. White has returned to full-time work at Princeton University; in the interim, Dr. Leland J. Haworth, Director of the Laboratory, will be in charge of the Project.

Dr. Donald D. Van Slyke has served full time since September 15 as Assistant Director for Biology and Medicine.

Changes in the Medical Department have included the activation of two new divisions, Bacteriology and Virology, and Biochemistry, on July 1 and September 1, respectively. Their heads, Drs. William M. Hale and Donald D. Van Slyke, have reported for full-time duty. Hereafter, the Medical Practice Division will be known as the Division of Industrial Medicine. Initial appointments to the remaining Division of Physiology are expected within the next few months.

Dennis Puleston was appointed Head of the Information and Publications Division following the death of Hyman H. Goldsmith.

Dr. Lincoln R. Thiesmeyer, Executive Assistant to the Director, resigned December 31, to become President of the Canadian Pulp and Paper Research Institute.

The Laboratory staff deeply regrets the deaths of three of its members during the past six months. Captain Robert D. Conrad, U.S.N. (Retired), formerly Assistant Director for Planning, died July 26 at Memorial Hospital, New York City, a victim of leukemia. Hyman H. Goldsmith, formerly Head of the Information and Publications Division, was fatally injured August 7 in a swimming accident in Vermont. Henry G. Brewer, Jr., of the Electronics and Instrumentation Division, died of poliomyelitis on August 14, while on vacation.

As of December 31, total Laboratory personnel of 1447 represented an increase of 36, or 2.2%, over June 30 figures. During the same period, the continuing scientific staff increased from 196 to 209, most of this increase occurring in the direct research group. At the end of the calendar year, the visiting scientific staff numbered 24. This December 31 total of 233 scientists includes 109 in physical sciences, 31 in reactor science and engineering research, 49 in life sciences, and 61 in supporting scientific activities. An additional total of 113 visiting, temporary, or guest scientists, representing affiliations with approximately 40 research institutions, participated in the work of the Laboratory for a continuous period of two weeks or more during the last half of 1949. Consultant contracts, as of December 31, were held by 129 scientists from 37 research institutions.

The number of technicians and laboratory assistants increased 11.8%, whereas clerical personnel decreased by 5.3%. These changes gave a ratio of scientists to nonscientists, as of December 31, of 1 to 5.2. This ratio, therefore, continues to decline, having been 1 to 5.4 on June 30, 1949; 1 to 5.8 on December 31, 1948; and 1 to 7.3 on December 31, 1947.

Significant changes have occurred in financial plans during the six months. During the fall of 1949, it became apparent that adjustments would be necessary in both the Operating and the Facilities Budgets. It was evident that facilities which had previously been budgeted, namely the nuclear reactor complex, the cyclotron, and the Cosmotron, would require larger amounts than had been set aside for their completion. Also, it was apparent that delays incident to operating these facilities would be reflected in a slower growth of scientific personnel and equipment, supplies, and related costs. Consequently, after full discussions with the AEC, adjustments were

made, and the following sums were transferred from the Operating and Capital Equipment Budgets to defray facilities costs:

	Operating	Capital Equipment
September	$200,000	-
October	273,000	$ 77,000
December	513,000	200,000
Total	$986,000	$277,000

Concurrently with the transfer of funds from the Operating Budget, it was necessary to revise the individual budgets of each organizational unit in the Laboratory. At the same time, the revised organizational budgets were related to program amounts established by the AEC. The new amounts were set up on the Laboratory's books, and, as has been mentioned earlier, the monthly fiscal reports of the Laboratory now record costs by both organizational units and programs.

Substantial progress was made in the construction of facilities during the past six months. Progress in constructing the machines is described in the body of this report. With respect to new modified and unmodified building facilities, more than 200,000 square feet were placed in operation, and approximately 72,000 square feet were withdrawn from use. The building to house the Cosmotron, which is the largest single unit now under construction, was 56% complete and approximately on schedule as of December 31. The building which houses the 60-inch cyclotron and 3.5-Mev electrostatic accelerator, together with their offices, experimental room, and staff shops, was completed August 1, and has since been occupied.

Considerable expansion, rearrangement, and consolidation of Laboratory space took place during this period following the completion of building modifications. Several laboratories were completed for the life sciences. The new biology laboratory was finished early in December and is now in use. Alterations to provide the pathology and bacteriolcgy laboratories were finished in October and November, and both laboratories have been occupied.

Construction completed for the physical sciences included alteration of a former mess hall, finished in December, into which members of the cosmic-ray and nuclear mass groups of the Physics Department will move during January; the building to house the motor-generator for the high pressure cloud chamber, completed in November; and laboratory areas in both the reactor and the cyclotron - Van de Graaff buildings. A small laboratory was also built at 11,500 feet for cosmic-ray research in Colorado. Space formerly occupied by the Accelerator Project has been occupied by the Electronics Division.

During the past six months, the reactor, its building, and the auxiliary equipment necessary for its operation, such as fans, control equipment, stack, and cooling towers, were completed and turned over to the Laboratory by the contractor, with the exception of the following items: 1) hot laboratory construction; 2) certain items of duct and plenum chamber repairs; 3) adjustments to the reactor structure itself, and 4) furnishings for the reactor laboratories and hot laboratories. Preparations of the reactor site for winter conditions, which involve grading, road work, temporary

planting, sodding, and slope protection, was successfully accomplished, despite unfavorable weather in November and December.

A total of 27 unclassified and restricted reports, and 3 classified reports were published during the period since June 30. The former category included 7 technical reports, 2 internal reports, a conference report, and a progress report. Open literature publications in scientific and professional journals numbered 81 (including items in press and abstracts of papers presented at meetings of scientific societies).

Several specialized technical conferences have been held, at which a variety of institutions from various parts of the country were represented. Department seminars and colloquia have been scheduled regularly. Laboratory-wide seminars have also been instituted in which departmental heads have reported on work in progress.

For the past three years, members of the Laboratory staff have been acquainting the general public with the nature of the work at the Laboratory through personal contacts in the surrounding communities and through the filling of speaking engagements. In recent months, the number of requests for speakers has declined appreciably. This is due partly to a feeling of greater familiarity with the Laboratory and its program on the part of nearby communities.

During the six months interval covered by this report, 22 speakers addressed 34 organizations, as compared with 39 speakers who addressed 106 organizations in the previous review period. The estimated average audience was 185, owing primarily to the fact that there were several speakers who addressed audiences of over 1000.

Because experience showed that visiting groups interfered with the work in the laboratories, "visiting days" for such interested groups will be instituted. The first visiting day, for employees and their families, is planned for Saturday, January 28.

PHYSICAL SCIENCES AND ENGINEERING

PHYSICS

After a steady growth from the time of the organization of the Laboratory in 1947 and through the first half of 1949, the staff of the Physics Department has now reached a level of 95 people, about half of whom are scientists and half technical or administrative assistants. Thirty-two of the staff have doctorates or the equivalent. Forty-two scientists are on permanent or term appointments; eleven are on leave for extended periods from university physics departments as visitors to the Laboratory. Among the latter group are 8 graduate students engaged in doctoral investigations. During the past six months, 12 scientists from other laboratories have visited the Laboratory for short periods for the purpose of participating in the research program of the Physics Department.

Twelve of the scientific staff with 4 technicians are studying transformations and excitations of nuclei by irradiation and radioactive processes; 9 scientists with 4 technicians are working on neutron optics, the measurement of neutron cross sections of nuclei, and on problems in solid state physics; 6 scientists with 3 technicians are working on the masses and the moments (mechanical, magnetic dipole, and electric quadrupole) of stable and long-lived nuclei; 14 scientists with 25 technicians are working on problems in cosmic rays and the physics of high energy elementary particles; and 5 scientists with 4 technicians are working on theoretical problems. Since July, 35 papers have been submitted for publication in scientific journals. Twelve of these were complete articles, 11 were letters and notes, 11 were abstracts of papers presented at scientific meetings, and 1 was a Laboratory publication.

During this period, the Physics Department has taken occupancy of laboratory space in the reactor building and in the cyclotron - Van de Graaff building. The west wing of the old mess hall at 53 Brookhaven Avenue has been renovated as laboratory and office space, and is now occupied by the Cosmic Ray Group. The central section of the same building has been renovated, and is nearly ready for occupancy by the Nuclear Mass Group. To meet current requirements of the cosmic ray research program, a modest cabin laboratory has been built at Berthoud Pass in Colorado, at an altitude of 11,500 feet above sea level. Work will begin there in January.

Although none of the major research facilities of the Laboratory are yet in operation, a number of researches have been carried out by the Department utilizing radiation sources at other institutions. Among these are the cyclotrons at Massachusetts Institute of Technology, Princeton University, and the Carnegie Institution of Washington; the electrostatic accelerator at the Carnegie Institution of Washington; the nuclear reactors at Oak Ridge National Laboratory and at Argonne National Laboratory; and the betatrons at the Picatinny Arsenal of the U.S. Army Ordnance Department and at the University of Pennsylvania. Cosmic-ray researches have been carried out on

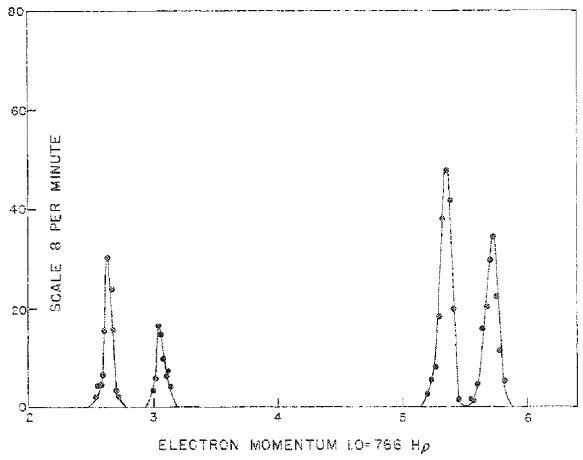
flights of a B-29 airplane operated by the Air Materiel Command of the U.S. Air Force, and with balloon flights launched by the Aeronautical Research Laboratory of General Mills, Inc., under the auspices of the Office of Naval Research. Some of the latter were flown in the Caribbean from the deck of a Navy aircraft carrier, others from Camp Ripley, Minnesota, and the University of Minnesota airport.

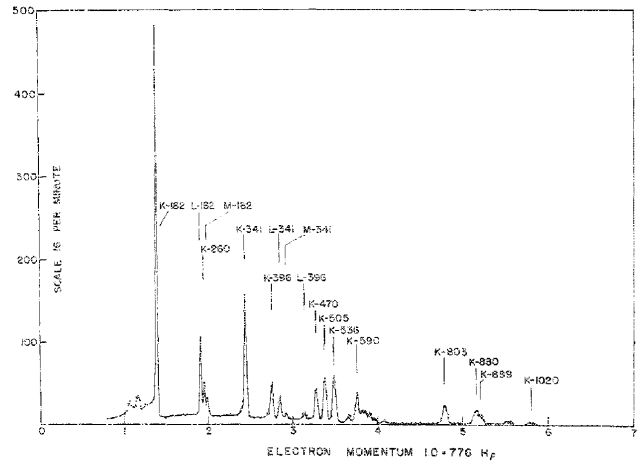
Contracts for assistance in developing and building instruments for the research programs of the Department have been negotiated with industrial firms and with universities. One, with Columbia University, is for a time-of-flight neutron spectrometer to be attached to the 60-inch cyclotron. Under another Columbia contract of longer standing, nuclear emulsion techniques are being developed for research with neutrons and high energy particles. A contract with the Airborne Instruments Laboratory and the Thorne-Browne Company for the construction of a low-speed neutron shutter for time-of-flight work in the region of thermal neutron velocities from the pile spectrum has been completed, and the instruments have been delivered. The Thorne-Browne Company has been given another contract for the construction of a spinning disk foil holder for studying neutron resonance widths. Under a previously existing contract, the Polaroid Corporation has assisted in developing plastic arc holders for cloud chamber illumination.

During the academic year, the Department has sponsored a series of weekly conferences which have alternated between discussions of researches carried on by staff members and of results obtained in other laboratories. In a series of weekly lectures sponsored by the Department, both staff members and visitors have expounded selected subjects of general interest to the Department and to the Laboratory. Conferences in more restricted fields have been conducted regularly by the Cosmic Ray Group and by the Theoretical Group. During the summer months, semiweekly lectures were given on selected topics by distinguished visiting scientists.

Excited States of Nuclei

The progress and program of the research activities of the Physics Department will be described in the order of the subjects already listed, the first of these being the transformation and excitation of nuclei by irradiation and by radioactive processes. Until the laws of nuclear structure are better understood, it will be important to assemble as much empirical data as possible on the properties of the various nuclides, for, just as the empirical study of spectroscopy led to the understanding of the laws of atomic structure, so one may hope that the empirical study of the stationary energy levels of the nuclides may serve as the basis for the clarification of the principles of nuclear structure. Facts of interest include: 1) the energy levels deduced from the transition energies emitted as gamma rays, and 2) the spin characteristics of each level. The latter may be inferred from the probabilities for transitions between levels and from the multipolarity of the emitted gamma rays determined from the ratio of the yields from the various shells of electrons emitted by internal conversion (the ejection of an electron from the same atom with energy equal to that of the gamma ray less the binding energy of the electron). Since the transition probabilities are frequently so high as to correspond to half-lives too short to measure by known methods, particular interest attaches to those excited states of nuclei which live long enough to be measured ($>10^{-9}$ sec), the so-called isomeric states.





Left: Gamma-ray spectrum of Pb^{204} obtained with the magnetic lens spectrometer. Each pair of lines is produced by a single gamma ray which has been internally converted in the K and L shells, respectively. The two gamma rays shown have energies at 374 kev and 905 kev.

Right: Gamma-ray spectrum of Bi^{206}. Some of the gamma rays are represented by lines produced by internal conversion in the K, L, and M shells, while others show only the K component.

Isomerism in Even-Even Nuclei

Among the latest findings is a case of double isomerism in Pb^{204}, an "even-even" nucleus (even N, even Z; a type for which isomerism is rare). This nuclide is produced by K capture from Bi^{204} with a 12-hour half-life. In the first step, the excited lead nucleus decays with a 68-min half-life by emitting a 905-kev gamma ray. This is followed by a second transition to the ground state in which a 374-kev gamma ray is emitted with a half-life of 0.3 μsec (measured by delayed coincidences). The first gamma ray is 10% internally converted, and has a K/L ratio of 3 to 2, indicating a multipolarity of the gamma ray of about 2^6. The second gamma ray is 5% internally converted, with a K/L ratio of 2 to 1, indicating a multipolarity of 2^3. Thus, the spin in the higher excited state, which has the remarkably high excitation energy of 1279 kev, must be between 7 and 9, and that in the first excited state must be 2 or 3. It is hoped to learn more about this question from a study of the angular correlation between the first and second gamma rays. Experiments are now in progress to find out whether this correlation is "remembered" for times of the order of 1 μsec and whether it can be affected by a magnetic field. In this way, the magnetic moments of an excited nuclear state might prove measurable. In these experiments, the Pb^{204} was separated chemically from its parent, Bi^{204}, which had been produced by deuteron bombardment of lead in the Massachusetts Institute of Technology cyclotron; the gamma-ray energies were determined in a lens spectrometer from energies of the electrons produced by internal conversion. An additional gamma ray of 217 kev has been found in a study of Bi^{204} in equilibrium with its daughter Pb^{204}. Other weaker lines may have been missed because of their being masked by the unusually rich gamma spectrum of Bi^{206}. The latter nuclide emits internal conversion electrons corresponding to gamma-ray energies of 182, 234, 260,

341, 396, 470, 505, 536, 590, 803, 880, 889, 1020, 1097, and 1720 kev (A.W. Sunyar, D.E. Alburger, G. Friedlander, M. Goldhaber, G. Scharff-Goldhaber).

Besides Pb^{204}, the only other even-even nucleus for which isomerism has been reported is Ge^{72}, which has a metastable state at 0.7 Mev with a half-life of 1/3 μsec. This state was previously observed following beta decay of Ga^{72}. The isomeric transition has been interpreted as a zero-zero transition (between two states of zero spin); such a transition cannot take place with gamma emission, but is completely converted internally. It was of interest to see whether this excited state could also be produced in other ways. As^{72} was therefore obtained by deuteron bombardment (d,2n) of Ge^{72} at Massachusetts Institute of Technology, and by proton bombardment (p,n) of the separated Ge^{72} isotope at Princeton University. It was shown by delayed coincidences that the 1/3-μsec of the metastable Ge^{72} does indeed follow the positrons emitted by As^{72}# (A.W. Sunyar, G. Friedlander, M. Goldhaber).

Nuclear Gamma Rays of Low Energy

Since low energy gamma rays from excited nuclei are likely to have been missed, a search has been started using an argon-filled proportional counter with a thin Be window to measure the pulse height resulting from photoelectrons emitted within the counter by the gamma rays in question. In addition to the nuclear gamma ray, one may also observe X-rays from the same atom, since the electronic shells of the atom are depleted by internal conversion. Supplementary to measurements of pulse height, the energies of both gamma and X-radiations have been confirmed by finding in which elements the radiations suffer critical X-ray absorption. In a sample of Sm^{151}, separated from fission products, a gamma ray of 21 kev was found together with L X-radiation. In a sample of Gd produced by slow neutron bombardment of Gd at Oak Ridge and containing the Pb^{161} daughter of 5.5-day half-life, a 26-kev gamma ray decaying with approximately the same half-life was observed. In a sample of Pa^{231} the L_I, L_{II}, and L_{III} X-rays, and a 27-kev gamma ray were found; and in U^{234}, isotopically enriched at Oak Ridge, the L_I, L_{II}, and L_{III} X-rays were identified without finding a gamma ray. The finding of a 27-kev gamma ray from Pa^{231} enables one to explain the 24-kev electrons found by Teillac as internally converted M electrons. The L radiation from the U^{234} source is probably excited by a highly converted gamma-ray transition from the Io^{230} nucleus which is left in an excited state in about one-quarter of the alpha decays of U^{234}# (G. Scharff-Goldhaber, E. der Mateosian, M. McKeown, A.W. Sunyar).

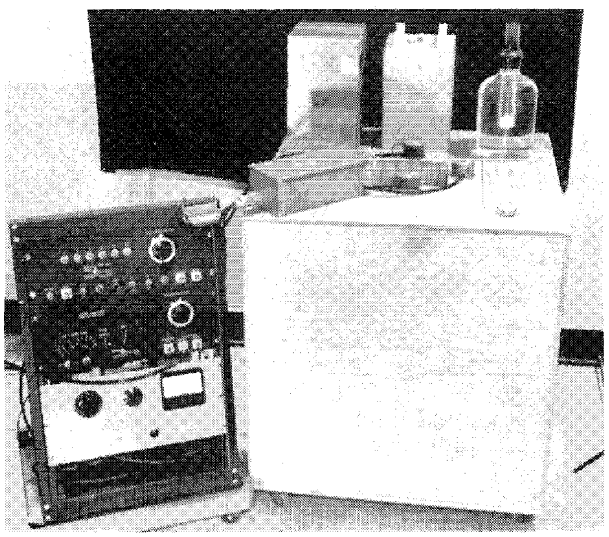
Photoneutron Detector

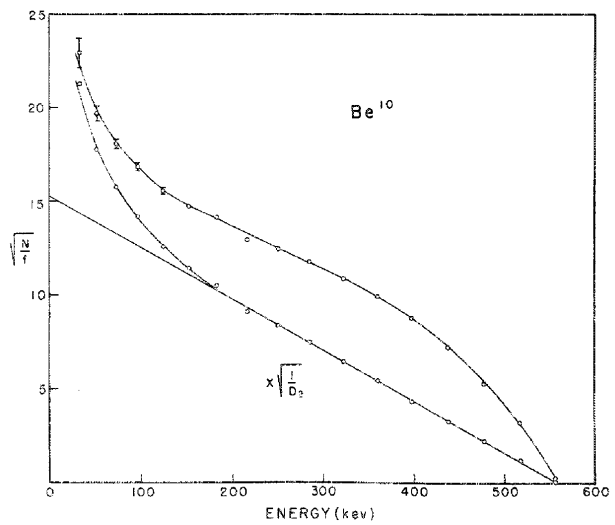
For the purpose of making a systematic search for gamma rays of energies above the photoneutron thresholds of Be and D (1.67 Mev and 2.23 Mev), an arrangement of $B^{10}F_3$ neutron counters has been imbedded in a large block of paraffin containing a cavity into which may be inserted gamma-ray source material and a surrounding mass of Be metal or heavy water. This arrangement can detect a very low intensity of gamma rays of energy above the photoneutron threshold and is completely insensitive to gamma rays of lower energy. The sensitivity of the arrangement is such that one microcurie of Ra in Be produces 35 counts/min above a cosmic ray and contamination background of 10 counts/min. The method will be useful in finding high energy transitions of low intensity in the presence of high intensities of

#Indicates publication. See Appendix for complete reference.

low energy gamma rays resulting from cascades between intermediate levels. The principal difficulty is the exclusion of impurities which emit high energy gamma rays. New results established with this instrument include a gamma ray of energy between 1.67 and 2.23 Mev in the 225-day Ag^{110}, which decays by K capture and by β^- radioactivity. No gamma rays of such high energy had been previously reported from this nuclide. A gamma ray in the same energy range was also found in Bi^{206}, which decays by K capture with a half-life of 6.4 days. The latter gamma ray was subsequently found at 1.72 Mev with a lens spectrograph. With Ag^{110}, Bi^{206}, and Ra sources, all having the same total gamma intensity (measured with an ionization chamber), the neutron counting rates were in the ratio Ag^{110}: Bi^{206}:Ra = 1 : 660: 2000# (E. der Mateosian, M. Goldhaber, D.E. Alburger).

A search for photoneutrons produced by long-lived fission products brought to light an interesting case. Ce^{144} (275 days) has a 17.5-min daughter Pr^{144} which was found to emit gamma rays above the Be photoneutron threshold. The gamma-ray energy was then determined with a lens spectrometer and found to be 2.185 ± .015 Mev. It has an intensity of about 2.5% per beta ray of Pr^{144}. Since Ce^{144} is a surplus product of pile operation, photoneutron sources of Ce^{144} + Be could be readily produced; they would prove valuable in many investigations. Another long-lived fission product, Ru^{106}, has a 30-sec daughter Rh^{106} which has also been found to emit a high energy gamma ray above the D threshold. It is hoped that several such sources of monoenergetic neutrons may be found which will be useful in the Laboratory# (D.E. Alburger, E. der Mateosian, M. Goldhaber, S. Katcoff, A.W. Sunyar).





Left: Photoneutron detector of high energy gamma rays. A cavity in the paraffin filled wooden box receives the beryllium metal block (left), or the heavy water bottle (right). The gamma-ray source may be placed in a small cavity in the center of each. Four neutron counters are embedded in the paraffin with their axes vertical.

Right: Beta-ray spectrum of Be^{10} (Kurie plot). The upper curve is uncorrected, and its departure from linearity indicates the "forbidden" character of the spectrum. After correction by Marshak's D_2 factor, the plot becomes linear, except for deviations explained by source thickness.

Beta Radiation of Be^{10}

The type of interaction between nuclei and electrons which gives rise to the phenomenon of beta radiation has been the subject of many theoretical studies. Recently, Marshak has pointed out that the shape of the spectrum of beta rays emitted when Be^{10} transforms to B^{10} can be a crucial test of the theory, for, in this case, the type of interaction required to explain the long half-life (2.7×10^6 years) leads to a predicted shape greatly different from the "allowed shape" (the distribution among energies usually found for short-lived emitters). The measurement of the shape of the spectrum of Be^{10} has presented a difficult problem because sources which are intense enough to give good statistical accuracy when measured in a lens spectrometer have in the past been so thick that the shape of the spectrum was distorted by absorption in the source.

Two years ago, however, Hughes, then at Argonne National Laboratory, initiated a program for the preparation of a source in which a mass of Be metal was given a long irradiation in the Hanford pile. The material was then purified chemically at Argonne National Laboratory from activities exceeding that of Be^{10} by a factor of a million. The residual Be was then separated magnetically at Oak Ridge, yielding a 4-mg sample containing 0.3% Be^{10}. In analyzing the spectrum, a careful study was made of the effect of source thickness and resolution on the observed shape by using the β^+ spectrum of Na^{22}, which is known to have an allowed shape with an upper limit very close to that of Be^{10}. This study included measurements made with the Na^{22} mixed with BeO to the same source thickness as that of the Be^{10} source. The final results on Be^{10} from a source of 0.4 mg/cm^2 gave the spectrum illustrated in the accompanying figure (upper curve) where it is reduced to a Kurie plot ($\sqrt{N}/f$ vs. energy, where N is the intensity per unit range of the momentum and f is the Fermi function of momentum involving the atomic number). The ratio predicted by Marshak's theory between this spectrum and the "allowed" spectrum is given by an energy dependent factor $\sqrt{D_2}$ which is seen, from the lower curve, to reduce the observed shape above 180 kev to a straight line, characteristic of the "allowed shape." Since deviations of the latter curve from a straight line at the low energy end are of approximately the same magnitude and of the same sign as those found in Na^{22} when the source was thickened with BeO, a truly thin source of Be^{10} would probably have yielded a "straight-line spectrum" to still lower energies. In the light of Marshak's theory, the fact that the D_2 factor is so effective in reducing the observed shape to the allowed shape implies that the disintegration may be described by a single matrix element. Be^{10} is thus the first example of a highly forbidden (long-lived) transition for which the theoretical explanation is as direct as those previously found for less forbidden and allowed transitions# (D.J. Hughes, D.E. Alburger, C. Eggler of Argonne National Laboratory).

Angular Distribution of Disintegration Products

Among the nuclear phenomena which are yet to find satisfactory theoretical explanation are the angular distributions of the products of nuclear disintegration resulting from bombardment by particles and photons. Nonspheric distributions in the center-of-mass system, the parameters of which depend upon the energy, have previously been observed for the protons and neutrons emitted as a result of proton, deuteron, alpha-particle, and photon bombardments, but the body of accumulated data must be greatly increased in order to provide a substantial basis for theoretical

treatment. The following sections describe the Laboratory's recent contributions to this field.

Photoprotons from Rhodium and Deuterium

Using photographic emulsions for recording the emitted particles, new results have been obtained on the angular distribution of protons ejected from D and Rh by a collimated beam of X-rays from the 20-Mev betatron at Picatinny. The energy of each proton was determined from its range in the photographic emulsion, and the yields in various proton energy ranges up to 11.5 Mev were determined in each of three directions, 20°, 90°, and 160° from the forward direction.

In D, results are similar to the University of Illinois results published while this work was in progress, with the addition that the experimental arrangement adopted here made possible the measurement of more tracks ejected at small angles to the beam, which has had the result of throwing some more light on nuclear forces. The theoretical evaluation of photodisintegration of D depends on the type of nuclear force assumed, as shown by Rarita and Schwinger, the strongest difference between the different forces appearing in their different predictions of the small-angle disintegrations. The measurements of the small-angle protons are not in agreement with the predictions from the neutral meson type of force, but are consistent with either "symmetrical" or "charged meson" forces. In Rh, although no significant difference was observed in the intensities at 20° and 160°, the 90° direction showed a significantly greater intensity than the average of the other two, particularly at the higher proton energies, where approximately four times as many protons were ejected into unit solid angle at 90° as at the other two angles. The cross section for the production of photoprotons from Rh by 17.5-Mev X-rays was found to be four times greater than the corresponding cross section of D. Using a theoretical value for the latter cross section, the Rh cross section is 3.6×10^{-28} cm^2 per steradian at 90°. The integral cross section of Rh determined by using the observed angular distribution is 3.5×10^{-27} cm^2# (N.W. Curtis, J. Hornbostel, D.W. Lee, E.O. Salant).

Neutrons Scattered in Deuterium

In another experiment, evidence regarding the force field between neutrons and deuterons was obtained from the angular distribution of neutrons of two different energies (5.5 Mev and 4.5 Mev) scattered in a chamber filled with deuterium gas. The neutrons were obtained from the (d,n) reaction on deuterium, making use of the electrostatic accelerator of the Carnegie Institution of Washington. The angle at which neutrons were scattered in the scattering chamber was calculated from the angle of the recoil deuterons as measured with a pair of proportional counters connected for recording coincident discharges. The ratio of the number of neutrons scattered through 180° to that scattered through 120° was about 6 to 1, a ratio which agrees with a theory based upon the assumption of a spherically symmetrical force field between neutron and deuteron# (E. Wantuch, E.O. Salant).

Compilations

Experimental data on the properties of the various nuclides is now accumulating rapidly, and contributions are being made from many laboratories. Since the

theoretical structure for systematizing this knowledge is still immature, comprehensive compilations of the accumulated facts serve a vital role to both experimenter and theoretician. One such compilation has recently been completed which summarizes the results of about 350 references on the properties of nuclides up to atomic number 10. This compilation includes the properties (spin and parity, width and half-life, and energy) of the known excitation levels together with the excitation functions characteristic of the various ways of reaching such levels (W.F. Hornyak). In another compilation, the excited levels of nuclides of atomic numbers between eleven and twenty have been listed from 110 references# (D.E. Alburger, E.M. Hafner). A third compilation lists spins and magnetic dipole and electric quadrupole moments of the ground states of 112 different nuclei# (H.L. Poss); a fourth presents revised data on neutron cross sections (R.K. Adair); and a fifth summarizes reaction energetics and mass determinations from oxygen to calcium (H. Motz). These compilations have been made as a part of the program for systematizing nuclear data sponsored by the A.E.C. and the National Research Council, and they will be submitted for publication in forthcoming issues of the Reviews of Modern Physics.

Neutron Cloud Chamber

Experiments in Canada and Oak Ridge have verified predictions that the neutron is radioactively unstable, the half-life being about 15 min. In order to measure the beta-ray spectrum of this most elementary reaction, a cloud chamber has been built which will operate in one of the neutron beams of the reactor. The chamber is to be filled with helium and D_2O vapor, and it is provided with thin aluminum entrance and exit windows. Techniques for providing a thermal neutron beam of high intensity, free from gamma radiation, are being developed by the Reactor Science and Engineering Department. The energy of the electrons resulting from neutron decays in the chamber will be measured by track curvatures in a magnetic field (A. Thorndike, A.W. Wotring, R.P. Shutt, L.B. Borst).

Proton Spectrograph

This instrument (described in the previous report) will be used in determining energies of protons emitted in reactions induced by protons and deuterons from the electrostatic accelerator. The iron yoke and coils of the magnet have been completed, and the chamber is being designed. Making use of some rather general methods of analysis developed for the purpose, studies have been made of the effect of the fringing field upon the focusing properties of the magnet (E.M. Hafner).

Spinning Disk Foil Holder

Widths of resonances in the absorption and scattering cross sections of various materials for neutrons will be studied with an apparatus, now in construction, which will consist of a rapidly rotating wheel for transporting absorbing foils either along or opposed to the direction of motion of the neutrons. When a foil of material which has a strong resonance to neutrons in the thermal region is placed in the neutron beam, the beam will be depleted of those neutrons whose velocities relative to the foil fall within the resonance band. If the foil is transported by rotating the foil holder, the depleted band can be displaced to either higher or lower velocities, measured relative to a second stationary foil. The effect on the beam intensity of

introducing such a stationary foil will determine the width of the resonance band in relation to the velocity of the rotating foil (A.W. Sunyar, M. Goldhaber).

Measurement of Nuclear Masses

The energies with which the neutrons and protons are bound together in the stable nuclei are data which must eventually be understood in terms of the forces between nucleons. These binding energies are most conveniently expressed as mass defects (the difference between the mass of Z free protons plus N free neutrons and that of a nucleus containing Z protons and N neutrons) which can be measured directly in a mass spectrometer. The masses of the lightest stable nuclei have been measured with satisfactory precision by deflection spectrometers, but these instruments fail to give significant accuracies for the heavier elements. It is hoped, however, that significant accuracy (0.1% of the proton mass) can be achieved through the use of the time-of-flight principle of mass measurement which is utilized in a new instrument known as the "chronotron."

In a homogeneous magnetic field, an ion moves in a helical orbit. The time to perform one revolution on this helix is proportional to the mass of the ion (M), and inversely proportional to its charge and to the magnetic field (H). This time is independent of the initial motion of the ion, and for a singly charged ion is equal to 652 M/H μsec. These facts form the basic principle for the time-of-flight mass spectrometer.

The essential parts of the spectrometer are an ion source capable of producing a pulsed beam of ions, and an ion detector. These are placed in a vacuum chamber in the magnetic field.

The accuracy of the mass measurement depends upon the total time of flight of the ions. For a given arrangement (size of source and detector and their separation), this time is proportional to the mass, since the maximum number of revolutions in the helical path is fixed by the geometry. The present aim is to measure masses to about 0.001 mass units. Since time can be measured to about 0.01 μsec, the total time of flight must be about 10M μsec, or about 1000 μsec for masses around 100.

The magnet now in use with the chronotron was obtained on loan from Westinghouse. It consists of a hollow sphere of 10-inch inside radius, with water-cooled copper windings arranged so as to give a homogeneous field inside the sphere. The cylindrical vacuum chamber, radius 7 inches, height 7 inches, is placed inside. The field strengths used are between 400 and 1200 gauss.

Three types of ion detectors have been used successfully: a) a Faraday cage; b) a scintillation counter; and c) an electron multiplier. The Faraday cage is the least sensitive, and rather slow in response. The scintillation counter consists of slivers of anthracene stuck to the end of a quartz, or lucite, rod which guides the light from the scintillations to an ordinary photomultiplier located outside the magnetic field. The ions are accelerated by about 20 kv just before hitting the anthracene. The electron multiplier detector is specially designed to operate in the magnetic field. The ions are accelerated by about 5,000 volts just before falling on the first plate, and the liberated electrons are deflected from one plate to the next by

both the magnetic and the accelerating fields. In all, there are fifteen plates. This is the fastest and the most sensitive of the three detectors, but it works for only a limited range of the magnetic field, and thus is not as suitable for survey work.

Two kinds of ion sources have been tried, both of which can be pulsed to give the ions either a fixed momentum or a fixed energy. For the alkalies, a wolfram (tungsten) strip, coated with the proper salts, forms a suitable source. For gases, the standard source, consisting of a cavity traversed along the direction of the field by an electron beam, is being used.

With the "momentum accelerator" which gives the same momentum to ions of different mass, an accelerating grid is pulsed to a potential of 200 to 400 volts during 1/4 μsec. The grid is far enough away from the source that the voltage pulse is over before the ions reach it. For a given magnetic field, the pulse voltage on this accelerator should be the same for all masses.

The "energy accelerator" gives ions of all masses roughly the same energy. If ions of different masses are to be put into the same circular path, the accelerating voltage must be inversely proportional to the mass.

Gaps in a constant ion beam have also been tried. In this case, the beam is deflected sideways, and is intercepted by a baffle during about 1/4 μsec.

The results obtained are not yet of satisfactory accuracy. A few attempts to obtain pulses with heavy ions have been disappointing; the pulses lacked definition and were spread out over 3 to 5 μsec. For light ions, on the contrary, the precision allowed by the present geometrical arrangement is easily obtained. However, these masses are already known, and new results are needed only for masses of about 100 and higher. Present indications are that most of the difficulties with the present apparatus are due to the ion source, and attempts to improve the length and shape of pulse for heavy ions are being continued.

In another modification of the chronotron which seeks to avoid the difficulties of nonuniformity of the magnetic field, the ion orbits are confined to a narrow gap between the poles of an iron magnet, and are deflected away from the source and into the detector by suitably timed pulses applied to a secondary pair of electrodes. First tests with this apparatus will be made soon# (S.A. Goudsmit, L.G. Smith, P.I. Richards, E.E. Hays).

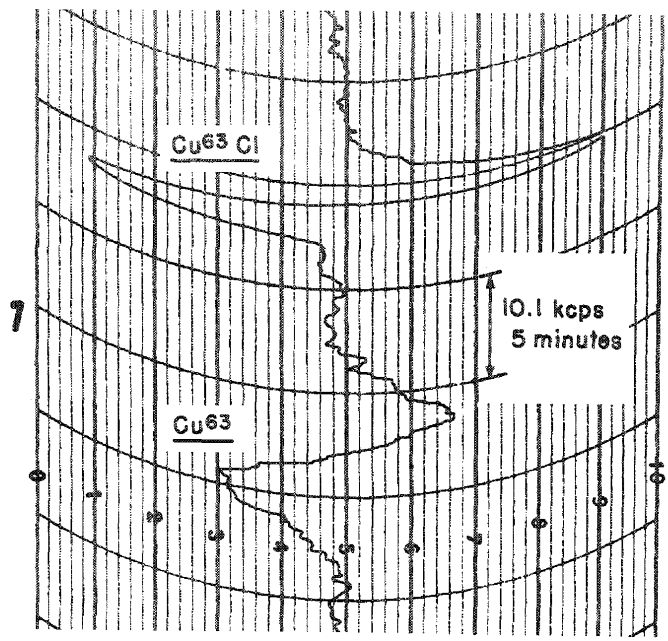
Nuclear Moments

As stated in previous reports, the nuclear moments laboratory has embarked on a program to measure nuclear spins and magnetic dipole and electric quadrupole moments of nuclei. The equipment includes a nuclear magnetic resonance absorption spectrometer which determines the nuclear g-value (ratio of magnetic moment to angular momentum) from the frequency at which radiation is strongly absorbed by nuclei placed in an externally applied magnetic field. The laboratory also has a microwave absorption spectrometer operating in the range 17,000 - 45,000 Mc with Stark modulation. With this instrument, one may study the rotational absorption spectrum of certain molecules in the gaseous state to determine such quantities as

nuclear spin, nuclear electric quadrupole interactions, mass ratios of isotopes, and electric moments of molecules.

g-Value of V^{51}

With the former instrument, the nuclear g-value has been observed for the previously unexplored nucleus $_{23}V^{51}$ and found to have the value $1.4713 \pm .0003$. This value was obtained by measuring the ratio of the resonance frequency of V^{51} to that of Na^{23} in the same applied magnetic field, and by using the g-value for Na^{23} obtained by Bitter. In two separate determinations, the V^{51} was in $Pb(VO_3)_2$ and V_2O_5, respectively# (W.D. Knight, V.W. Cohen).



Resonance absorption curves of the Cu^{63} nucleus in the metal and in CuCl. The shift of about 28 kilocycles results from the anomalous paramagnetism of the conduction electrons in the metal.

Shift of Nuclear Magnetic Resonance in Metals

Although the resonance absorption frequency of a nucleus must be regarded as proportional to the actual magnetic field at the nucleus, it had always been assumed that, except for a small correction for the diamagnetism of the closed electron shells, this field would equal the applied field. It is true that the conduction electrons contribute to the paramagnetism of metals, but the susceptibility from this source when averaged over the whole volume of the metal is too small to account for an observable frequency shift. However, in comparing the resonance absorption frequency of the Cu nucleus in CuCl with that in the metallic state, a shift toward higher frequency in the metal, many times that which could be readily accounted for, was observed. The shift Δf, like the frequency f itself, was proportional to the magnetic

field; the values observed for Cu and other metallic elements when the metal was compared with a salt are:

Metal	$\frac{100\ \Delta f}{f}$
Li^7	0.03
Na^{23}	0.10
Al^{27}	0.16
Cu^{63}	0.23
Cu^{65}	0.23
Ga^{71}	0.45
Be^9	No shift

In addition to the shift, there were also noticeable differences in widths of the absorption lines of the metals and the salts.

In attempting to explain the observed effects, the higher frequency of the resonance in the metal may be attributed to a local magnetic field at the nucleus which is due to the paramagnetism of the conduction electrons far more than is indicated from the bulk susceptibility, because of the tendency of those electrons to congregate at the lattice points. With this concept, the frequency shift can be related to the hyperfine structure in the free atom and to the bulk susceptibility of the metal by an argument which has been given in a published report of the work; the results are in rough agreement with the measured effects. Further measurements of this effect and a more rigorous theoretical treatment should lead to a better understanding of the electronic states in solids# (W.D. Knight, V.W. Cohen, C.H. Townes).

Paramagnetic Resonance of a Stable Free Radical

The paramagnetic resonance for electrons has been studied by observing resonance absorption in a stable organic free radical α, α-diphenyl-β-picryl hydrazyl, $(C_6H_5)_2N\text{-}NC_6H_2(NO_2)_3$, which has a magnetically free unpaired electron. This material, when placed in a cavity resonant in the TE_{01} mode to K-band microwaves, showed the strongest and narrowest electronic paramagnetic resonance absorption yet reported. When this cavity was placed in a magnetic field of approximately 8600 oersted, the transmitted power was reduced to a third by the presence of only 2 mg of the free radical, and the width of the resonance at half maximum absorption was 1.45 oersted. Because of its sharpness and intensity, this resonance may be useful for stabilizing or measuring magnetic fields. The ratio of the resonant frequencies of protons and of the free radical in the same magnetic field was 15.178×10^{-4} from which one finds a g-value of the free radical of $2.0042 \pm .0004$. Considerations for understanding the sharpness of the resonance in this and in other substances are discussed in a published report# (C.H. Townes, J. Turkevich).

Neutron Optics

A beam of monoenergetic neutrons can be represented by de Broglie plane waves propagated with a certain phase velocity. Because of elastic (without loss of energy)

interactions of such a beam with matter, the phase velocity in the material will differ from that in vacuum, and the material will exhibit the optical characteristics of a medium whose index of refraction differs from unity. From the point of view of wave propagation, these interactions can be thought of as giving rise to scattered wavelets which are coherent in the forward direction. The critical angle for total reflection from the surface is a measure of the index of refraction, and the index is related to the cross section per atom for the "coherent" interaction by a simple mathematical formula involving the wavelength.

Coherent n-p Cross Section

One of the most important interactions from the point of view of the theory of nuclear forces, namely the neutron-proton interaction, was very accurately measured by the mirror technique in an experiment done jointly with Argonne National Laboratory. The mirror in this case consisted of the surface of an organic liquid containing hydrogen and carbon nuclei in a ratio which was carefully selected so that the negative interaction with hydrogen (an interaction which reduces the index of refraction below unity) is nearly canceled by the positive and well-measured interaction with carbon. Since the index depends upon the small difference of two rather large and well-balanced interactions, a measurement of the critical angle with ordinary accuracy ($\pm$ 0.1′) resulted in a very accurate value for the coherent interaction of neutrons with hydrogen. This interaction expressed in terms of the coherent cross section of a free proton is $(0.443 \pm .008) \times 10^{-24}$ cm^2# (D.J. Hughes, with M.T. Burgy and G.R. Ringo of Argonne National Laboratory).

Reflection from Surface Films

Studies of the reflection of a collimated beam of neutrons from glass mirrors and from thin metallic films deposited on glass were made with the use of the reactor at Oak Ridge National Laboratory. It will obviously be a technical advantage if neutron reflecting mirrors can be made by evaporating thin layers of material on a polished surface of glass or other material of lower critical angle, and it is of interest to determine how thick such layers should be for the reflection to be characterized by the deposit rather than by the substrate. Experiments of this kind may in fact be used to study the effective depth of penetration of totally reflected neutrons and for determining the thickness of surface layers. The observed critical angle for total reflection from a surface coated by one or more thick films should be characteristic of the material having the lowest index of refraction. In these preliminary experiments, the neutron beam was collimated to a width of 2′ of arc, and wavelengths shorter than 4.4 A were filtered out with BeO. As expected, the critical angle for Mn, V, and Ag surfaced mirrors was found to be the same as for uncoated glass surfaces (i.e., 16′), since, of these materials, glass has the largest critical angle. Copper showed a larger angle than glass (21.7′), but the reflection showed a break at the glass angle indicating that the copper was too thin for total reflection. Aluminum is expected to have a smaller critical angle than glass, but Al_2O_3 should have a larger angle. The results of the aluminum coated mirror showed a break at the angle of glass and another break at a slightly higher angle, indicating the presence of a partial film of Al_2O_3. Although the critical angle was not measured, an indium mirror gave clear indication of total reflection, indicating an index of less than unity (A.W. McReynolds, S. Pasternack).

Scattering by Small Particles of Carbon

Using the same collimated beam of BeO filtered neutrons, studies have also been started of the small angle scattering in transmission through thin samples of finely divided carbon as a function of particle size. Clear indication of a diffraction broadening effect has been found in powder samples having grain sizes of 50 A and 300 A, but the results have not yet been interpreted (R.J. Weiss).

Neutron Monochromators

In connection with plans for a neutron diffraction apparatus suitable for studies of molecular and crystalline structure, a detailed study has been made of the resolution and intensity limitations of a Debye-Scherrer-Hull spectrometer of the type used by Wollan and Schull (Oak Ridge National Laboratory). The effectiveness of a single-crystal neutron monochromator is proportional to both its peak reflectivity at the Bragg angle and to the ratio of the width of the rocking curve to the angular spread permitted by the collimating system, provided the former is the smaller angle. Measurements made with the Oak Ridge reactor yielded the following results on several crystals:

Crystal	Reflecting Plane	Peak Reflectivity of a Thick Crystal	Width of Rocking Curve (minutes of arc)
NaCl	200	0.10	8
Ni	111	0.16	60
Pb	111	0.22	20
Fe	110	0.18	8

Since the geometrical spread of the collimating system of the proposed instruments is 15 to 20 minutes, it is clear that Pb is the best monochromating crystal of those tried; it should yield about five times the intensity of the NaCl crystal (A.W. McReynolds, S. Pasternack, R.J. Weiss).

Neutron Cross Section Measurements

The program for measuring neutron cross sections is still in the instrumentation phase. A mechanical shutter and electronic timing circuits for use with neutrons of energy less than 0.3 ev have been procured on an outside contract; this equipment is ready to operate. It has been described in a previous report (F.G.P. Seidl). Circuits for a much higher energy time-of-flight velocity analyzer to be used with the 60-inch cyclotron are being built on a contract with Columbia University, and are scheduled to be ready by early summer 1950 (C.P. Baker). Plans are also being made for the construction of a "fast chopper," or neutron shutter, to work with one of the neutron beams from the reactor, and to resolve about the same range of velocities as those resolved by the cyclotron equipment. It will have the advantage that small samples can be used for cross section measurements (D.J. Hughes, F.G.P. Seidl).

Solid State Physics

Crystal Growth

The research program in the physics of the solid state has been planned to take advantage of all of the various possibilities offered by the special facilities of the Laboratory. Besides the use of neutron beams from the reactor for investigating crystalline structure and neutron optical properties of the solids, the progress of which is described above, these studies will also exploit radioactive tracer techniques, and will be concerned with radiation damage. One of the studies for which both optical and tracer techniques may prove useful is that of crystal growth; experiments in this field have been started, although, in the preliminary phase, other techniques have been used. These studies have been concerned with the orientation

Sodium chloride crystals grown from solution on a polycrystalline surface of silver. It is to be noted that, over each silver grain, the sodium chloride crystals are parallel to one another and that some of the silver grains are more favorably oriented for crystal growth. The resulting density variation is particularly marked between the light and darkly etched areas in the central region, where twinning has occurred.

of alkali halide crystals grown by evaporation on single and multiple crystal substrates of several metals. While the orientation of metallic crystals formed by evaporation on cleaved ionic crystals had already been reported, very little work had been done on the growth of ionic crystals on metal substrates. In the present studies, sodium chloride crystals became oriented on the (100) and (111) planes of silver; and sodium, potassium, and rubidium chlorides were oriented on the (111) plane of bismuth. Only sodium chloride was oriented on the (111) plane of antimony. On silver, bismuth, and antimony in polycrystalline form, sodium chloride was oriented by nearly every grain; but in polycrystalline iron, only particular grain orientations were effective in producing orientation of ionic crystals, and these only in the case of cesium chloride.

An interesting conclusion from the observations is that the condition for oriented overgrowth has little, if any, relation to the commensurability of the ionic and

metallic lattice spacings. An observation that the oriented crystallites frequently straddle grain boundaries and maintain the same orientation over considerable distances on both sides of the boundary indicates that orientation is determined in an early state of nucleation. These results may have useful applications for determining crystal size and orientation of metal specimens without the use of diffraction techniques; they also give insight into the problems of the adhesion of surface films of one material upon another# (G.W. Johnson).

High Energy Particle Physics

The next important step in physics is the study of high energy nuclear processes. At energies above the hundred million volt level, meson production is important, and questions of cross sections and multiplicities of meson production in nucleon-nucleus collisions, as well as those concerning the nuclear processes involved in meson absorption, are subjects for experimental investigation. Until the Cosmotron becomes operative, some progress with these problems is being made through the use of advanced techniques in cosmic-ray experiments.

It has already been well established by many experimental investigations, using balloons, airplanes, and mountain-top laboratories, that the primary cosmic rays incident upon the top of the atmosphere are made up very largely of protons and other nuclei having energy spectra extending upwards from a lower limit imposed by the earth's magnetic field, and depending upon the latitude and the direction from which the rays are incident. These particles are also known to interact with the nuclei of matter (oxygen and nitrogen in the atmosphere, and other materials carried as a part of the apparatus) and to produce "penetrating showers" of secondary ionizing particles which diverge at rather large angles from the shower center with power to penetrate large thicknesses of absorbing material.

Latitude Effect and Atmospheric Absorption of Penetrating Showers

In an experiment for studying the energies of the primary protons, effective in producing penetrating showers, and their absorption in the atmosphere, an arrangement of coincidence counters imbedded in a large block of lead has been flown at various elevations in a B-29 airplane. This apparatus responded mainly to the penetrating showers, and therefore measured the residual intensity of the proton component. Flights were made in both high and equatorial latitudes, where the average proton energies were respectively 6 Bev and 22 Bev. Measurements at elevations up to 30,000 ft above sea level showed that the proton component is absorbed according to an exponential function of the atmospheric depth measured in units of 110 gm cm^{-2}, this being the mean path between absorptive collisions. No difference in the rates of absorption was found at the two latitudes. The ratio of the intensity at the higher latitude to that near the equator has been measured in two series of flights, from Rome, N.Y., and from the Canal Zone, and was found in each instance to have the value $1.11 \pm .019$, the probable error being derived from the entire body of data. This ratio showed no significant variation with altitude. Since the total primary proton component is known to be about three times more intense at the higher latitude, it may be concluded that most of the field-sensitive protons, and particularly those of energy less than about 10 Bev, are ineffective in producing penetrating showers of the kind to which this apparatus responds. An interesting conclusion from this and other

experiments which result in the same rate of absorption of the shower producing rays is that the average path for absorption is nearly twice that to be expected from the geometrical cross section of air nuclei; it indicates that nuclei are either semi-transparent to high energy protons or that the primary rays lose only a part of their energy at each encounter# (T. Walsh, O. Piccioni).

In the study of the east-west effect of penetrating showers referred to in the previous report, additional data have been obtained from flights in Panama and in high latitudes, but the analysis is not yet completed (A.J. McMahon, W.F. Burditt, B. Rossi of Massachusetts Institute of Technology).

Nature of Particles in Penetrating Showers

Experiments were described in the previous report which proved that the divergent secondaries which make up the penetrating showers are π-mesons (particles having a mass about 315 times the electron mass and an average life prior to transformation into μ-mesons of the order of 10^{-8} sec). In that work, the characteristic decay time of the μ-meson (2×10^{-6} sec) was used to detect, through a delayed coincidence technique, positive π-mesons which were stopped by an absorber and transformed there into μ-mesons. Because of their nuclear reactivity, the negative π-mesons were not so detected but were always captured in dense matter before transformation could take place. Also, in these experiment, μ-mesons which had been created elsewhere and were stopped in the same absorber could be recognized as such and eliminated from the calculations by looking at the difference in numbers of delayed coincidences when the absorber was changed from an element of low atomic number, such as carbon, in which both positive and negative μ-mesons decay, to one of high atomic number, such as sulfur, in which only the positives decay. Final analysis of the experiments, which were completed at a mountain station in Colorado in the spring of 1949, showed that locally produced mesons from the penetrating showers are π-mesons and that these make up the large majority of all the rays which diverge from such shower centers and are able to cross some 10 inches of lead. By comparing the absorption of the shower particles in iron with that in lead, the stopping powers were found to be just in the ratio of the expected ionization losses in these two materials; there was no evidence of a nuclear reaction. Essentially the same conclusion resulted from a comparison of the number of shower particles stopped in iron with the number of delayed coincidences resulting from stopped mesons.

The results indicated that the average path for nuclear absorption of π-mesons in iron is more than 1000 gm/cm^2, or about ten times greater than that found in the previously described experiments for protons in air. The mesons concerned had energies of a few hundred million volts# (O. Piccioni).

Reactions by Primary Cosmic Rays in Emulsions

In order to investigate interactions between nuclei and protons and neutrons of very high energy (many billions of electron volts), studies are under way of "stars" produced in nuclear emulsions at various altitudes and latitudes; these stars are caused by disruptions of the atoms of the emulsion. In emulsions exposed in balloons at 93,000 feet over Cuba, where the earth's magnetic field permits only those cosmic-ray protons of more than 8 Bev to reach the emulsion, there appears a pattern of

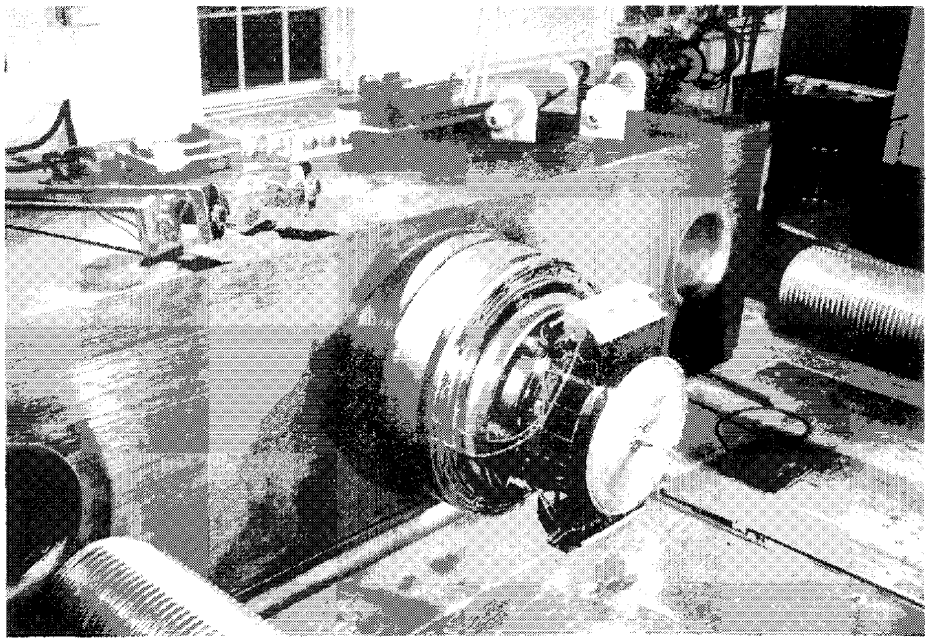
tracks (called a "broom" from its shape) characteristic of the disintegrations produced by such high energy protons. Details of the features of these brooms are given in a published report of the experiments. Balloon flights have also been made over Minnesota, where the earth's magnetic field permits protons as low as 3 Bev to reach the emulsions. A comparison of Minnesotan with Cuban results has yielded some information about the mechanism of the high energy disintegrations.

Although interpretation of the accumulating data is still in its infancy, some conclusions can be drawn. That the brooms represent creation of mesons is no longer in doubt. One event, for example, contained 54 tracks, a number exceeding by 7 the protons present in the heaviest nucleus in the emulsion (Ag). The handles of the brooms represent tracks of incoming primary protons; brooms without handles represent creation of mesons by neutrons of energies comparable with the proton energies; and brooms of both kinds picture the predominant process by which cosmic-ray mesons are created. The lightest tracks in the brush (fast mesons and other relativistic particles), on the average 2.5 per disintegration, appear generally in narrower cones than do the heavily ionized tracks. The probabilities of disintegration of the various nuclei based upon count of stars of various heavy-prong numbers is found to be roughly proportional to their geometric cross sections. The ratio of all stars produced over Minnesota to those over Cuba is 3.5, the ratio for those stars produced only by primary protons being 5, a figure agreeing well with the ratio of primary protons at the two localities reported by Princeton workers. The correspondence of these ratios shows that, in the energy range from 3 to roughly 15 Bev, the probability of disintegration and the production of neutrons by primary protons depends only slightly, if at all, on the energies of the protons# (C.B. Fisk, J. Hornbostel, E.O. Salant, J.E. Smith).

Balloon-Borne Cloud Chambers

Nuclear interactions of high energy primary cosmic rays have also been observed in cloud chambers flown by balloons to altitudes of approximately 95,000 feet, in connection with the "Skyhook" project of the Office of Naval Research. These cloud chambers were 12 inches in diameter; they contained one graphite plate and three lead plates in which the rays could multiply and thus reveal something of their nature. Out of 704 photographs taken at altitude, there were 54 events which can be recognized as nuclear disruptions produced in the plates by incoming cosmic rays. In two of these events, secondary rays from the disruption behaved in a manner characteristic of π-mesons in that they either disintegrated or produced secondary disruptions in the gas. About 40% of the stars contained clusters of lightly ionized tracks resembling the broom tracks found in emulsions with an average multiplicity of 4 or 5. The behavior of these lightly ionizing rays in passing through the lower lead plates is inconsistent with their being either protons or electrons, but is consistent with their being mesons.

Although a few showers have been found which are typical of electrons or photons, the small number of these limits the primary electron intensity to, at most, a few percent of the total cosmic radiation. Examples have also been found of "soft sprays," events in which a very large number of uncollimated tracks of low penetration appear to originate from a point in one of the plates. Events of this character have been found previously, but have not yet been explained (A. Thorndike, A.W. Wotring).



Sixteen-inch high pressure cloud chamber mounted with illuminating arcs on the pole piece of the large electromagnet. During operation, the chamber is advanced into a position inside a pressure cylinder, and the large steel member becomes a part of the magnetic yoke (not shown at the right).

High Pressure Cloud Chambers

Previous reports have referred to a large high pressure cloud chamber which is being constructed to study mesons, nuclear disruptions, and other rare events in the cosmic radiation at sea level. This chamber has an expansible volume 16 inches in diameter by 6 inches deep, and is designed for operation at a pressure of 300 atmospheres in a steady field of 18,000 gauss or a pulsed field of 35,000 gauss. Experience with a smaller chamber operating in the same pressure range indicates that, in the large chamber, about one random picture in thirty will contain events representing the interaction of cosmic rays with nuclei; at about the same rate, mesons will be seen stopping in the gas, where they will either disintegrate or react with nuclei. For operation with the steady magnetic field of 18,000 gauss, the expansions will be triggered by an arrangement of counters which will respond to neutrons liberated in nuclear disruptions or when negative μ-mesons are captured, and will thus time the photographs to catch those events of greatest interest. The large chamber is now completely assembled, and operation will begin early in 1950 (R.P. Shutt, E. Fowler, A.L. Johnson, W.A. Tuttle, T.H. Johnson).

A small high pressure cloud chamber which was brought to the Laboratory from the Bartol Research Foundation, where it was built before the war, has served as a preliminary working model for solving many of the problems associated with the design of the larger and more powerful instrument. With this instrument, it has been possible to test the formation of cloud tracks in high pressure gases with various vapors and to work out methods for reducing turbulence and background fog, as well as for extending the period of sensitivity and reducing the time between expansions. Another important use of the small chamber has been to determine the frequency with

which interesting events occur in photographs obtained in high pressure gas. For example, in a run of 3350 photographs with this chamber filled with argon at 140 atmospheres, nuclear disruptions by high energy cosmic rays occurred at the rate of one for each 130 expansions; this is at about the same rate per gram of matter as observed in photographic emulsions. During the same run, 22 mesons were found stopping in the gas volume, 15 of which displayed a decay electron. This rate of stopping is also in agreement with data obtained in other laboratories by other methods. The small chamber has also been successfully operated when filled with helium at 70 atmospheres, and it has been used for studying the scattering of electrons and positrons in helium and in argon (R.P. Shutt, G.R. Hoke, G. O'Neill, W.A. Tuttle).

Meson Scattering

The strength of the interaction between mesons and nuclei is a problem which bears directly upon current efforts to understand the part which mesons may play in holding nuclear particles together in the nuclei. In one of the experiments in the cloud chamber laboratory, this interaction will be measured by the deflection which the ray experiences as it passes through a lead plate placed in the center of an 18-inch cloud chamber. Since the deflection depends upon the momentum of the rays, as well as upon the strength of the interaction with the lead nucleus, the former quantity will also be measured in the same apparatus by noting the change in direction of the ray as it passes from one cloud chamber and thence through a magnetic field into the second chamber, which contains the lead plate. The magnetic field in this apparatus is established between the poles of a powerful permanent magnet. The experiment, which is still in its preliminary phase, will collect statistics on the scattering angles in the lead, and correlate these with the magnetic deflection, or momentum, of the incident ray. The apparatus for this experiment has now been completed (W.L. Whittemore, R.P. Shutt).

Theoretical Topics

Quantum Electrodynamics

In spite of the remarkable success of quantum electrodynamics in describing the deviations of the energy levels of the hydrogen atom (Lamb shift) from the values as predicted by the elementary Dirac theory, and the deviations of the spin magnetic moment of the electron from twice the orbital magnetic moment, it has been widely believed that there are fundamental difficulties in the quantum theory of interacting fields. The reason for this belief came from the fact that the application of the conventional perturbation theory, even in the covariant formulations, has apparently led to infinite particle self-energies, infinite vacuum zero point energies, and infinite vacuum polarizability.

These infinities are, however, entirely fictitious, and the result of the specialized way in which perturbation theory has been applied. It can be proven, by an alternation of the perturbation theory for high energy virtual processes, that the particle self-energy, vacuum self-energy, and vacuum polarizability are, in fact, exactly zero to all orders in the coupling constant (e^2/hc in electrodynamics). The above conclusion is also valid for other field theories. The mathematical technique used was to

transform the original Hamiltonian (expression for the energy) of the field theory into a new transformed Hamiltonian by means of a unitary transformation, so that the transformed Hamiltonian contains no interaction terms unless there are at least two particles present.

It is pertinent to say that carefully applied mathematical limiting processes are required in order to find the above-mentioned unitary transformation. The usual perturbation theory fails because it does not eliminate interaction terms in the Hamiltonian which couples the "vacuum" and "single particle" states with other states; instead, it gives such couplings an infinitely large magnitude.

It is almost certain that previously computed "Lamb shift" and spin magnetic moment corrections will not be substantially altered by this new computational method. It is also not unreasonable to hope that meson field theories may now be applied to solve the problem of nuclear forces# (H.S. Snyder).

Cross Section of (n,2n) Reactions

The energy dependence of the cross section of (n,2n) reactions near the threshold has been derived using the nuclear dispersion theory formalism. Configuration space is divided into three regions: an internal region, corresponding to the compound nucleus, an intermediate region, in which one neutron and the remaining nucleus are sufficiently far apart so that their nuclear interaction vanishes, and an external region, in which two neutrons do not interact with the residual nucleus. Boundary conditions are derived for the stationary wave function in the external region. An approximation to these boundary conditions allows the determination of the external region wave function, whose asymptotic form yields the result $\sigma(n,2n) = (E-E_t)^2$, where E is the incident neutron energy in the center-of-mass system, and E_t is the (n,2n) threshold energy. The neutron-neutron interaction in the external region does not alter the energy dependence of (n,2n) near the threshold. This derivation is valid for an energy range too small to allow comparison between theory and experiment. A crude perturbation theory argument yields the same result# (G.A. Snow).

Cascade Theory

An improved form of solution has been found of the diffusion equations of the cascade theory of electron showers, which converges rapidly and lends itself to numerical computations. Tables have been prepared which show the expected number of particles as a function of thickness of material when there is incident a) a single electron, b) a single photon, or c) a 1/E spectrum of photons# (H.S. Snyder).

Scattering of Fast Charged Particles

The curvature of a track in a cloud chamber produced by an applied magnetic field is frequently used to measure the momentum of the particle and the principle error arises from the false curvature induced by random scattering. Since the scattering depends upon the momentum of the particle, it has also been used in the determination of the mass. Making use of the theory of correlated probabilities, an exact solution has been obtained for the small angle plural and multiple scattering of fast charged particles, and several theorems of interest have been derived concerning the curvatures produced by scattering# (W.T. Scott, H.S. Snyder).

ELECTRONICS AND INSTRUMENTATION

During the period under review, the size of the Electronics and Instrumentation Division remained practically constant. Its staff now numbers 45, including two draftsmen on loan from the Drafting Group, and one engineer on leave from Cornell University and detailed to the Accelerator Project. Six visiting scientists and two extra technicians were attached to this division for various periods of time during the summer. The Laboratory suffered a serious and regrettable loss in the untimely death of H.G. Brewer, Jr., on August 14.

Now that the space formerly occupied by the Accelerator Project has become available, a slight rearrangement will be made, particularly in the machine shop, to permit a more convenient floorplan. This is necessary to avoid the hazards and inconveniences entailed in passing through the shop when going from one half of the laboratory to the other. No additional plans exist for building alterations or the purchase of major capital equipment in the coming year.

Research

Work was continued during the summer on parallel plate spark counters.# A suitable technique having been developed for producing reliable and efficient counters, it was applied to cosmic ray measurements (L. Madansky, R. Pidd, B.L. Robinson).

Studies of the polarization of annihilation radiation using scintillation counters were also carried on during the summer (G.B. Collins, J. Krauslaar).

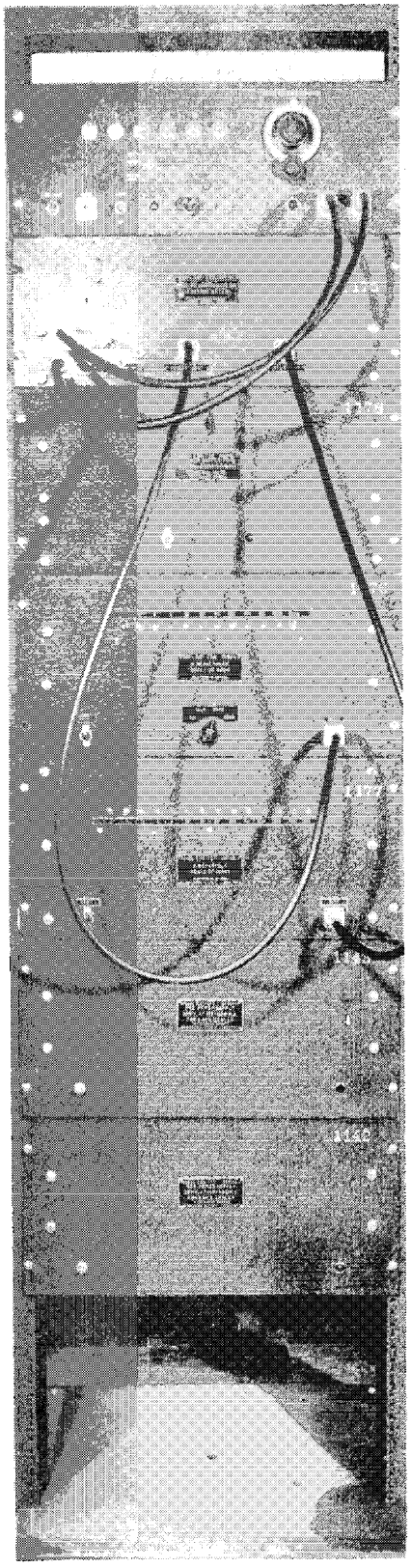
Research was begun at the Laboratory, and is expected to be continued at Harvard University, on the gas discharge mechanisms of the G-M counter, including studies of the photoelectric properties of the cathode, and measurements on the light emitted in the discharge. Using a photomultiplier and amplifier, it was possible to study the speed of propagation of the discharge along the anode, corroborating results obtained by other methods (R.B. Holt).

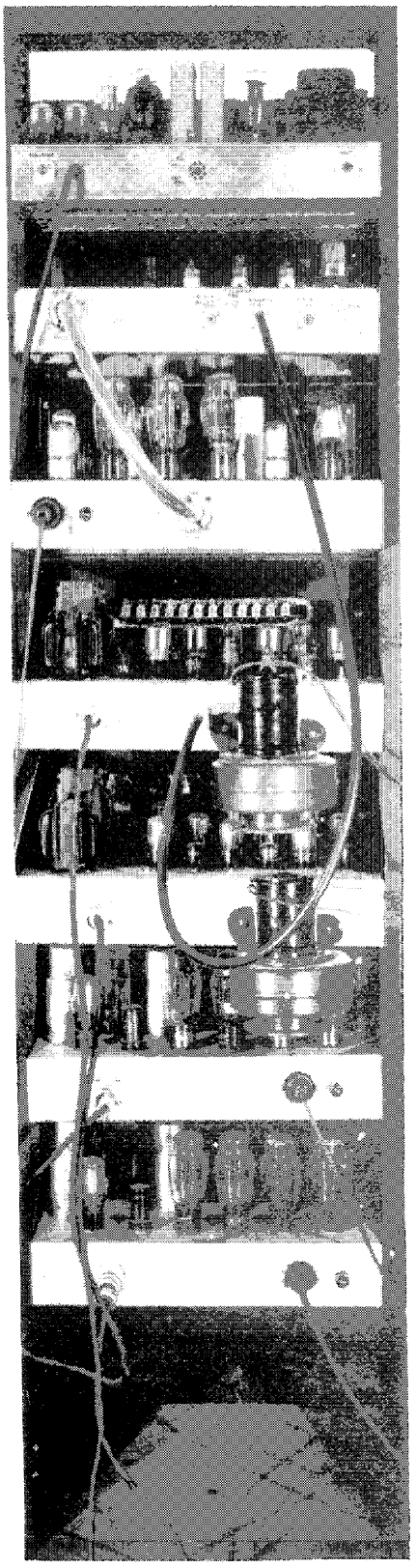
The usefulness of proportional counters has been extended in cooperation with members of the Biology and Chemistry Departments. In addition to the "gooch" counter mentioned in the last report, a method of air monitoring for C^{14} has been developed, the gas phase counting of soft beta emitters has been studied# (W. Bernstein, R. Ballentine), the half-life of C^{14} has been redetermined, and the proportional counter has been applied to analyzing X-ray spectra.# The latter appears to be a promising method of doing radiochemical analysis (W. Bernstein, H.G. Brewer, W. Rubinson).

Development and Construction

Some 65 electronics items have been completed since July 1, ranging in size from preamplifiers to a 2 kw regulated power supply. Of special note are the follow-

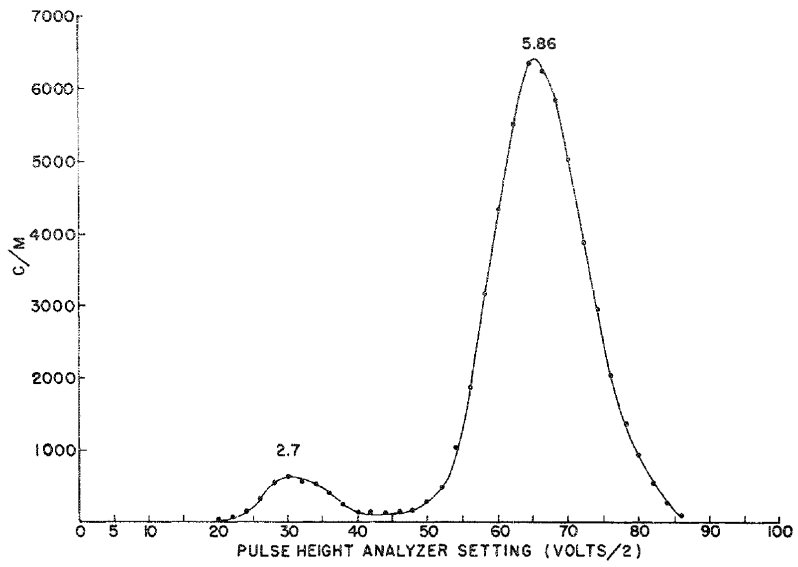
# Indicates publication. See Appendix for complete reference.





Front and rear views of equipment for measuring radio-frequencies up to 5 Mc/sec in very short times. This is being used in studies on the oscillator for the Cosmotron.

ing: 1) A precision frequency meter which will measure frequencies in the range of 100 kc to 5 Mc to an accuracy of 0.1% in 100 μsec.# This was built for determining the instantaneous frequency of the oscillators for the Cosmotron (R. Chase). 2) A circuit for measuring short time intervals (1-10,000 sec) which is useful in studies of the variation of the magnetic field in the Cosmotron magnet (R. Chase). 3) Precision frequency dividers for the Physics Department and Cosmotron measurements (S.L. Kramer). 4) V.H.F. frequency tripler for precision frequency measurements in microwave spectroscopy (J.B.H. Kuper). 5) A precision pulser for nuclear research which is an improvement over the Los Alamos Model 100 (S. Rankowitz).



Typical spectrum of Mn X-rays from the K-capture decay of Fe^{55}, obtained with an argon-methane proportional counter and single channel pulse height analyzer. The smaller peak at 2.7 kev is due to electrons from the K shell of argon; the separation between peaks provides an energy calibration for the pulse height analyzer scale.

A variety of special chambers and counters were built, filled, and tested for research by the Physics, Chemistry, Biology, Medical, and Reactor Departments. Xenon arcs have been developed with the cloud chamber group for use with the high pressure cloud chamber. Studies of end window and conventional G-M tubes have continued. Some 100 externally quenched counter tubes were made for the area monitoring shacks.

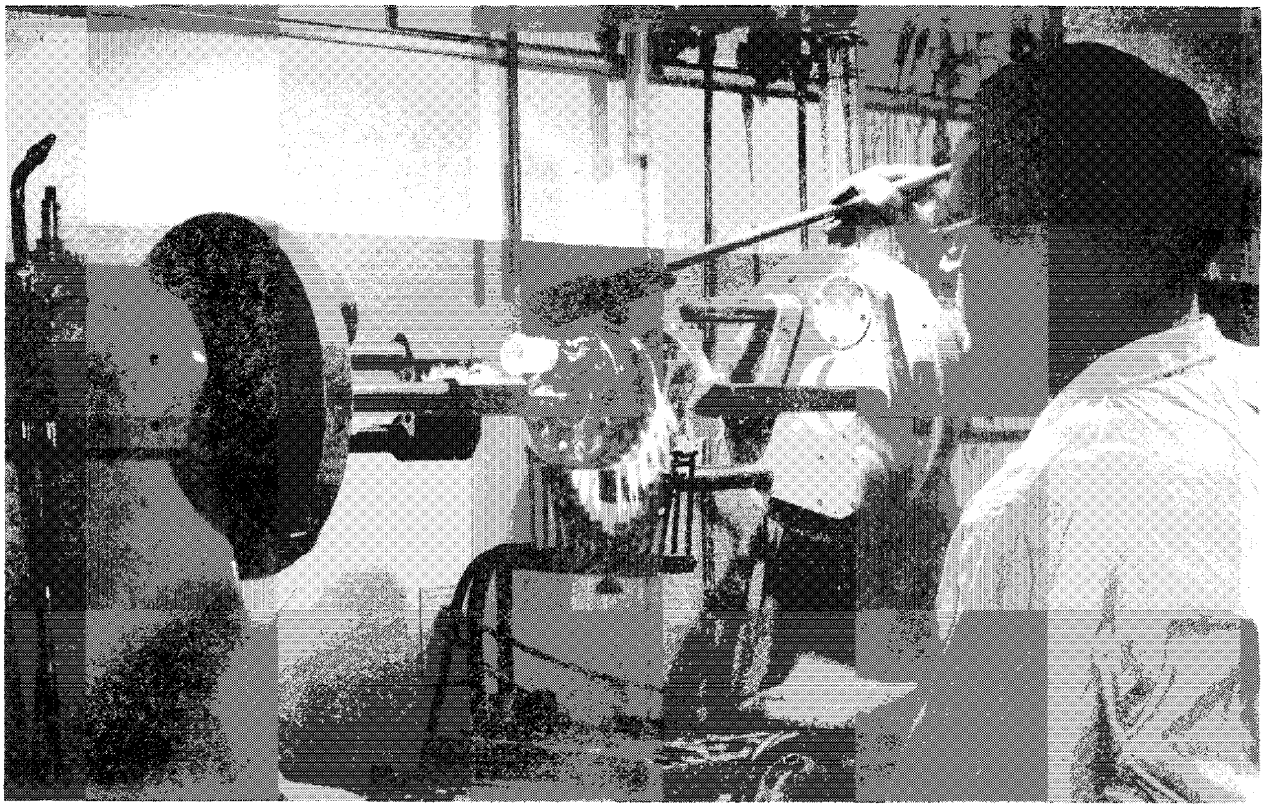
Other electronic items which were produced include nonoverload amplifiers, regulated power supplies for magnets and generators, camera modifications, lead shields for a B-29 experiment, and vacuum systems.

Under development are a pulse height analyzer similar to that described by Watkins of Los Alamos (Rev. Sci. Inst. 20, 495 (1949)) and two others based on cathode ray tubes. A precision single-channel pulse height analyzer is under development, and an improved nonoverload amplifier is under test. An extremely stable (0.01% over long periods) high voltage supply is being built. All of these items are of particular interest in high precision applications of proportional counters. Another method of energy discrimination, now being assembled, records the path length of particles in a multielectrode ionization chamber (S. Rankowitz, H. Motz). Other

current projects include special chambers and counters, a scintillation survey instrument, a special oven for growing crystals, a study of the natural activity of Long Island water, and a portable device for measuring atmospheric potential gradients.

Health Physics Instrumentation

The continuous dust monitor, mentioned in the last report, has been completed, and several units are installed to record both alpha and beta-gamma contamination. The method appears to be very sensitive, and has revealed interesting data on the day-to-day fluctuations of the natural "active deposit" on airborne dust. There is a striking correlation with meteorological conditions: in calm air with a marked temperature inversion, the activity of the dust collected may be 20 times the average. By placing detectors along the traveling filter paper, it is possible to separate the radium B and thorium B activities (J.B.H. Kuper, W. Bernstein, E.H. Foster). Several other instruments in the monitoring shacks have been revised to improve reliability of operation. Health physics survey instruments are calibrated and serviced at the rate of 40 per week. An automatic beta laundry monitor is under test. Numerous other health physics instruments have been modified or improved: Beckman MX-3 meters were converted for alarm use; "Cutie Pie" and "Chang and Eng" meters were modified to perform more reliably; and a high level survey instrument was designed. Assistance was also given on the Health Physics training course.



Glassblower fabricating special chemistry apparatus on large lathe.

Repairs and Miscellaneous

A careful record of repairs is kept to determine the performance of various instruments. Some 90 scalers and 75 other instruments were repaired, including meters, temperature controllers, pH-meters, and spectrophotometers.

Performance tests were run on a number of commercial instruments. Voltage regulator tubes, especially the RCA 5651, have been rigorously studied to determine the maximum degree of regulation obtainable. The 5651, temperature and current regulated, is extremely stable ($\sim 0.01\%$). Technical supervision was provided on the RCA hand and foot counter contract, and assistance was given on the Columbia University contract for a neutron spectrometer.

Extensive facilities are now available for electroplating and evaporating metals, and for hydrogen soldering. The range of usefulness of the microoscilloscope has been considerably extended by attaching a fast-triggered sweep and intensifier. The glass shop completed over 200 jobs, mostly for other divisions of the Laboratory. The bakeout oven was enlarged, and the controls improved.

ACCELERATOR DEVELOPMENT AND CONSTRUCTION

Total personnel in the Accelerator Project now numbers 87, including ten members employed on the operating staff of the 60-inch cyclotron and four on that of the 3.5-Mev electrostatic accelerator. Three engineers, two physicists, and twelve electrical and mechanical technicians have been added since the summer.

Good progress has been made on the three electronuclear machines for which the Accelerator Project is responsible; no major design problems remain, although operating experience will undoubtedly call for redesign of some features. During the past six months, work on the Cosmotron has undergone a transition from planning and designing to actual construction. With the commencement of construction and installation, the steady increase in scientific and engineering staff has been through substantial expansion in technicians and operating personnel.

In taking on new staff members, care has been exercised to employ only those whose services will continue to be of value after the accelerators are engaged in research.

As an experiment last summer, four undergraduates and three graduate students in physics and engineering were employed for periods ranging from eight to twelve weeks. The general usefulness and spirit shown by these men has warranted a repetition of the operation next summer. Work done by the summer "students" ranged from helping with magnetic measurements to making theoretical calculations on ion orbits.

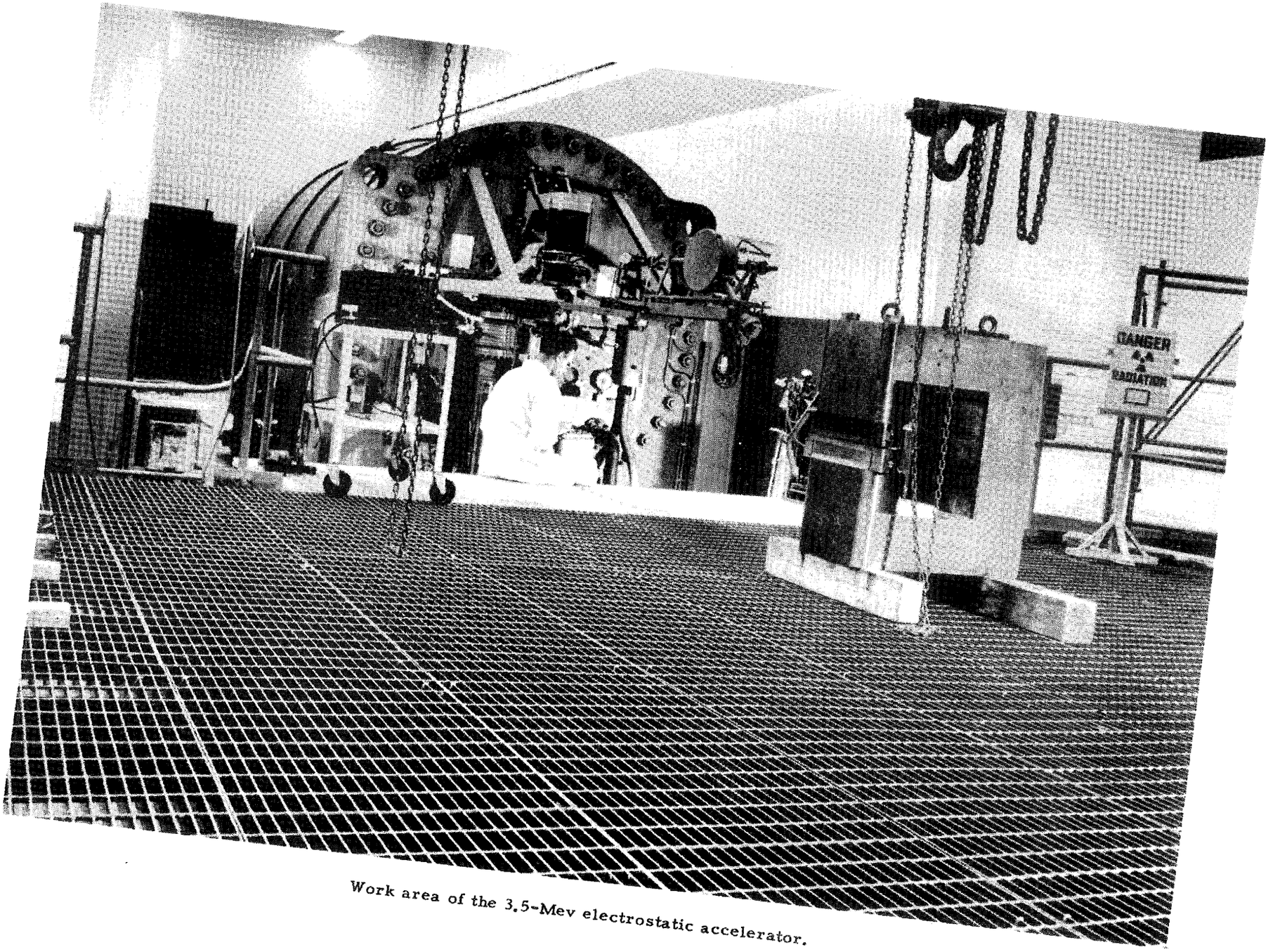
In addition to the summer students, four men of faculty status from nearby universities spent between one and three months at the Laboratory. Their help and experience proved a valuable stimulus to the permanent staff; it is anticipated that succeeding summers will see a marked increase in the number of visiting scientists.

Consultants from universities have also been of assistance. With first class scientific talent in such great demand and so difficult to obtain, the Laboratory has been fortunate in securing the services of several men on a sporadic, but nevertheless valuable, basis.

60-Inch Cyclotron

Virtually all the equipment was delivered by Collins Radio Company by the end of this review period. With installation already well under way, there is every reason to hope for operation by early spring. Target chamber parts are now being fabricated in Laboratory shops. Considerable effort is being expended on making possible remote control of nearly all aspects of hot target handling, for it is expected that large consumers of cyclotron time will be the nuclear chemists and others who need high activities not obtainable from a nuclear reactor (W.W. Merkle, D. Howard).

A slow neutron spectrometer is being constructed for use with the cyclotron. The high intensity from the 60-inch machine will make it possible to increase



Work area of the 3.5-Mev electrostatic accelerator.

considerably the resolution and ultimate energy over that already achieved. It is similar in concept to spectrometers already used at Columbia and Cornell Universities. Much of the electronic design and construction has been subcontracted to Columbia University. The highest energy at which clean and reliable measurements can be made is expected to be between 1,000 and 10,000 ev. While it is hoped to be able to extend this eventually, the initial emphasis will be on exploiting the easily realized capabilities. There is a considerable gap between the lowest monoenergetic neutrons generally obtainable from an electrostatic machine and the highest energy generally measured by other methods. It is hoped that this spectrometer will be able to reduce the gap. The quite good resolution available at low and intermediate energies should make possible the detailed comparison of several different resonances in the same nucleus, which has up to now not been possible (C.P. Baker).

Very high monoenergetic sources of neutrons and protons will be available from (d,d), (d,T), and (d,He^3) reactions. It is planned to study the scattering of these neutrons and protons by several light nuclei up to and including He^4. This will probably make use of either a cloud chamber or the photographic emulsion technique (E.O. Salant).

3.5-Mev Electrostatic Generator

The General Electric Company machine was delivered and installed during July and August. Since that time, a series of troubles, mostly vacuum, has prevented satisfactory operation. A well focused proton beam of about 1.5 Mev was obtained for a short time, but until all vacuum leaks are corrected, research work cannot start. With vacuum tubes in place but not evacuated, a reliable voltage of 3.0 Mev has been obtained with 170 p.s.i. of N_2 plus about 5-10% of CO_2. With further drying of the gas and seasoning, it should be possible to run stably at 3.5 Mev (C.M. Turner, E.M. Hafner, G.J. Hoey).

The experimental problems which are well advanced in instrumentation are as follows:

Gamma-Ray Energies

A study of nuclear energy levels in light and medium light elements is to be made by measuring the gamma radiation emitted during the bombardment of various targets by protons or deuterons. A thin lens magnetic spectrometer has been constructed to measure the energy of photoelectrons ejected from a thin converter by the gamma rays under study. This instrument has been thoroughly tested during the past year in studying the beta and gamma spectra of various radioactive materials, including K^{40}, Be^{10}, P^{32}, Na^{22}, Co^{60}, Cd^{115}, Bi^{206}, and Bi^{209} (D.E. Alburger).

Q Value Measurements

A magnetic spectrograph, incorporating special features to provide high resolution, high sensitivity, angular flexibility, and a certain degree of discrimination against target contaminants, will be available for measurements of discrete spectra of charged particles (E.M. Hafner).

(p,d) Scattering

The differential cross section as a function of angle at a proton energy of about 6 Mev will be measured using monoenergetic protons from exothermic (d,p) reactions. Photographic detection will be used (E.M. Hafner).

(n,2n) Cross Sections

The 14-Mev neutrons from deuterons on tritium will be used to bombard medium nuclei, and the resulting inelastic neutron spectra will be measured using knock-on protons in photographic emulsions (E.M. Hafner).

Range Measurements

High precision measurement of the ranges of heavy particles, especially from (d,p) and (d, α) reactions, is planned. A multiple proportional counter is being constructed for this purpose. This counter will allow the rapid accumulation of data and should be subject to small drift. It is hoped that it will be possible to count low range alpha particles within the high background of scattered deuterons from (d, α) reactions (H. Motz).

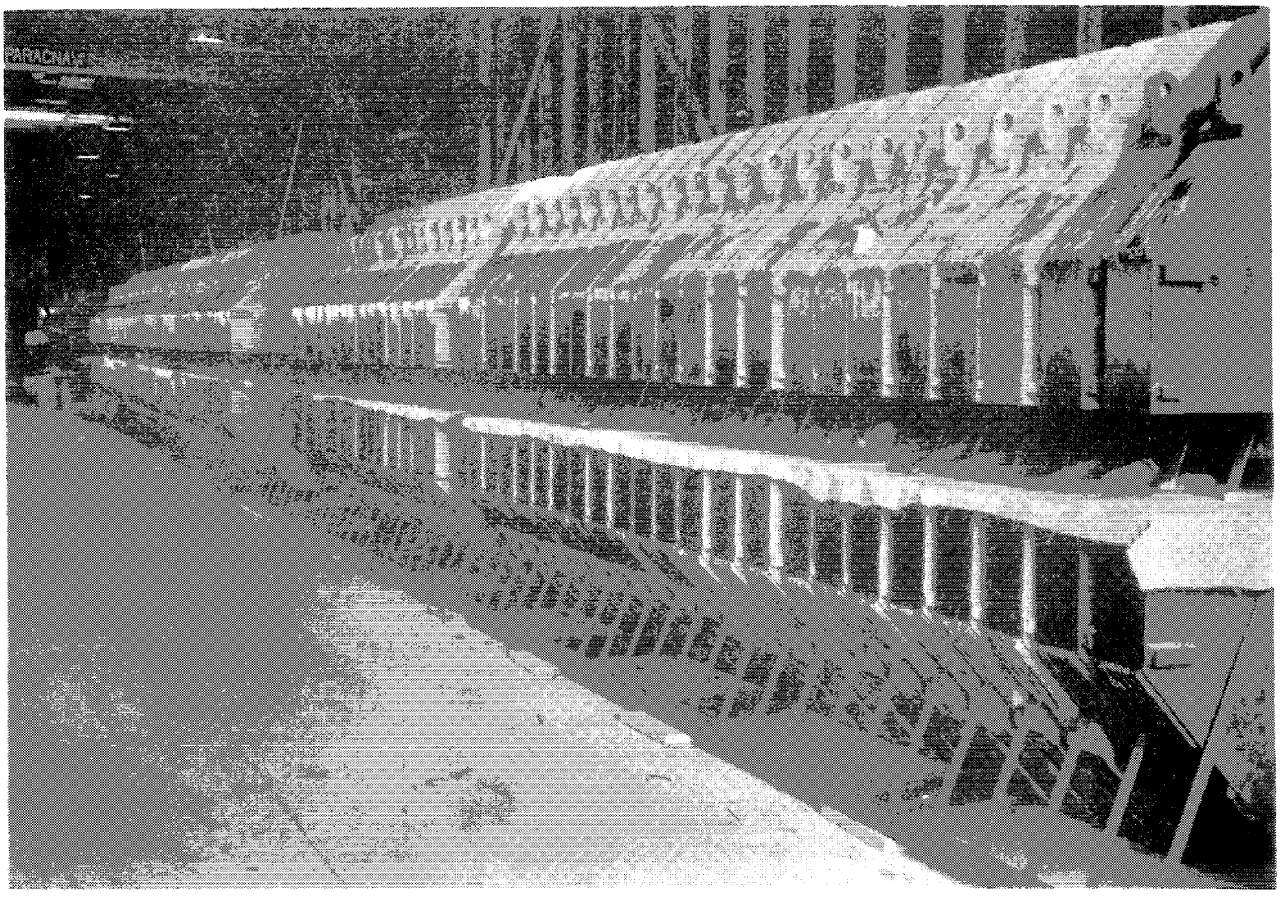
2.5-Bev Proton Synchrotron (Cosmotron)

Magnet Construction and Testing

Nearly all design obstacles have now been cleared, and construction is well under way. Essentially the entire order of magnet steel has been delivered to the Laboratory by the Bethlehem Steel Company. The elaborate testing program, in which every block of twelve half-inch plates is given a complete series of magnetic tests, has proven to be a very formidable undertaking, but well worthwhile. Sufficient variations between blocks have been uncovered, particularly in remanent field, so that a prearranged order of stacking will definitely increase the effective aperture over that which would have been obtained by random stacking. A large computing program had to be activated in order to analyze the data obtained from the testing program. From the data, a stacking order will be worked out which provides the smoothest possible magnetic field. By February 15, actual erection of the magnet blocks on the final foundation will be started by Bethlehem Steel Company; in 12 weeks, according to the contract, it will be essentially completed. Due to the necessity of keeping the magnetic median plane accurately coincident with the plane of the ion beam, it is essential to erect the blocks to very close mechanical tolerances. A procedure has been worked out with the erecting company which should guarantee an accurate placement of each block (W.H. Moore, J.M. Kelly, M.H. Blewett).

Copper coil fabrication has been proceeding on a cautious basis until all production difficulties are ironed out. All the hollow copper bars were helium leak tested for possible cracks, and one was found, thus justifying the entire costly procedure. All silver soldered end joints will similarly be helium leak tested. Experience has been gained in wrapping the copper bars with Empire cloth and placing them on the accurate wooden test quadrant. It is expected that winding of the first quadrant will commence in January (J.A. Kosh).

Copper for Cosmotron magnet being insulated in preparation for winding.



Iron blocks for Cosmotron magnet on the floor of the test building.

The 20,000-kva motor-generator flywheel rectifier set to excite the magnet is nearing completion at Westinghouse Electric Company, and is due to be delivered in February. Tests made thus far look satisfactory. Transformers, switch gear, and various auxiliaries have been arriving steadily (A. Wise).

Radio-Frequency System

Variable frequency generator. A signal generator has been developed which is electrically tunable over the required 12 to 1 frequency range, and which has adequate frequency stability. It is an LC oscillator in which the inductance is varied by saturation of a ferromagnetic core. The core consists of two toroids of a ferromagnetic ferrite having an initial permeability of the order of 1000. The oscillator tank winding threads both cores, while the d.c. control winding has a figure eight configuration around the cores, so that no coupling exists between the two windings. The required tuning range has been covered with some latitude with this oscillator. When the temperature of the ferrite is held constant to 0.1°C, the oscillator frequency is stable and reproducible at any control current to better than 0.1% (A. Pressman).

Frequency control. In the primary frequency control system, the Cosmotron magnetic field is taken as the independent variable. The magnetic field will be measured continuously, and the frequency will be automatically adjusted to the correct value. The frequency control system has three essential components -- first, an integrating circuit which converts the voltage from a pickup coil in the Cosmotron magnet to a voltage signal directly proportional to magnetic field; second, a network which converts the magnetic field signal to the appropriate frequency control signal; and, finally, an amplifier which applies the control signal to the winding on the ferromagnetic core in the master oscillator. Prototypes of these components have been built and tested and found to have adequate performance characteristics.

One of the more difficult problems connected with the frequency control system is that of measuring the overall performance of the system. The Electronics Division has assisted materially in this connection by developing equipment with which accurate frequency measurements can be made, even when the frequency is undergoing its most rapid changes. This device includes several fast cycle counters with associated timing circuits. Dynamic tests of the radio-frequency system are now under way using this equipment (A. Pressman, W.H. Surber, J.C. Logue).

Magnetic field check points. As a monitor on the primary frequency control system, auxiliary signals can be fed into the control amplifier from devices in the Cosmotron magnet which make intermittent, highly accurate checks of the value of the magnetic field. For this purpose, a study is being made of peaking strips, proton moment detectors, and electron moment detectors. Any one of these devices will yield a sharp pulse at a prearranged magnetic field. The appearance of this pulse will be electrically compared with signals derived from the radio-frequency system, and corrections will be made if necessary. About fifteen such corrections during the one-second cycle should be adequate (J.C. Logue, J.M. Kelly).

Radio-frequency amplifier. The power amplifier will have about 4 Mc bandwidth, and its output stage will be push-pull Machlett ML-554's in class B, at a level of about 2500 volts and some tens of amperes. Early stages of the amplifier will be in the auxiliary control room adjacent to the wide band oscillator, while the high level

stages will be on the Cosmotron floor near the proton accelerating unit. The main 300-kw d.c. power supply for the high level stages has been built and delivered by the Amertran Company (L. Yuan, M. Plotkin, T. McLean).

Radio-frequency core. The ferrite core, which is the final proton accelerating unit, is to be constructed of a combination of ferrite (Ferramic) rod sections and ferrite (Ferroxcube) slab sections of the types described in the previous progress report. The rod sections are about half constructed. The slab sections have been ordered from the Philips Company, and will be delivered during the first three months of 1950 (M. Plotkin).

Ion Injector

Very good progress has been made by the High Voltage Engineering Corporation in the design and building of the large electrostatic generator for injecting protons at 3-4 Mev. A voltage of 4.8 million has been reached on test (no ion beam); soon ion beam tests using a pulsed high intensity ion source will be made. Delivery is predicted for February or March (C.M. Turner, G.J. Hoey).

The ion-optics of injection have come in for a very detailed analysis. Our goal is a beam 1/8 inch in diameter and parallel to 0.3 degrees. It is believed that suitable magnetic and electric lenses have been designed to accomplish this. Two magnetic lenses are contemplated; one is at the magnetic beam analyzer where semicircular rotatable inserts replace the conventional fixed pole magnet; the other is a new type parallel wire lens which will be placed immediately in front of the electrostatic inflector. The purpose of this parallel wire lens is to counteract the rather short vertical focal length of the electrostatic inflector (J.G. Cottingham).

Control Wiring

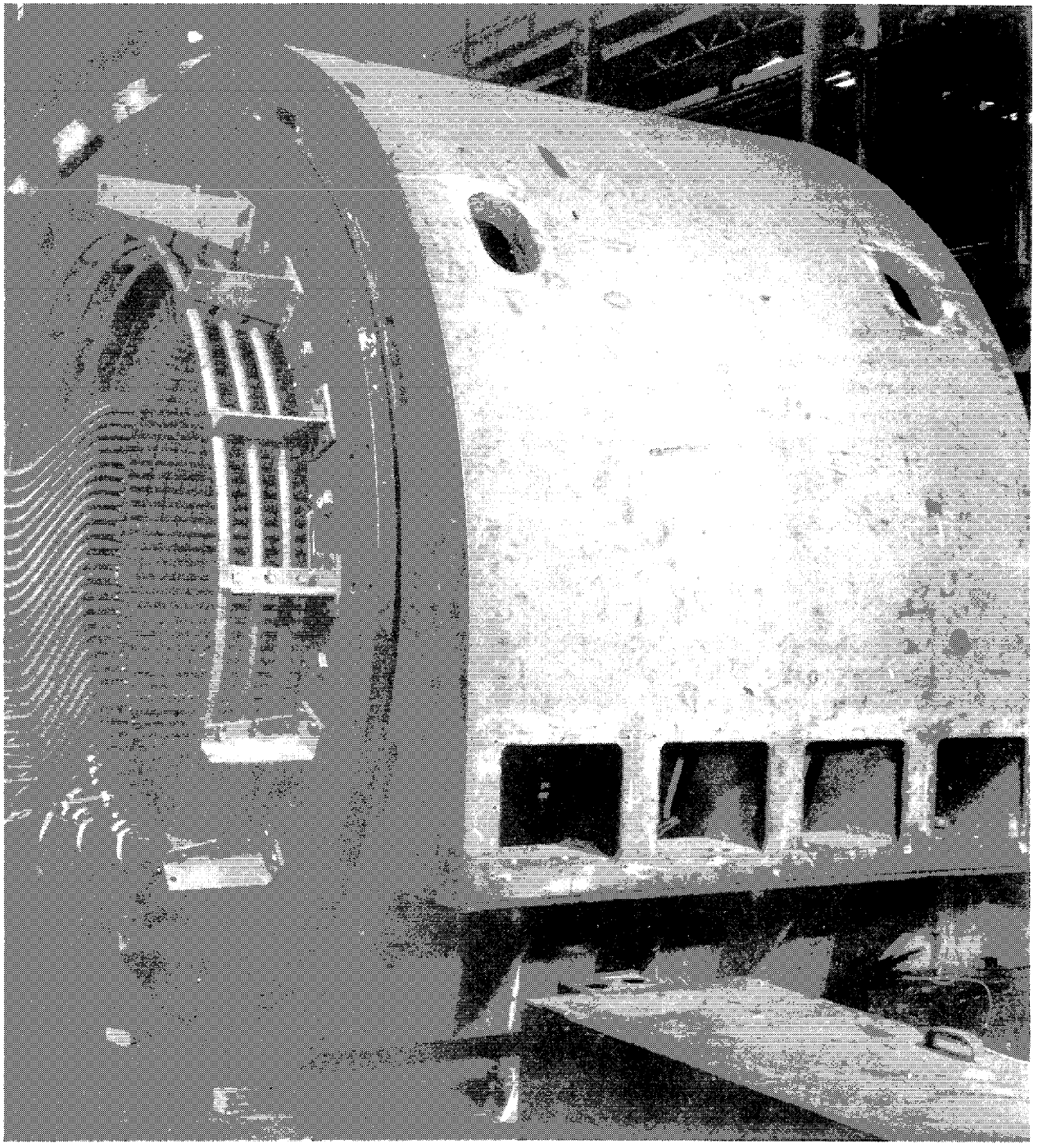
The very large job of interconnecting the many elements of the system is just beginning to be brought under control. Until most of the components are frozen, it will be difficult to finish the control wiring; so it appears quite likely that control wiring will be one of the last things to finish up (R.R. Kassner, G.K. Green).

Vacuum Chamber

A major design problem has been the attainment of a vacuum chamber which is relatively simple, vacuum tight, and free from eddy current difficulties, which provides for pole face windings, and which does not seriously decrease the effective aperture. Many suggestions have been advanced, but none have been completely convincing. The design currently in favor employs a heavy metal back and front wall, and 2-mil Inconel top and bottom sheets which are cemented by vinyl seal to a plastic top and bottom for strength. Rubber gaskets will seal the top and bottom to the heavy front and back walls. Care must be exercised to avoid closed loops which would link the changing flux in the gap and have induced in them currents which would then distort the magnetic field. The 2-mil Inconel is the thickest sheet which can be used without resorting to excessive "laminating" of the metal which is perpendicular to the changing flux. Test chambers are now being designed in order to gain experience with the problems (W. Liben, I.J. Polk, J.J. Mede, and others).

Building

The building is to be weather tight by January 1, and entirely finished by June or July. Roof and walls are nearly complete, while floors and their integral raceways are now being poured. The generator room is well along, with heavy foundations complete and much of the flooring in. The floor for the main room is being poured at the present time.



Synchronous generator stator in process of manufacture at Westinghouse Electric Company.

CHEMISTRY

During the past six months, the staff of the Chemistry Department has grown from 40, including 30 scientists, to 48, of whom 37 are members of the scientific staff. In addition, seven visiting scientists were in residence for varying lengths of time during this period.

Five of the six wings of the laboratory are occupied and in use. The laboratory for the 2-Mev electron accelerator has been designed, and a portion of the unfinished wing is being converted for this installation. The remainder of this wing is still to be provided with research laboratory facilities; the construction of an addition to house the helium liquefier remains to be accomplished.

In the following sections are described the investigations which the Chemistry Department has carried on in the past six months. The projection of these activities, together with new investigations which will be mentioned, constitutes a present forecast of the research program for the next year.

As indicated in past statements of program, the research of the Department is devoted principally to studies of: the properties of elements of particular interest in the field of atomic energy; the chemical effects of radiations and of nuclear transformations; the application of nuclear tools to chemical problems; and various types of nuclear problems which can be profitably studied by radiochemical methods.

In consonance with the general purpose of the Laboratory, much of the work contemplated in the research program will make use of the major nuclear machines as sources of radiations and of isotopes. Since it has not yet been possible to use these instruments, the statements about their use made in earlier program reports apply with little change; they will be recapitulated briefly at appropriate places.

General Chemistry of Various Elements

The heavy elements in the neighborhood of uranium are believed to belong to a transition series in which the 5f shell is being filled with electrons, analogous to the rare earth series. In order to characterize this transition series more firmly, a program of study of the electronic states of ions of these elements has been undertaken. This work has commenced with measurements of the magnetic susceptibility of salts of tetravalent uranium, and will be continued and extended to salts of other heavy elements. It will be further extended by measurements on the absorption spectra of compounds of the heavy elements and of the rare earths. The latter are of interest because of their analogy with the heavy element transition series, and also because a number of important fission products belong to the rare earth group. It is also planned to undertake studies of the solution and dry chemistry of protactinium, with the hope of increasing present knowledge of the properties of this interesting and important element and of its compounds.

Data on the magnetic susceptibilities of UF_4, KUF_5, K_2UF_6, $CaUF_6$, and Na_3UF_7 have been reported.# The susceptibilities of the salts obey the Curie-Weiss law,

#Indicates publication. See Appendix for complete reference.

$\chi = C/T+\theta$, above liquid nitrogen temperature. The magnetic moments computed from the data lie in the range 3.25-3.45 Bohr magnetons, which may be compared with the expected moment 3.58 for the free tetravalent uranium ion if it has two 5f electrons and exists in a $^3H_4$ state. Thus, the results support the hypothesis that tetravalent uranium belongs to a second rare earth series. The magnetic states of the chlorides are also being studied. It has been reported (H. Bommer, Z. Anorg. Allgem. Chem. 247-249, 249 (1941)) that UCl_4 exhibits a magnetic moment of 2.71 Bohr magnetons. This compound has been further studied, with results which give better fit to a Curie-Weiss law than the data of Bommer, and which indicate a magnetic moment of 3.17 Bohr magnetons.

All of the tetravalent uranium compounds which have been studied obey the Curie-Weiss law over a wide temperature range, but, in contrast to the rare earths, have rather large values for the Weiss temperature θ. In view of the unusual magnitude of this quantity for the compounds studied, it was thought worthwhile to investigate the factors responsible for the Weiss temperature. It has been thought that it may arise from either the effect of the electric field of the crystal (e.g., in the previous progress report) or from Heisenberg exchange interactions between neighboring paramagnetic ions. Attempts to account for the data in terms of only crystal field effects have been unsuccessful, and it seems likely that exchange interactions are operative in these compounds. In order to study such exchange interactions further, experiments were carried out with MnF_2, which is paramagnetic, and whose ground state is an S state which is not expected to be split by the crystal field. This salt was diluted in the crystal with isomorphous ZnF_2 (diamagnetic). In such mixtures, the electric field around each paramagnetic ion is essentially independent of the composition, but the number of neighboring paramagnetic ions varies with composition. It was found that the magnitude of the Weiss temperature θ for these mixtures is a linear function of the mol fraction of manganous fluoride, as expected from the theory of the effect of the exchange interaction. This is considered to be confirmation of the exchange type of interaction and its effect on θ. Using the technique of diluting paramagnetic salts with isomorphous diamagnetic salts, it is planned to study the magnetic and optical behavior of a number of compounds, which will include UF_4, UCl_4, UCl_3, UCl_5, MnF_2, NiF_2. An extension of this work will be an attempt to modify the symmetry of the crystal field around paramagnetic ions by solution in substances of different crystal structure. By these techniques, it is hoped, in particular, to gain a better understanding of the absorption spectra of the heavy elements (N. Elliott, L. Corliss, Y. Delabarre).

In connection with the absorption spectra of the rare earths and heavy elements, it is planned to pursue a recent development (S. Freed and C.J. Hochanadel, J. Chem. Phys. 17, 664-5 (1949)) in which techniques were devised for preparing solutions of salts of the rare earths which are fluid at the temperature of liquid nitrogen, and for measuring their absorption spectra. The reduction in temperature brings about a sharpening in the energy levels, resulting in a great refinement of the spectra. It thus becomes possible to study the quantum states of the ions in solution and the effect on these states of the electric fields about the ions. A systematic study along these lines will be carried out with salts of the rare earths and heavy elements. The spectrographic region investigated will be the ultraviolet and visible. In correlation with these studies, other measurements will be made on the properties of the low temperature liquid solutions, such as the determination of solubilities and other equilibria, electrical conductance, viscosity, vapor pressure, and surface tension.

The main equipment necessary for the preparation of the solutions and for the spectroscopic measurements has been assembled, and it is expected that trial runs will be made soon (S. Freed, K. Sancier).

Radiation Chemistry

Radiation chemistry is concerned with the study of the chemical reactions brought about by high energy ionizing radiations. In order to support quantitative investigations in this field, a 2-Mev electron accelerator of the Van de Graaff type is being acquired. It will constitute a high intensity source of cathode rays and X-rays, of accurately controllable intensity and energy. This instrument will be capable of supporting a number of investigations simultaneously, since irradiation time will usually be only a small fraction of the total laboratory time involved in an experiment. For this reason, it seems appropriate to indicate a number of the different types of problems which can be profitably studied with it. The degree of exploitation of the various possibilities will depend on the number of staff members and interested visitors from other laboratories.

So little is known about the details of the action of high energy radiations on molecular systems that new and interesting information is certain to result from controlled, quantitative experiments on the behavior of almost any substance exposed. Among the types of problems which may be expected to be of interest, and which could be studied are:

1) Mechanism of reactions induced in simple gases,
2) Nature and specificity of reactions of organic compounds,
3) Mechanism of reactions in aqueous solutions,
4) Characterization of the activated electronic states of various types of crystals (especially at low temperatures),
5) Radiation effects in systems of biological interest (e.g., proteins, nucleic acids),
6) Effects of large doses of X-rays on physical and electrical properties of materials of technological interest (e.g., plastics, ceramic insulators),
7) Radiation induced corrosion by air, water, or lubricants.

Present interest in the Department centers on radiation induced reactions in aqueous solutions. This program in chemical kinetics will be initially concerned with the rate of combination of dissolved hydrogen peroxide and hydrogen in the presence and absence of bromide and other interfering ions. It is hoped to ascertain the absolute yield for direct peroxide formation from water by the radiation, and the relative values of the rate constants of various reactions involving the free radicals H and OH. Later, it may prove possible to determine the absolute yield of free radicals by proper admixture of solutes or by other methods.

A technical problem which must receive attention is that of accurate absolute dosage measurement, since, in the experiments, it is desired to know the amount of energy dissipated in the system of interest by the radiation. Several factors render the absolute calibration of air ionization chambers open to serious question at the energies and intensities which will be employed. It is planned to attempt accurate dosage calibration by calorimetry. For relative measurements, chemical actinometry may prove more convenient and precise than use of ionization chambers.

Progress with the above program in the past six months has consisted mainly of the completion of plans for housing the electron accelerator, and the beginning of construction. The machine itself is on order, and expected to arrive during January 1950 (A.O. Allen, E. Johnson).

Recoil Atoms and the Chemical Effects of Nuclear Transformations

In contrast to the macroscopic changes produced by radiation in chemical systems, with which radiation chemistry is concerned, are the effects of a nuclear transformation on the atom in which that transformation occurred. These effects are the subject of investigation in what has been called "hot atom" chemistry. The chemical fate of such an atom can be traced if the product of the nuclear transformation is radioactive, and one of the aims in this type of study is to ascertain the final state of chemical combination of the atom resulting from the nuclear transformation. This is a question of particular practical importance in the concentration, by the Szilard-Chalmers method, of radioactive atoms formed in (n,γ) reactions.

The effects observed, e.g., bond rupture and the incorporation of the product atom in new states of chemical combination, are initiated by the concentration of some portion of the energy evolved in the nuclear transformation onto the atom in question, either by recoil or by electronic interaction. The energy so acquired is usually large compared to chemical bond energies, so that bond rupture results. During the time in which the excess energy is being lost to other atoms in the system, the "hot atom" may participate in chemical reactions which would not ordinarily occur because of their high activation energy.

One type of question being studied is to ascertain the different kinds of stable chemical binding in which the recoil atom ultimately finds itself after it has lost its excess energy. It has been proposed (W.F. Libby, J. Am. Chem. Soc. 69, 2523 (1942)) that the mechanism through which a recoil atom is incorporated in stable molecules is that, by impact, it dissociates a molecule of the liquid into radicals, and is trapped in a liquid cage until it combines with one of the radicals trapped with it. Consequences of this idea have been developed in a theoretical discussion of the yields of different species of radioactive molecules as affected by the composition of the system. (J.M. Miller, J.W. Gryder, R.W. Dodson, J. Chem. Phys., in press. The work reported in this paper was carried out in part at Brookhaven National Laboratory, in part at Columbia University.) Related experiments are being carried out with mixtures of bromoform and benzene. The aim is to determine, as functions of the composition, the yields of radioactive $CHBr_3$, CBr_4, C_6H_5Br, and of water extractable activity, for both Br^{80} and for Br^{82} (J. Silverman, R.W. Dodson).

A series of experiments aimed at finding whether C^{14} decay always results in bond rupture was described in the preceding progress report. The method employed is to measure the amount of $HC^{14}N$ which grows in doubly-labeled acetylene, $HC^{14}C^{14}H$, as a consequence of the beta decay of one of the adjacent C^{14} atoms. The hope that irrelevant processes leading to the formation of $HC^{14}N$ by other mechanisms could be eliminated has not been completely realized. The last four milkings from about 0.5 mc of C^{14} in 30 micromoles of C_2H_2 gave, for the ratio of the number of $HC^{14}N$ molecules formed to the number of beta decays in $HC^{14}C^{14}H$: 400, 18, 6, and 3.

It seems unlikely that unequivocal data will be obtained for the acetylene system; other systems will be considered (W.W. Miller, R.W. Dodson).

The recoil of atoms from surfaces following electron capture by the nucleus is being studied with the aim of measuring the energy spectrum of recoils caused by neutrino emission, and of developing useful techniques for the observation and measurement of recoil atoms. Experiments have been performed with Be^7 in which the recoils, after passing through a retardation grid, are detected by means of a vibrating reed electrometer. The deposits are prepared by vacuum distillation of carrier-free Be^7, and throughout the course of an experiment are handled completely in vacuo. The retardation spectra obtained in a series of experiments have shown that the positive recoil ions, from deposits on either platinum or wolfram (tungsten) surfaces, have energies from zero up to about 30 ev; ions with the expected upper limit of about 57 ev have not, as yet, been observed. (Recoil ions from Be^7 decay with energies up to 57 ev have been observed by P.B. Smith and J.S. Allen, Bull. Am. Phys. Soc. 24, #7, 14-5 (1949), using electron multiplier detection.) The efficiency of recoil from the deposits on platinum was 20-30%. It is evident that energy loss in leaving the surface is one of the major difficulties in the way of obtaining a true recoil spectrum; the attempted preparation of clean, smooth, monatomic layer deposits is being further pursued with the hope that these will make possible measurement of the true shape of the recoil spectrum. Low energy (70% less than 10 ev) negative particles (assumed to be Auger electrons) have been observed in all of the experiments in a ratio of about one for each positive ion (R. Davis).

Chemical Studies with Isotopes

Under this heading are described investigations in which isotopes are used as tracers in studying the kinetics and mechanisms of chemical reactions, and studies of the effects of isotopic substitution on molecular properties.

A project is being carried out which has as its aims the preparation of organic molecules (mainly hydrocarbons and their simple derivatives) containing known amounts of tracer atoms in known positions, and the study of the properties of the isotopically substituted substances. Catalytic synthesis methods are emphasized with the additional objective of obtaining insight into the catalytic reaction mechanisms by determining the distribution of tracer atoms in the products.

The following substances have been isolated from the mixture of Fischer-Tropsch synthesis products, and have been purified and stored: C_2D_6, C_3D_8, C_4D_{10}. The CD_4 is being purified. By bromination of the olefins, samples of $C_2D_4Br_2$, $C_3D_6Br_2$, and $C_4D_8Br_2$ have been obtained. Further work will include the isolation and purification of deuterocarbons from the liquid fraction, and the fractionation of the deuterocarbon wax mixtures which have been accumulated. The infrared spectrum and, when possible, the mass spectrum of each product is recorded. Various deuterium tracer experiments aimed at elucidating the nature of the reactions which occur on the catalyst surface have been performed; the complexity of these processes, however, does not yet permit firm conclusions to be drawn. Preliminary interpretations favor the idea that the reaction involves polymerization of carbon atoms on the surface, with subsequent hydrogenation, rather than the growth of CH_2 chains up from the surface. The reaction $H_2 + D_2 = 2HD$ is found to go on the surface in the

presence or absence of CO. The distribution of hydrogen isotopes in the methanes formed when mixtures of H_2, D_2, and CO are passed over the catalyst has been examined. All of the expected isotopic species are observed. Further work on the spectra of the pure compounds will be required for accurate interpretation of the mass spectra of such isotopic mixtures, because of isotope effects on the relative probabilities of rupture of C-D and C-H bonds (S.O. Thompson, J. Turkevich).

The study of the catalytic reduction of acetone, aimed at synthesizing $(CH_3)_2CD_2$ has been continued. In the complete reduction to propane, the introduction of deuterium in not limited to the central carbon atom. However, partial reduction to isopropanol has permitted localized introduction of deuterium, $(CH_3)_2CDOD$ being formed. $(CH_3)_2$ C DOH and $(CH_3)_2CHOD$ have also been prepared. The infrared and mass spectra of the three compounds have been determined. It is planned to use $(CH_3)_2CDOD$ as an intermediate in the synthesis of $(CH_3)_2CD_2$ (L. Friedman, J. Turkevich).

Reactions between H_2O, C, CO, and CO_2 involved in the "water gas reaction," are being investigated, using both ordinary kinetic techniques and tracer O^{18}. The reactions $C + H_2O = CO + H_2$, $2CO = C + CO_2$, and the catalytic process $CO + H_2O = CO_2 + H_2$ are of interest, also, for the possible preparation, without isotopic dilution, of O^{18}-labeled CO and CO_2 from H_2O^{18}. The reactions will be studied from this point of view, and also with respect to the intervention of oxygen from the charcoal surface or from the iron oxide - chromium oxide catalyst employed in the third reaction (J. Amick, J. Turkevich).

Experiments on the rate of exchange between anhydrous aluminum bromide and ethyl bromide in carbon disulfide solvent were reported in the previous progress report. It has been necessary to interrupt this work; its present status may be summarized as follows. Above a mol ratio $R = C_6H_5NO_2/AlBr_3$ of 0.2, the addition of nitrobenzene inhibits the exchange rate. The reaction is essentially stopped at R greater than 0.81. Assuming second order kinetics, the rate constant for the exchange passes through a maximum at R = 0.2. These remarks apply to runs made at 0°C. A single series of results at 15°C for R = 0.469 point to an activation energy for the reaction of some 9200 calories per mole (H.C. Thomas).

A study of the exchange reaction between cerous and ceric cerium in aqueous solutions has been completed; the results are being prepared for publication. In nitric acid solutions, the rate is found to be first order in the overall cerous concentration and in the overall ceric concentration, which is consistent with a bimolecular encounter as the mechanism of the electron transfer process. At constant ionic strength, the rate decreases with the inverse square of the acid concentration. An analysis of the data suggests that the reaction proceeds through two parallel paths, one involving unhydrolyzed cerous and ceric ions, the other involving unhydrolyzed cerous ion and doubly hydrolyzed ceric ion. In perchloric acid, it is again found that the exchange rate decreases with increasing acidity, in this case with the inverse first power of the acid concentration. With respect to the reaction order in the cerium concentrations, the surprising result was found that, at low ceric concentrations, the rate is independent of the ceric concentration. At constant acid, the rate data are represented by an expression of the form $R = k\,(CeIII) + k\,(CeIII)(CeIV)$. The first order term is accounted for if one reaction path proceeds through an excited state of cerous ion, the rate of thermal excitation of which is the rate controlling step.

In this connection, the existence of a low (1000-2000 cm^{-1}) excited state of cerous ion was proposed earlier (S. Freed, Phys. Rev. 38, 2122 (1931)) and experimentally verified (F.A. Krögger and J. Bakker, Physica 8, 628 (1941)) in observations of the fluorescence spectra of crystals and solutions of cerous salts (J.W. Gryder, R.W. Dodson).

The electron transfer exchange reaction between thallous and thallic thallium is also being investigated. Earlier work (G. Harbottle, Thesis, Columbia University, 1949) has shown that the rate of this reaction is powerfully affected by chloride ion; and the effects have been ascribed to the formation of chloride complexes. The chloride system is being studied further, and an attempt is being made to obtain rate data at electrolyte concentrations low enough to permit an interpretation of the effect of ionic strength on the rate. In perchloric acid, the ionic strength effect has been studied at perchlorate concentrations from 0.6 to 6.1 formal. It is found that, above acid lf, the effect of adding $NaClO_4$ is of the same order as that of adding an equivalent amount of $HClO_4$. In connection with these experiments, the absorption spectra of thallous ion in hydrochloric acid solutions have been measured with the Cary recording spectrophotometer. The previously observed absorption maximum at 2450-2500 A has been confirmed, and more accurate values of the apparent formal extinction coefficient have been calculated for this peak. The height of the absorption maximum at 2135 A shown by thallous ion in water was found to obey Beer's law (L. Eimer, G. Harbottle, R.W. Dodson).

A fairly extensive study has been made of the exchange reactions of the nickel in tetracyanonickelate ion with free nickel ion, and with nickel ion in various other complex ions. The exchange between the cyanide complex and nickel ion was found to be slow, even though the related exchange of cyanide between the complex ion and cyanide ion in solution is very fast. As a by-product of this study, it has been shown that there are two nonequivalent kinds of nickel in solid nickel cyanide, i.e., the structure is probably $NiNi(CN)_4$. The exchange of nickel in the cyanide complex with nickel in the nickel ammonio complex is very fast, but is slowed to a measurable rate by large amounts of neutral salt. Essentially the same is true for the analogous exchange involving the nickel in trisethylenediamine nickelate ion. In contrast, the exchange of nickel in the cyanide complex with nickel in either nickel oxalate ion or the complex nickel tartrate ion is quite slow. The mechanism of the latter four exchanges probably involves a direct bimolecular reaction. However, further experiments are needed to check this point. Further plans call for a more detailed study of the kinetics and temperature coefficients for one or two of these exchange reactions (F.A. Long).

Rate studies are also being made on the exchange reaction between nickel ion and nickel in the complex ion formed with ethylene diamine-tetra-acetate ion. From present data, the exchange rate appears to be proportional to the 3/4 power of the hydrogen ion concentration in the pH range from 3 to 5. In more acid solutions, the order is apparently higher. More limited observations have been made on the order of the reaction with respect to other constituents, on the temperature coefficient, and on the effect of neutral salts; these will be extended (C. Cook, F.A. Long).

The mechanism of the acid catalyzed hydrolysis and the basic hydrolysis of γ-butyrolactone has been studied with the aid of O^{18} tracer and the results written up for publication. The hydrolyses were carried out in O^{18}-labeled water. By regenerating the lactone and examining it mass spectrometrically, it was found

possible to locate the position of O^{18} in the molecule. The data show that only one of the oxygens in the regenerated γ-lactone has exchanged with the H_2O^{18}, and it was established that this is the oxygen in the carbonyl group. From this result, it follows that both the acid and basic hydrolysis of the γ-lactone go through acyl oxygen cleavage (F.A. Long, L. Friedman).

A study of the uptake of dyes by textile fibers is being made with the aid of radioactive tracer isotopes. Color index #1088, an anthraquinone sulfonic acid dye, was selected as suitable for this project because the clean monosulfonation, which is the last step in its synthesis, permits the convenient introduction of S^{35} into the molecule. Snythesis of the active dye has been successfully carried out, resulting in a sample of specific activity one microcurie per milligram. Preliminary dyeings of human hair have been performed in order to determine the reproducibility of the method and study the necessary self-absorption corrections. The method appears satisfactory; the high specific activity will make it possible to carry out kinetic experiments, using finer fibers such as wool or nylon. This investigation is being carried out by P. Stam, of the Textile Research Institute, Princeton, N.J., as a guest of the Laboratory.

Research has been continued on the effects of isotopic substitution on the rates and equilibria of chemical reactions. The C^{13} isotope effect in the decarboxylation of malonic acid has been investigated, using the C^{13} present in natural abundance as tracer. The results have been published.# The ratio of rate constants for the rupture of the C^{12}-C^{12} bond in $C^{12}H_2(C^{12}OOH)_2$ and the C^{13}-C^{12} bond in $HOOC^{13}C^{12}H_2C^{12}OOH$ was found to be 1.037, which may be compared with the value 1.021 predicted by the theory which has been developed for such effects. The ratio of rate constants for the rupture of the C^{12}-C^{12} bond and the C^{13}-C^{12} bond in $HOOC^{13}CH_2C^{12}OOH$ was found to be 1.020, the predicted value being 1.020. A theoretical study of isotope effects in certain other reactions has been carried out, and will be reported later. Tables are under construction which will facilitate rapid computation of the effect of isotopic substitution on the entropy, enthalpy, and heat capacity of gases. These should prove to be a useful complement to similar tables (J. Bigeleisen and M.G. Mayer, J. Chem. Phys. 15, 261-7 (1947)) for the computation of the free energy and equilibrium constant which have previously been published. Future experimental work is planned on the effect of isotopic substitution on the rates of reactions of some nitrogen and oxygen compounds with N^{15} and O^{18} as tracers. Exchange equilibria of the compounds will also be studied. Experiments on the rates and equilibria of exchange reactions between deuterium and protium halides are planned. The equilibrium data will be compared with the predicted equilibrium constants, which have been calculated. From a study of the rates, it is hoped to determine the effect of bond length and bond type on the rates of these reactions (J. Bigeleisen).

Mass Spectrometry

Three mass spectrometers are being operated in the Department: a Nier type isotope ratio mass spectrometer, built by Consolidated Engineering Company; a General Electric analytical mass spectrometer; and an experimental Nier type instrument similar to the G.E. machine. The Consolidated and G.E. instruments were used extensively during the past six months in connection with investigations reported elsewhere in this report; some service analyses have been made for other institutions.

It has been necessary to determine the mass spectrometric patterns and appearance potentials of a number of different compounds, and measurements of this kind will be continued. For example, a pronounced pressure effect on some of the relative intensities in the patterns exhibited by lactones has been observed, and will be looked into further. CH_2N_2 will also be measured. This compound may serve as a source of CH_2 radicals, and the appearance potentials may permit as estimate of the ionization potential of the CH_2 radical (L. Friedman, A.P. Irsa).

As reported in the previous progress report, the experimental instrument has been used in a study of discrimination effects and in measurements of the relative yields of ions formed by electron impact in H_2 and in D_2. The appearance potential curves for H^+ and D^+ exhibit a characteristic break when a hot wolfram (tungsten) filament is used in the ion source. This break is interpreted as indicating two modes of formation of ionized hydrogen atoms, the higher voltage mode being by the primary reaction $H_2 + e = H^+ + H + 2e$. Below the break, the peak intensities show a linear dependence on pressure and on electron beam current, indicating that the monatomic ions are formed in a single ionizing act, and suggesting that they are produced by the ionization of hydrogen atoms which are formed by the dissociation of H_2 or D_2 on the hot filament. This was confirmed by installing a low temperature oxide coated cathode. With this electron source, the break was absent, and only the higher voltage mode of formation was observed. It is planned to continue appearance potential measurements for some simple molecules and radicals, with special reference to the connections between such data and the problems encountered in radiation chemistry (O. Schaeffer, J. Hastings).

Neutron Diffraction

The design of a neutron spectrometer suitable for structure determinations has been undertaken in collaboration with the Solid State Physics Group. The basic design is substantially complete. It is planned to build a double crystal instrument similar to the one now being used at Oak Ridge. The apparatus will utilize a 2" x 2" beam of neutrons emerging from a parallel Soller slit collimator inserted in the nuclear reactor shield. Monochromatization of this beam is to be accomplished by reflection from a large metal single crystal. (Transmission is also being considered.) The monochromatic beam passes over a spectrometer table about which a $B^{10}F_3$ counter can be rotated to detect radiation scattered by the sample. Additional Soller slits are to be placed between the monochromatizing crystal and the sample, and between the sample and the $B^{10}F_3$ counter. By utilizing Soller slits of individual dimensions 1/8" x 2" x 22", and a metal monochromatizing crystal, it is hoped to obtain approximately 4-5 times the intensity and about 2-1/2 - 3 times the resolving power of the present Oak Ridge equipment. An additional gain in intensity is expected to come from the increased flux anticipated from the Laboratory's reactor. The Soller slits permit the use of a wide neutron beam without sacrificing geometrical resolution. The principal advantage of using a metal monochromatizing crystal in place of rock salt lies in the ability of the former to reflect neutrons over the entire angular range permitted by the geometry of the collimating system.

The most uncertain factor in the design involved the feasibility of using a metal single crystal as a monochromatizer. To investigate this aspect of the problem, some exploratory determinations of rocking curves of nickel, lead, iron, and rock salt

single crystals were made using the double crystal spectrometer at Oak Ridge. (We are grateful to the Oak Ridge group for putting their apparatus at our disposal.) The results indicate that these metal crystals are superior to rock salt in regard to both rocking curve width and peak reflectivity (L. Corliss, J. Hastings).

Organic Chemistry

Several enterprises aimed at using or facilitating the use of isotopes in problems of organic chemistry are being carried on. This work might properly have been described in the previous section, "Chemical Studies with Isotopes;" however, it proves convenient to discuss it in a separate section. Two general types of investigation are receiving attention: the development of synthetic methods for the convenient incorporation of tracer isotopes into complex organic molecules; and the study of organic reaction mechanisms with isotopic tracers, and by means of isotope effects on reaction rates.

The development of a synthetic method employing potassium carbonyl for the preparation of C^{14}-labeled meso-inositol was described in the previous progress report. Further study of the intermediate steps in this synthesis has indicated the occurrence of side reactions, the products of which should be characterized. Because of the potential usefulness of the alkali carbonyls for the synthesis of other compounds in addition to the inositols, an effort will be made to find out more about their structure and reactions (R.C. Anderson).

A synthsis of C^{14}-labeled ascorbic acid (vitamin C) is being carried out in collaboration with the Biology Department. The procedure involves a succession of biological and chemical syntheses, starting with radioglucose. It has been rehearsed with inactive materials on a semimicro scale; techniques for obtaining satisfactory yields on this scale have been devised. The first three of the six steps have been successfully completed, and the remaining three should be straightforward (A. Bothner-By, M. Gibbs).

Another problem under study is the incorporation of radioactive cobalt in vitamin B-12. It is felt that the labeled material would be of great value in studying the physiological action of this substance, and might also be useful in therapeutic applications. Several possible methods including exchange, activation in situ, and "hot atom" synthesis are being considered. A sample of B-12 concentrate has been kindly furnished by Charles Pfizer Company in order to make this work possible (R.C. Anderson).

At elevated temperatures, barium adipate, $(CH_2)_4(CO_2)_2Ba$, decomposes into barium carbonate and cyclopentanone. The degree of fractionation of carbon isotopes in the products has been measured, using natural C^{13} and C^{12}, in order to see what could be learned about the mechanism of the pyrolysis by this approach. The C^{13} isotope effect was found to be 0.1% or less (cf. that found in the dècarboxylation of malonic acid). This result is consistent with the idea that the rate controlling step in the cyclization of barium adipate is the removal of one of the α-hydrogens, which was suggested earlier as a step in the mechanism. Other possible reasons for the lack of an isotope effect are being investigated. It is planned to synthesize deuterated adipic acid, and pyrolze a mixture of deutero and protio barium adipates, comparing

the cyclization rates of the two species during the course of the reaction. A substantial difference should be found if the rate controlling step is that suggested above (A. Bothner-By, J. Bigeleisen, L. Friedman).

Some difficulties have been encountered in the simultaneous C analysis and C^{14} assay of small samples of organic compounds when published procedures were used. Therefore, a procedure has been devised which is simple, rapid, and reliable. Since the method may be of interest in other laboratories, the details will be published in a BNL report (H. Prosser, R.C. Anderson).

In addition to the above, the members of the organic group have performed a number of service syntheses and compound purifications for members of the Chemistry and Physics Departments.

Analytical Chemistry

Increasing provision has been made for service analyses in support of the work of various groups in the Laboratory; concurrently, the demand for such assistance has continually increased. The aims of the analytical group are to perform chemical analyses necessary in the program of the Laboratory, and to engage in research on problems of analytical chemistry. During the past six months, numerous analyses have been performed for members of the Chemistry Department, the Physics Department, the Department of Reactor Science and Engineering, the Accelerator Project, the Health Physics Division, the Safety Group, the Technical Services Division, Architectural Planning and Plant Maintenance Department, and Security Office. By far the greatest number of requests originate in the Department of Reactor Science and Engineering (R. Stoenner, S. Hunter, A. Medalia, M. Slavin).

In the spectrographic laboratory, the Baird 1 meter grating spectrograph has been put into operation, and has been used for a large number of spectrochemical analyses during the past month. It is now available to the Laboratory for service analyses. The Jarrell-Ash 3 meter grating spectrograph will be put into operation as soon as its grating is received (M. Slavin).

Many problems have arisen which required more than the routine execution of standard analytical methods. Some of these will be mentioned: Appropriate modifications have been made in an existing method for radioiodine assay, in order to make it suitable for the determination of radioiodine in sewage; two members of the Health Physics Division have been trained in the necessary techniques. A study has been made of the composition of the gases evolved during the solution of U_3O_8 in concentrated nitric acid. The ratio of NO_2 to NO was measured by absorbing the gases in standard alkali, backtitrating, and titrating the nitrite with $KMnO_4$. Nitrogen dioxide is always in excess, the mol ratio NO_2/NO varying from 4 to 30, depending on conditions. Gravimetric and volumetric methods are being developed which will, it is hoped, simplify the ever-recurring problem of U-Fe and U-Al alloy analysis. Service analyses of bismuth alloys have called attention to a point of controversy in the literature between the merits of weighing Bi as Bi_2O_3 or BiOCl. Contrary to several accepted procedures, the experience has been that, even with large amounts of bismuth, the precision of the BiOCl method surpasses that of the Bi_2O_3 method (R. Stoenner).

The problem of analyzing the laboratory distilled water for organic matter has led to the development of an improved procedure for this purpose, based on the Fenton reaction. Ferrous iron and hydrogen peroxide are added to the water sample at room temperature; after 15 minutes, the excess of ferrous iron is titrated with ceric sulfate. This method has proved satisfactory for the detection of such relatively stable compounds as benzene, pentane, and acetic acid, as well as more easily oxidized compounds, such as acetone, ethanol, and gelatin. A spectrophotometric method for cerium based on the ceric absorption peak at 320 millimicrons has been devised (with the aid of B.J. Byrne of the Sanitary Engineering Group) which is considerably more sensitive than the usual colorimetric method. Several kinds of micro electrodes designed to eliminate the disadvantages of the conventional dropping mercury electrode in polarographic analysis have been studied. A streaming mercury electrode has shown promise (A. Medalia).

Nuclear Problems

The general program includes the study of the decay characteristics of radioactive substances and the study of nuclear reactions by measurements on the radioactive products of the reactions. In the past six months, work has been carried out with radioactive materials prepared at Oak Ridge, Massachusetts Institute of Technology, and the University of Pennsylvania.

The half-life of C^{14} has been measured in two completely separate and, in some respects, different determinations. The work does not clear up a discrepancy between two groups of values previously reported at about 6400 years (R.C. Hawkings, R.F. Hunter, W.B. Mann, and W.H. Stevens, Can. J. Res. 27B, 545 (1949)) and 5600-5700 years (A.G. Engelkemeir, W.H. Hammill, M.G. Inghram, and W.F. Libby, Phys. Rev. 75, 1825 (1949); W.M. Jones, Phys. Rev. 76, 885 (1949)), but does indicate a basis on which to make a choice of values, and a possible source of discrepancy. Both determinations involved measurement of the C^{14} abundance in CO_2 with mass spectrometry, successive aliquot dilutions, and, finally, an absolute beta count with an internal gas sample counter. Using a CO_2-CS_2 G-M counter, a half-life of 6360 ± 200 years is found, in excellent agreement with the 6360 ± 200 years obtained by Hawkings et al., who also used this type of counter. The other sample was counted as CO_2 in a CH_4-CO_2 proportional counter; in this case, the computed half-life is 5513 ± 170 years, in excellent agreement with the value 5589 ± 75 years found by Jones, who used an argon-ethanol-CO_2 filled G-M counter, and in good agreement with the value 5720 ± 47 years reported by Libby et al., who used a similar counter. It is believed that values in the lower group are more reliable, and that the discrepancy must arise from an inherent inefficiency of about 15% in the CO_2-CS_2 counter (W.W. Miller, L. Friedman, W. Bernstein, R. Ballentine, A.O. Nier of the University of Minnesota, R.D. Evans of the Massachusetts Institute of Technology. This work was carried out in part at the Laboratory, in part at the other institutions named.).

Work on the isolation of Se^{79} and I^{129} from old Oak Ridge slugs has been continued. A selenium sample purified by repeated precipitation and distillation has come to constant specific activity; the complex absorption curves indicate the presence of 150-kev beta particles. Identification is not yet considered conclusive. A procedure has been tested on a 10-mg scale for the conversion of I^{129} into CH_3I, to be used for mass spectrometry and absolute beta counting. In collaboration with

members of the Physics Department, it has been shown, by a combination of chemical separations, and radioactivity and neutron measurements, that fission product Pr^{144} emits hard gammas above the Be photoneutron threshold (1.67 Mev). Their half-thickness in lead was found to be 15.2 g/cm^2, corresponding to an energy of 1.8 Mev for monoenergetic gammas. Beta-ray spectrometer measurements by D.E. Alburger of the Physics Department indicate that this is an average over at least two groups. The value listed in the current literature is 1.25 Mev. Preparations are being made for the measurement of ranges of fission recoils of known mass number in aluminum (S. Katcoff).

A systematic program has been started in which the objective is to observe and characterize extranuclear radiations associated with alpha and beta decay. At present, X-ray measurements are being made on alpha and beta emitters, using an X-ray proportional counter and pulse analyzer constructed by the Electronics and Instrumentation Division. With this exceedingly useful instrument, X-ray spectra have been measured for several radioactive substances, particularly Po^{210}. In the latter case, peaks are found at 10.5, 12.5, and 14.7 kev, in close correspondence with the known L X-ray levels of Pb. A line at 2.4 kev is tentatively identified with the M α line of Pb. The yields have been estimated roughly at 5×10^{-4} L X-rays and 5×10^{-4} M X-rays per polonium alpha emitted. Peaks are also observed with Bi^{210}, P^{32}, and S^{35}. Effort is being put on improving the calibration and stability of the instrument, so that identification of the various peaks observed can be made with greater assurance (W. Rubinson).

The proportional counter - pulse analyzer is being used to investigate the radioactive decay of K capture nuclei. Ni^{57} and I^{126}, whose decay schemes are of interest in connection with certain nuclear reaction yields, are to be studied. These nuclides will be produced by alpha-particle bombardment of Fe and Sb, respectively, at the cyclotron of the Carnegie Institution. Procedures have been worked out and tested for the separation of Ni^{57} and I^{126} from the target materials and interfering radioactivities and for source preparation. Work is now in progress to determine the resolution and energy scale of the instrument and to analyze the factors which must be taken into account in order to derive absolute disintegration rates from the counting data. A vacuum system capable of operation at several atmospheres pressure has been built and used for outgassing and reproducibly filling proportional counters. Tubes filled on this system with 90% argon and 10% methane mixture have shown good characteristics (M. Perlman).

In the study of nuclear isomers, it is often desirable to separate the upper and lower isomers. The possibility of "hot atom" chemical separation of the parent and daughter has been investigated for Hf^{181} and Ag^{110}. Radiochemical purifications of neutron-bombarded titanium indicate that the existence of the reported 72-day Ti^{51} isomer is doubtful. In the case of Hf^{181}, hafnium acetylacetonate was prepared, and a chloroform solution of it extracted with water. With Ag^{110}, similar experiments were done with the dithizonate and 8-hydroxyquinolate complexes in chloroform, with the tetraphenylporphin complex in ether, and also with some complexes in aqueous solution. In no case was observable separation achieved. Experiments of this type are being continued; also, an apparatus is being constructed for the physical separation of the daughter by recoil (J. Miskel).

A search for new cases of nuclear isomerism has been continued. Neutron-irradiated arsenic, copper, gallium, and gold have been examined for the possible existence of long-lived isomers in the radiative capture products. Assuming formation

cross sections of 10^{-26} cm^2, the results indicate that no metastable states with half-lives between 0.1 and 10^4 years are formed. Other elements are being similarly examined (J.J. Howland).

Other work on nuclear isomers has been continued, partly in cooperation with members of the Physics Department. A number of sources of Ga^{72} and As^{72} were prepared from deuteron bombarded germanium oxide for a study of the Ge^{72} isomer of $3x10^{-7}$ sec half-life, which grows from Ga^{72} by β^- decay and from As^{72} by β^+ decay, and possibly by K capture (G. Friedlander).

The possible growth of the 17.5-sec isomer of stable Se^{77} from 40-hour As^{77} was investigated radiochemically. The As^{77} grows by β^- decay from 12-hour Ge^{77}, which was obtained by deuteron irradiation of GeO_2 in the Massachusetts Institute of Technology cyclotron, and by neutron irradiation of GeO_2 in the Oak Ridge reactor. Selenium was rapidly separated from solutions containing As^{77} by various chemical procedures. No 17.5-sec decay could definitely be established in any of the selenium fractions. When corrections for the times of separations, the chemical yields, and the counting efficiencies for the Se^{77} and As^{77} radiations are made, the results show that no more than 2% of the As^{77} decays go to the 17.5-sec isomer of Se^{77}. This result was confirmed by the fact that no selenium K X-rays were observed when strong samples of As^{77} were counted with a proportional counter and pulse analyzer; such X-rays are emitted in the highly converted isomeric transition of 17.5-sec Se^{77} (J. Miskel, G. Friedlander).

A thorough study of the 68-min isomer of Pb^{204} has been undertaken. Outside of the very short-lived Ge^{72} mentioned above, this is the only even-even isomer known. The already well-established mass assignment was further corroborated by X-ray bombardments of lead enriched in Pb^{204}, and of ordinary lead with the University of Pennsylvania betatron. These experiments showed that the 68-min period is not produced by (γ,n) reactions on Pb^{204} or Pb^{206}, thus excluding its assignment to Pb^{203} or Pb^{205}. The 68-min Pb^{204} was obtained by chemical separation from its parent, 12-hour Bi^{204}, which in turn was produced by deuteron bombardment of lead in the Massachusetts Institute of Technology cyclotron. Chemical procedures for periodic milkings of Pb^{204} from Bi^{204}, as well as for the preparation of thin sources of Pb^{204} and carrier-free sources of Bi^{204} and Bi^{206} in satisfactory yield and high radiochemical purity, have been worked out. The chief results of the coincidence counting and beta-ray spectrographic experiments will be reported at the New York meeting of the American Physical Society in January. It is found that a 905-kev transition in Pb^{204} is followed by a 374-kev transition, the latter having a half-life of about $3x10^{-7}$ sec. Further work, particularly on the angular correlation between the two successive gamma rays in the 68-min Pb^{204}, and on the decay scheme of Bi^{204} is planned. The latter will be done with Bi^{204} sources prepared by deuteron bombardment of lead enriched in Pb^{204} (G. Friedlander, with D.E. Alburger, M. Goldhaber, G.S. Goldhaber, A.W. Sunyar).

The first of three permanent-magnet 180° electron spectrographs has been put in operation; a first test with a Bi^{206} source indicated satisfactory performance. It covers an electron energy range from about 20 to 280 kev. With properly prepared sources, a resolution of from 0.3% at the high energy end to 2% at the low energy end appears attainable. Delivery of the two other magnets, which will cover lower and higher energy ranges, is expected shortly. Improvements in the sample introduction

system are being planned to facilitate use of the spectrographs for relatively short-lived activities. The instruments will be principally used in the study of isomeric transitions and K-capture decay schemes (G. Friedlander, E. Wilson).

When the cyclotron goes into operation, it is planned to use it for the production of nuclear species whose decay characteristics are to be investigated, particularly some isomers and K-capture activities, and for the study of excitation functions of various nuclear reactions induced by deuteron, alpha-particle, or proton bombardment. Particularly, the comparison of excitation functions of several reactions produced in a given target nuclide will be of interest. The characterization of decay schemes is intimately connected with the measurement of excitation functions; for in order to obtain absolute cross sections or even relative cross sections for the production of different radioactive species from counting data on these species, one has to know their decay schemes in some detail. Use of the electrostatic generator for the study of some excitation functions of (n,γ) and (n,n) reactions is also contemplated (G. Friedlander, M. Perlman, J. Miskel, J.J. Howland).

Because of the delay in starting the reactor, there has been no recruitment in the staff of the Reactor Science and Engineering Department for this period. The staff now comprises 60 engineers and scientists, 63 technicians and mechanics, and 17 administrative and clerical employees, a total of 140 people, and a reduction of two since the middle of the year. Five of the scientific staff are on leave from other institutions; two more are research fellows working on their doctorate theses; one guest research fellow, not included in the above totals, is also doing thesis work, but is not paid by the Laboratory. The scientific staff of the Department was increased during the summer by a total of 16 scientists and engineers, who were engaged in various activities within the Department for periods ranging from one week to four months, the average time being about six weeks.

During this review period, the reactor laboratory building has been completed, except for the installation of laboratory furniture. Three of the laboratories, as well as one of the counting rooms, are partly occupied by members of the reactor research groups. The offices are now occupied by administrative personnel. The Laboratory has taken over the entire reactor complex, except for the hot laboratory, and is now responsible for maintaining security in this area. The hot laboratory building will be completed soon, and the Hot Laboratory Operations Group will move in at that time.

The waste tank farm has already been accepted by the Laboratory.

The details of the work summarized in the three following sections will be found in a classified progress report of the Department, which is being issued at this time.

Present Status of the Reactor

The reactor itself, its building, and its associated equipment such as fans, controls, etc., are complete except as noted below.

As a result of the inadequacies found in the air cooling ducts, and because of the practical impossibility of correcting any structural defects inside the reactor shield after operation at full power, it was considered necessary to review the design of the entire reactor structure from the shield inward. Since many of the stresses involved were due to thermal effects, the Ferguson Company subcontracted with the Babcock and Wilcox Company to make this review. This review, covering all parts of the structure, is now virtually completed. A number of weak points have been discovered. While the complete engineering details of all the needed repairs have not been decided upon, it is clear that the structure can be modified and strengthened, so that the reactor can be operated at the full design power of 30,000 kilowatts. However, it will take some time to complete the engineering details of the repairs; therefore, it is not expected that the reactor will be ready for operation before the summer of 1950. In the meantime, the operators have been testing and running all the auxiliary equipment and instrumentation for the reactor, so that by the time it is possible to start loading

the fuel, there should be very little likelihood of delays due to inexperience in operating or maladjustment of these components.

Reactor Design Review

During the past six months, a major part of the effort of the Department has been spent in reviewing the design of the reactor and in making various measurements and tests needed by Babcock and Wilcox in their study of its structure.

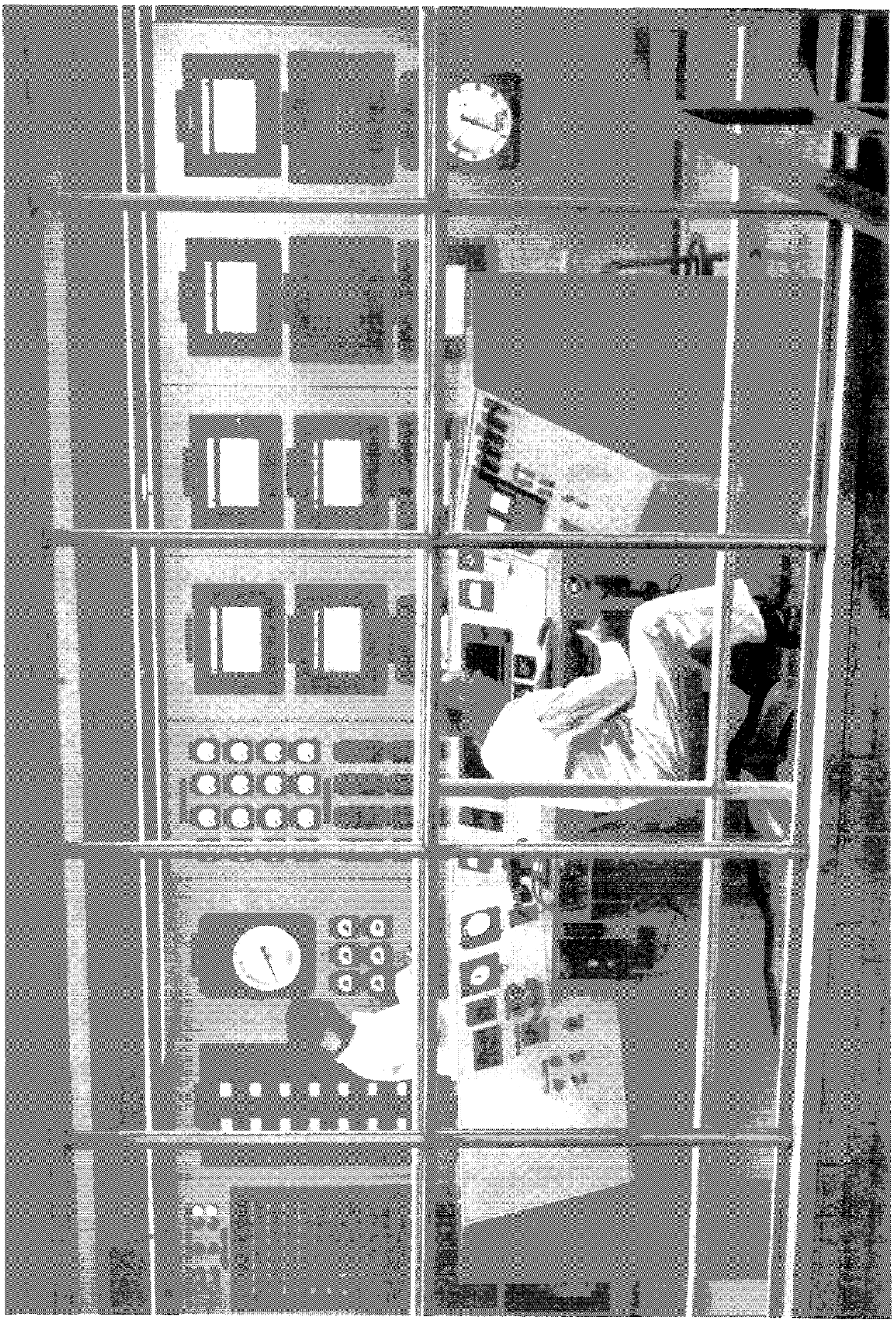
The Chemical Engineering Division studied the temperature gradients throughout the structure under various operating conditions by means of electrical analogs which they have built. The Metallurgy Division has tested the mechanical strength of many of the components of the reactor. This division has also set up and tested models of some of the proposed repair parts for the structure. The Reactor Theory Group has calculated the effects produced under various conditions of operation, especially the transient effects during shutdown and startup. The Shielding Group has measured various physical properties of the shield material. The Reactor Evaluation and Physics Group has determined some of the physical constants of various reactor materials. Full-scale sections of the reactor have been set up and tested by the Operations Group. In addition, Dr. Jacobus has been loaned full time by the Accelerator Project to work with a group of engineers from the Operations Group who are checking the Babcock and Wilcox designs for the repairs and cooperating in these design calculations.

Research

The Chemical Engineering Division is continuing studies on the properties of graphite and on the uranium fuel system. The Division also calibrated the cooling air venturis and found their performance to be in good agreement with manufacturers coefficients. Studies are also being made on properties of reactor fuels.

The equipment for the Reactor Chemistry Group has been in operation for over a half year. While no final conclusions can be reached, sufficient data have been accumulated to indicate that the methods of attack are quite promising. If the experimental results continue to be as successful, it may be possible to have a small test unit designed and ready for operation in the reactor when the reactor is started.

The Metallurgy Division is continuing various tests on the behavior of the fuel elements under varying conditions. So far, these tests indicate satisfactory life under operating conditions in the reactor. Some interesting results have been obtained in the phase-rule research, and this work will be continued for various systems. Equipment is being designed for the work on radiation effects on materials, and is to be ready when the reactor is in operation. The equipment for the single-crystal laboratory has been set up. Several magnesium crystals 2" in diameter have been grown, and techniques for making larger and specifically oriented crystals are being investigated. The metallography section has examined numerous samples for other departments. Some development welding, joining light gage Inconel (0.010") to heavy stainless steel sections, was done for the Accelerator Project.



Nuclear reactor console and instrument panel.

The Shielding Group has been developing a design for the primary shielding facilities for carrying out bulk shielding tests. Plans are made to evaluate the Laboratory reactor shield as soon as operations are at a high level. Thereafter, a program of bulk shielding tests, along with investigations of some of the more fundamental problems in scattering and absorption, are designed to provide information required by the reactor development program of the Atomic Energy Commission.

The Reactor Theory Group has worked on some aspects of the reactor design and reactor physics, partly in connection with Laboratory operations, and partly to extend present theories. In addition, studies were made in the following two unclassified fields.

1. Beta decay of the neutron. Calculations have been made of the relation between proton and electron energies in the decay of the neutron in connection with Dr. Borst's proposed experiments on this problem. The results were discussed with members of the Physics Department's Cloud Chamber Group who are designing a cloud chamber for the experiments.

2. Selection rules for beta decay. Dzhelepov (U.S.S.R. Academy of Sciences, Reports 65, 149-50 (1949)) has proposed new selection rules for beta decay. According to him, the selection rules can be formulated on the basis of the rearrangement energy of a nucleus:

$$X = E - E_K - E_M,$$

where E is the change in energy of a nucleus which undergoes a transition $M \rightarrow M \pm 1$, and is given by the difference between the upper limit of the spectrum and the electron rest mass, E_K is the change in coulomb energy of the nucleus, and E_M is the change in mass. On this basis, beta transitions are allowed if, in the process, there is no rearrangement of the nucleus and $X = 0$; they are always forbidden when there is a rearrangement and $X = 0$. These selection rules are being checked against available data, since it seems that they may be useful in studying transitions for which the spins of the nuclei are unknown and, in particular, in the case of short-lived isotopes. These selection rules are, of course, also of interest from the viewpoint of the general theory of beta decay.

The Reactor Physics and Evaluation Group has continued development of methods of measurement of neutron densities in the reactor as it is being loaded. A coincidence counting apparatus to count the beta and gamma coincidences for a gold foil is being developed in an attempt to measure the absolute value of the neutron density in the reactor. For the purpose of calibrating the activities of foils in terms of a known flux, a standard pile similar to that at Argonne has been constructed. It is a square column of high purity graphite, 7' x 7' x 10', consisting of 30 layers of graphite, with provision for inserting a foil in the center of each layer. One of the standardized 1-curie radium-beryllium sources is placed in the 21st layer up from the bottom. This pile is now being tested to determine the thermal neutron flux distribution, and the indium resonance neutron distribution, as well.

The remaining items are not classified, and will not be included in the classified report.

Chemical Engineering Research

Arrangements for a doctorate thesis (Columbia University) at the Laboratory on velocity and temperature gradients in flowing mercury under isothermal and non-isothermal conditions in a circular pipe were completed in the spring of 1949. The design and construction of the apparatus have been completed. Considerable difficulty has been experienced in attaching thermocouples in such a way as to eliminate irregularities caused by the heater coil windings. These local conditions have been thoroughly analyzed by electrical analog study of these regions, and a tentative solution is now being tested. It is expected that active experimentation can be started after a few months of trial runs (S.E. Isakoff).

The electronic analog of ion exchange beds has proven very useful in clarifying the behavior and mechanisms of ion exchange processes. The effects of a variety of sinusoidal concentration-time feed inputs has been studied, and several critical methods of chemical experimentation have been developed. At present, the analog is being used for the solution of a variety of practical cases of ion exchange beds. These results are being correlated, and a report on this work is in preparation. A doctoral thesis at Columbia University is continuing study of the analog from the applied mathematics viewpoint of uniqueness and inherent errors (B. Rosen).

Arrangements were completed in July for a doctorate thesis (Cornell University) at the Laboratory on the mechanism of ion exchange processes using tracer isotopes on several promising kinetic studies developed through the analog work. These possibilities have been thoroughly explored, and a rather comprehensive literature survey of mechanism investigations has been completed. The experimental work will begin shortly after the first of the year (C.J. Raseman).

Hot Laboratory Operations

Over half of the effort has continued on checking construction details of the hot laboratory, the waste tank farms, and the waste treatment area. The tank farm and piping was accepted as complete early in October, 1949. The hot laboratory building and the treatment area are 95% complete. The entire project is scheduled for completion in February, 1950. Major items to be completed are the installation of doors and periscopes in the three hot cells, the case work for the five semi-hot caves, instruments and piping and the treatment area, and most of the painting and flooring.

The remainder of the effort of the Hot Laboratory Operations Group was expended in preparing for initial operation of the laboratory. This included the study and development of processing methods for short-lived iodine isotopes, design and testing of the ventilation monitoring system, and the design, construction, and testing of a variety of remote operation equipment. Developments have been reported on ventilation studies on a radiochemical semi-hot cell# (J.J. Keyes), a sealer and cutter for plastic tubing# (G.J. Selvin), a totally sealed rotating funnel# (G.J. Selvin), and an improved method for directing liquid flow in a totally enclosed system# (L.G. Stang, G.J. Selvin).

Besides the general responsibilities of maintaining operations in the laboratory, the Group contemplates the following work: the construction, installation, and testing

#Indicates publication. See Appendix for complete reference.

of the "closed cycle" dissolver now under design with the A.D. Little Company, preparation of dissolver solutions for use by others, preparation of short-lived radioiodines from fission, isolation of milligram quantities of protactinium, preparation of fission products for measurement of poisoning action in reactors, study of "shadow" shielding as applied to partially enclosed gamma sources, and assistance in design of special shielding devices.

The waste operation group has had an intensive training and equipment familiarization program in preparation for the start of reactor and hot laboratory operations. Tests are being conducted on special equipment for use in the waste system, and planning is nearly completed for a comprehensive operational test of the entire waste system. Testing and the gradual activation of the waste area as a routinely operating installation is expected to be completed by June, 1950.

Isotopes Production and Distribution

During the past year, the functions and duties of the Isotope Group at the Laboratory have become more clearly defined, as regards both intra-Laboratory traffic and the relationship with the over-all AEC isotope program. This group is now responsible for:

1. Acquisition, distribution, and record keeping on all radioisotopes obtained from Oak Ridge for use within the Laboratory.
2. Distribution of radioisotopes, irradiated materials, and tagged compounds to be produced in the reactor, or elsewhere in the Laboratory, to all authorized users outside the Laboratory.
3. Control and accountability of all source and fissionable materials, as well as some other special materials used in the Laboratory program.
4. Control and accountability of naturally radioactive sources at the Laboratory.

Although the reactor is not yet in operation, the traffic in isotope materials during the past year included some 165 separate items requisitioned by the various departments in the Laboratory and a few outside users. A building has been outfitted with facilities and tools for receiving, handling, and storing these active materials and waste products which result from their use. A monthly report is issued showing the total activity of all the isotopes on hand after being reduced to their current activity levels.

In connection with the accountability for source and fissionable materials, a manual has been drafted, entitled Procedures Covering the Handling of S/F Materials and S/F Accountability for BNL, which describes the system established to assure tight control. Monthly inventory reports are prepared and submitted to the AEC.

Waste Concentration

In the past year, the Waste Concentration Group has been involved in three tasks:

1. A continued study and evaluation of the problems of liquid waste disposal at the Laboratory.

2. The design of waste handling and waste control facilities.
3. The development of processes needed for adequate waste control.

The primary aim of the Group has been the development of a process which would reduce large volumes of slightly contaminated wastes. The requirements for such a process are very stringent, inasmuch as the effluent from the process must meet the Laboratory's discharge standard of 3×10^{-12} curies/ml, while the feed to the process is expected to be over a million times that concentration.

Initial studies were made of evaporative processes. These are fully described in a Laboratory report.# The studies were mainly concerned with the carry-over of radioactive material in the liquid entrainment present in the vapor stream from a simple evaporator. Two de-entrainment units were studied -- a bubble-cap column and a packed tower. The results of the experiments clearly indicated that these units would remove only macroscopic entrainment and that microscopic entrainment would also have to be removed in order to effect the required decontamination.

This work led to the development of two processes which are now considered very promising, and also led to a much better understanding of many of the phenomena involved in the behavior of aerosols in evaporative equipment.

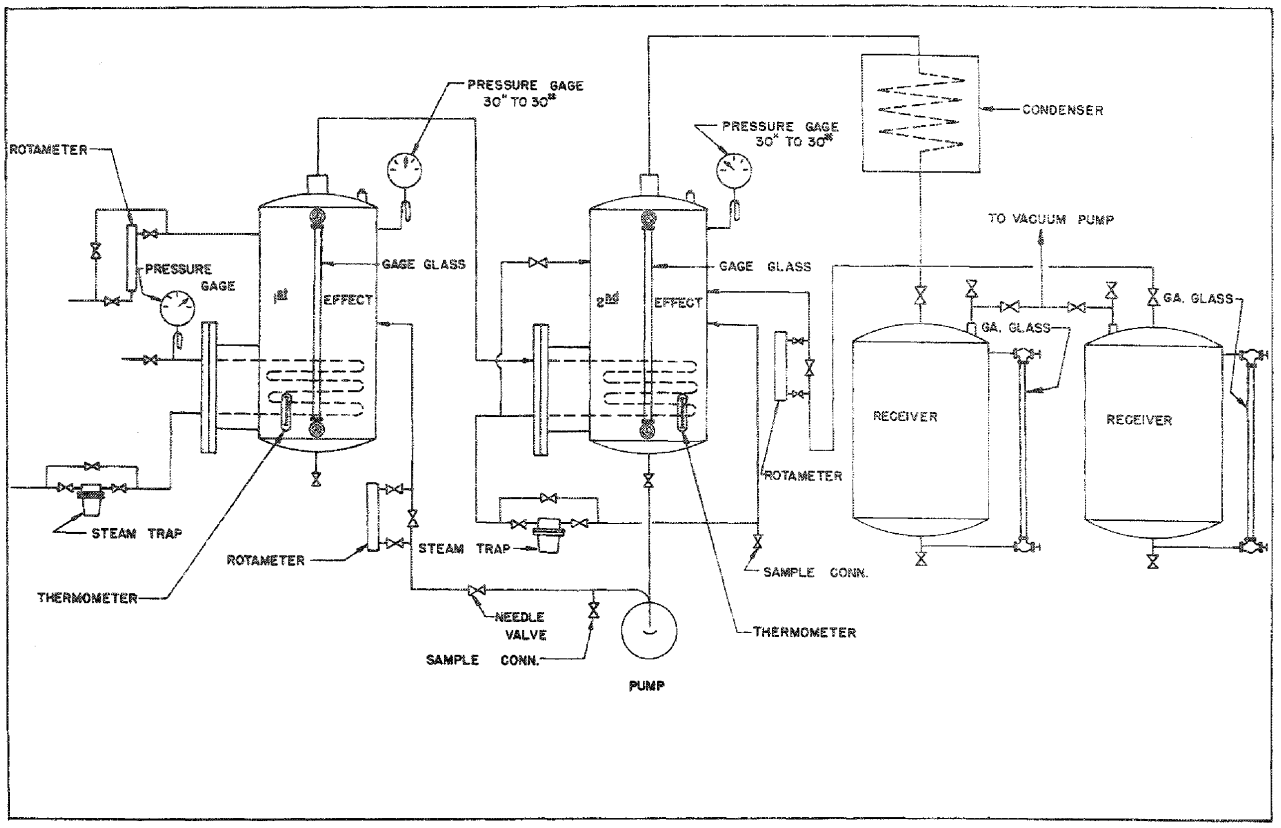
Process A (filtration process) involves simple evaporation, superheating of the vapor, and passage of the superheated vapor through a superfine glass wool filter before condensation. In theory, a normal distribution of liquid droplets are entrained in the vapor leaving the boiling liquid surface; the liquid entrainment is evaporated in the superheater, leaving a solid particulate in the flowing gas stream; the solid particulates are filtered from the gas stream by passage through the superfine glass wool.

Process B (total condensation process) involves multiple evaporation. A rather unique system has been devised which will effect economical multiple distillations. Schematically, the system is shown in the accompanying figure. Both systems will be described in detail in a progress report soon to be issued.

Both of these processes have been tested on a pilot plant scale, and both have demonstrated decontaminations of greater than a million. However, neither system has been completely evaluated as yet. This work is now progressing, with emphasis on comparative studies of the economics of liquid waste disposal at the Laboratory. Attempts are being made to establish broad bases of comparative costs for various methods of waste handling and to evaluate the studied processes for concentrating wastes on a cost basis (B. Manowitz, R.H. Bretton).

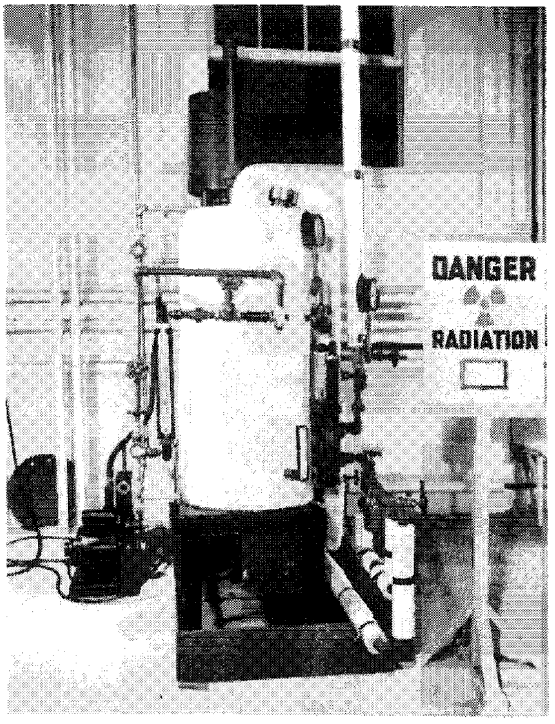
Waste Disposal

The group concerned with waste disposal is now working full time on the problem of permanent disposal of radioactive wastes. Experimental work on this project was begun two months ago, and a few significant results have been obtained. The immediate objective is to determine the ion exchange capacities of certain of the clay minerals for the longer lived fission products of high yield values. In particular, the montmorillonite clays are known to have relatively high cation exchange



Above: Flow diagram for experimental double effect evaporator system.

Right: Experimental double effect evaporator system.



capacities, and two commercial clays in this group are being studied with reference to strontium.

The tests are being made to determine 1) the maximum exchange capacity, 2) the extent of the reverse reaction in the presence of other cations, 3) the effect of dehydration of the clay at various temperatures on the reverse reaction, and 4) the loss of exchanged cations by water leaching.

The results of these tests are far from being conclusive or complete, but some significant trends are discernible. It has been found that strontium does undergo an exchange reaction with the clays, and that water leaching removes only a very small percentage of the exchanged cations. However, the reverse reaction in the presence of an excess of another cation extends virtually to completion. There is some evidence that drying the clay limits the extent of the reverse reaction. This offers a promising lead for future investigation.

Further investigation on the clays will include 1) the effect of higher dehydration temperatures on the loss of exchange capacities, 2) the effect of pH of the solutions, 3) an elucidation of the mechanism of the exchange reaction through a study of the effect on the rates of reaction, concentration, temperature, particle size, etc., and 4) a study of the exchange of ions of different valence and radii.

Although the present study of radioactive waste products in clays is directed toward the problem of permanent disposal, the information obtained should prove to be highly useful in the analyses of problems such as those involving the behavior of radioactive contaminants in ground waters. It is planned that some ground water problems of this nature will be included in the sanitary engineering program.

During the past summer, two independent investigations were made by visiting members of the group. These are reported in memoranda: 1) "Phosphate Relationships in Activated Sewage Sludges," by Charles Smallwood, September 14, 1949, and 2) "Precipitation of Mixed Fission Products by Alum and Activated Silica," by E.W. Moore, August 8, 1949 (L.P. Hatch, W.S. Ginell).

Waste Heat Recovery

A study made by Dr. C.E. Lucke of Columbia University has indicated that, if the exhaust air is over 400°F, steam generation is feasible. With 450°F air, about 40,000 lb/hr of steam at 40 p.s.i. can be generated. At present, types of commercially available standard equipment which would meet these specifications are being discussed with a number of manufacturers. A tentative layout will be made as soon as the final specifications of the boilers and turbogenerators are settled. From this, a cost estimate will be made to show whether such power recovery is economically advantageous if it is demonstrated that the reactor can be operated so as to meet the requirements of air mass flow and temperature.

Physics Research

Radioactivity of K^{40}

A sample of KCl,* enriched approximately 100-fold in K^{40}, was investigated to study the K^{40} radiation. Results of the beta and gamma radiation were given in the last progress report. In addition to beta-ray and gamma-ray emission, K^{40} is known to decay by K capture giving off a characteristic X-ray whose energy is approximately 3.2 kev.

The method used for detection of the K-capture X-rays was by means of a proportional counter filled with a mixture of either argon and methane, or neon and methane. The sample under investigation was placed near a beryllium window which has low absorption for soft X-rays. In conjunction with the proportional counter, the electronic equipment included a special nonoverloading amplifier and a sliding pulse height analyzer, both designed and built by the Electronics Division.

In an effort to calibrate the apparatus for energy, several known K-capture sources were used: Se^{75}, Zn^{65}, Fe^{55}, A^{37}. All of these gave good peaks at the approximate energies expected. The values of X-ray energy of Se, Zn, and Fe are all above that of K^{40}, while A^{37} is slightly below. An intensity calibration was not undertaken.

In making a run with the K^{40} sample, only a slight indication of a peak was observed, which may or may not have been real. This means that either the size of the sample was too small, or else there are no detectable X-rays due to K capture in K^{40}.

A sample of greater enrichment will be investigated in the near future. Then an effort will be made to calibrate accurately the setup for intensity. If the more highly enriched sample still fails to give a peak, at least an upper limit can be set for the number of X-rays emitted per beta emission, since the beta and gamma decay constants are fairly well known (J.J. Floyd, L.B. Borst).

High Efficiency Neutron Counters

A program for the development of neutron counters has been initiated recently to meet anticipated needs for better neutron detectors, especially in the energy region from thermal to about 100 ev. The program consists of the development of neutron scintillation counters and large high pressure BF_3 pulse-ion chambers.

The use of a scintillation counter for neutron detection is attractive largely because of the high efficiency to be expected relative to a conventional BF_3 counter. The research will concentrate on finding a phosphor containing boron which has the rerequired characteristics. Detection of the neutron will be by means of the $B^{10}(n,\alpha)Li^7$ reaction, the emitted alpha particle producing the scintillation.

Several borate crystals appear promising, among these zinc borate and cadmium borate. Attempts will be made to improve the luminescent properties of these crystals by introducing activators. Preliminary considerations indicate that cerium, silver, and cesium are possible activators.

*Obtained through Stable Isotopes Division, AEC, Oak Ridge, Tennessee.

It is planned to try the various borates in the form of large single crystals, and also in the form of crystal powders immersed in a liquid. Other possible arrangements include the suspension of a phosphor in a boron glass (such as zinc sulfide in fused boric acid), and mixtures of a powdered phosphor with a powdered borate crystal. Apparatus for the production of large single crystals from both fusion and solutions has been partially assembled.

Designs for several types of large high pressure pulse-ion chambers are under consideration. One design is a large parallel plate chamber having plates about 50 cm long and 10 cm high, which will be filled with enriched BF_3 to a pressure of 2 to 5 atmospheres (V.L. Sailor).

BIOLOGY

The Biology Department, continuing its slow growth, now has 19 scientists, 20 technicians, and 4 administrative and clerical employees.

The first phase of new laboratory construction is essentially complete, and, although final testing is not yet finished, the building at 46 Bell Avenue has been occupied by 31 members of the Department. Although not all of the special equipment has been delivered, much of it is on hand and will be installed during the next few months. The electrophoresis apparatus and the ultracentrifuge will be installed in January. The electron microscope will be in operation by the end of February, and the X-ray machine should be delivered and installed by the middle of March.

Biological Effects of Radiation

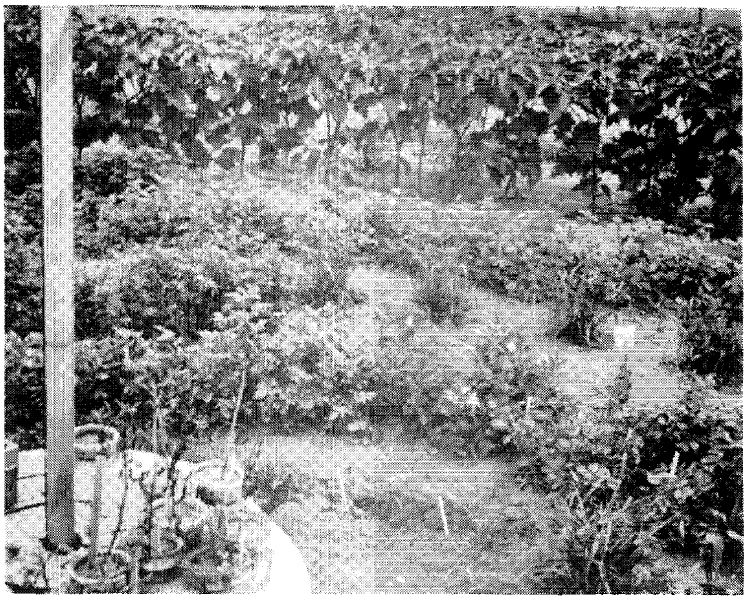
1. Animals

Studies are continuing and will continue for some time on the role which the endocrine system plays in the physiological responses to irradiation. During the past six months, it has been found that 650 r of X-ray irradiation is sufficient to shorten the life span of adrenalectomized rats from an average of 8 to 4 days. If on the day of operation a regimen of 1 cc of desoxycorticosterone acetate per day, or 3 cc of adrenal cortical extract per day (Upjohns), is instituted, 60% and 80% of the animals, respectively, survive 600 r of X-rays for longer than two weeks. All animals were exposed to the 160 kv X-rays three days after the operation, and were also given 1% NaCl solutions to drink instead of tap water during these three days.

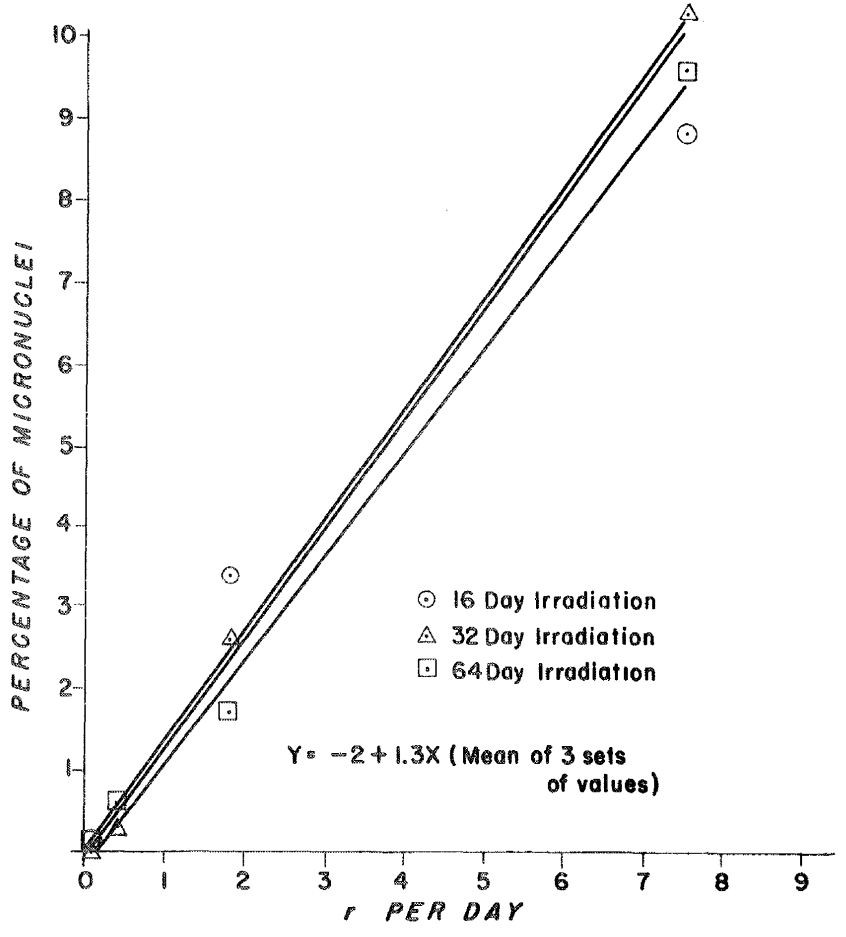
It has been reported that a high concentration of histamine appears in the blood after exposure to X-rays. In attempting to check these findings, an existing chemical method was adopted for spectrophotometric analysis. No histamine has yet been found, but an unknown compound with absorption at 395 μ appears to be greatly reduced in concentration in blood after irradiation. Attempts are being made to identify this unknown compound.

Additional experiments are planned to study the effects of adrenal corticotrophic hormone and aureomycin upon the radiation sickness syndrome in rats. Other experiments on the electrolyte and water balance in animals exposed to ionizing radiation will be much expedited in the new quarters, since a room is now available for maintaining animals at constant temperature, and a new X-ray machine will make it possible to control more precisely the levels of exposures to X-rays. Similar studies will be carried out on neutron-exposed animals as soon as the reactor is available for such work (A. Edelmann, H.E. Abritis, F. Summers, L.F. Nims).

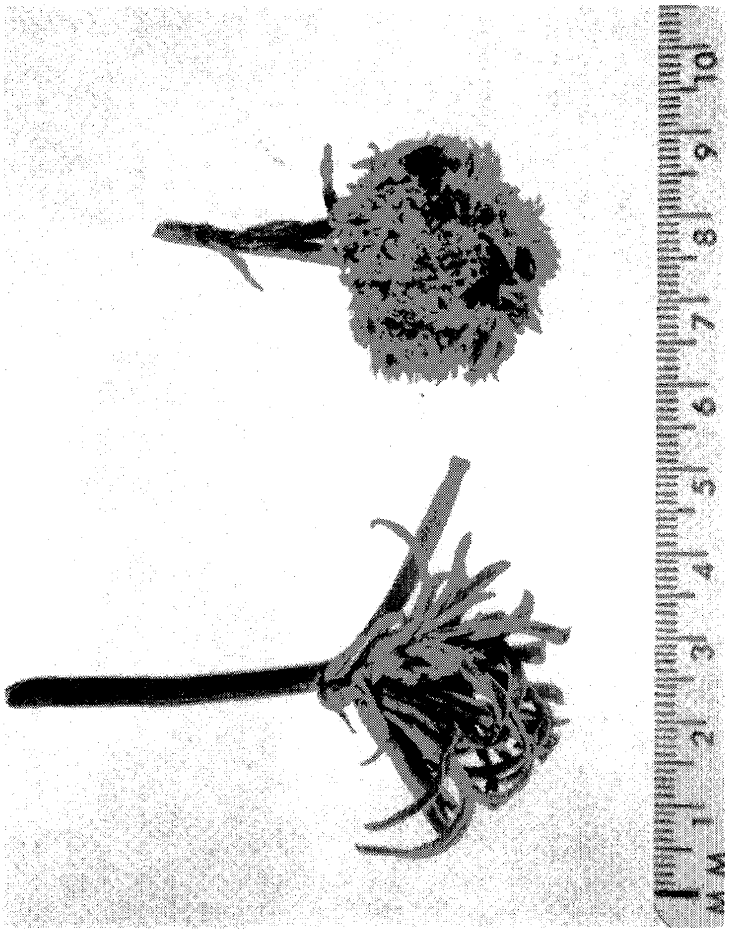
Interior of laboratory in new biology building, showing center bench arrangement. Services suspended above the bench make it possible to remove the bench without disconnecting any of the facilities.



Potatoes, Tradescantia, snapdragons, marigolds, Jimson weed growing at distances from 2 to 7 meters from a 20-curie gamma-ray source occupying the site marked on the metal tube at left. Growth appeared fairly normal at levels up to about 100 r per day, although closer examination showed effects in some plants. Mutations in corn were also observed.



Graph showing amount of chromosome damage (micronuclei) in Tradescantia microspores (young pollen cells) after 16, 32, and 64 days exposure to gamma radiation from radioactive cobalt. It is significant that the percentage of cells showing chromosome damage does not increase with the longer exposures.



Abnormal flower formation in Tradescantia (spiderwork) which develops as a characteristic response to long continued gamma radiation (after 30 r per day for two months or longer).

An exploratory study has been completed of the combined effects of X-ray irradiation and hemorrhage. It has been found that a single dose of 200 r has little effect on the hemoglobin levels of normal rats up to one week after exposures. However, recovery of normal hemoglobin levels in the irradiated bled rats is significantly slower than in bled controls. The animals were bled so as to produce a drop of 25% to 30% in hemoglobin levels initially. The behavior of the total white count, lymphocyte count, and neutrophils after bleeding was not markedly altered by irradiation. An unexpected finding with respect to the neutrophils, following both hemorrhage and irradiation, was an immediate increase of 200% in the total neutrophil count with a return to normal values in 24 hours (M.W. Holt, F. Summers, A. Edelmann).

2. Plants

Pilot experiments in the gamma field were extremely profitable this summer in giving new and significant information concerning the effects of continuous exposure upon several species of plants under field conditions. It is also clear that some of the phenomena studied need further examination under controlled conditions; eventually one of the facilities of the Biology Department should be a temperature, humidity, and light controlled "greenhouse" in which irradiation exposures can be made which are similar to those made in the field.

In *Tradescantia paludosa*, normal growth occurred up to levels of 7.5 r of cobalt 60 gamma irradiation per day. Above 30 r per day, little or no growth took place. Complete pollen abortion resulted after 16 days exposure at 122 r per day, and after 32 days at 30 r per day. The lowest exposure to give a significant increase in chromosome aberrations as judged by micronuclear counts was 0.4 r per day for 16 days. This represents some 1300-fold increase over background radiation of 0.3 mr per day. Further interesting observations were the findings that aberration frequency reached a maximum at 16 days, and that plants examined at 32 and 64 days showed no further increase.# The micronuclei apparently represent "one-hit" aberrations, as they bear a straight line relationship to dosage. Also, an interesting morphological aberration was observed in several plants which received 30 r per day for several weeks. These plants were all sterile at 32 days, and no anthers could be obtained at 64 days. However, the floral parts were overdeveloped and seem to be hypertrophied. In extreme cases, the sepals elongated to several times their normal size and all other floral parts were absent (A.H. Sparrow, R.C. Sparrow, G.R. Davison, V. Pond).

Potatoes grown in the gamma field showed no significant relation between yield and dosage after more than 100 days of exposure, and with total doses as high as 7500 r. This is in contrast to single exposure of potato tubers to X-rays in which a single does of 1200 r is sufficient to produce a significant decrease in the yield.

During the coming year, similar experiments will be carried on in these and other plants; neutron effects and beta-ray effects will, if possible, be compared with those observed for X- and gamma rays. The seed balls have been collected from the exposed potato plants, and the germination behavior of these seeds will be studied in the spring (A.H. Sparrow, E. Christensen, F. German).

Corn, like the potatoes, also grew quite normally at high levels of exposure to gamma rays. The mutations obtained are now being analyzed; a preliminary examina-

#Indicates publication. See Appendix for complete reference.

tion of the data indicates that the mutation rates are much higher than expected. It will require experiments carried on for several years to determine whether this is due to the continuous exposure the developing plants received or whether other factors are at work. The types of mutations produced differ somewhat from those observed in single exposures to X-rays and resemble more closely those produced by ultraviolet in radiation of pollen. A number of sectorial seeds have been found, indicating chromatid rather than chromosome effects. The relative insensitivity of the growth characteristics, in contrast to high radiation sensitivity of the genes, in corn poses problems of great scientific interest, and will be intensively studied in the coming year (W.R. Singleton, F. German, M. Koester).

One of the lines of study on corn is examination of the factors which control sugar production in both radiation induced mutants and normal control stocks. Several varieties of corn are under study, and the concentration of sucrose in the stalk is being followed during the development of each plant. One line, C-103, maintains a level of sucrose in the stalk as high as 10%, even during development of the ear. It is apparent that sugar content of the stalk is under the control of several genes, and that the rate of synthesis, translocation, and utilization differs greatly in the various strains. An attempt will be made to use C^{14}-tagged compounds in corn to study the ability of the corn plant to transport sugar from the leaves to the stalk against the large osmotic gradient existing in the plants (R. Van Reen, W.R. Singleton).

3. Cells

Control series on the spontaneous rate of chromosome breakage in unexposed Trillium erectum plants are almost complete.# It has been found that fragment counts are significantly higher in microspore resting stages than in other stages examined. An unusual type of spontaneous chromosomal fragmentation has been found in one plant. In the most extreme cases, some 4% of microsporocytes show aberrations with up to 30 breaks in one cell, which is equivalent to an exposure of 100 r at the most sensitive stage or 5000 r at the stage of low sensitivity. Statistical analysis shows that the distribution of such abnormal events differs considerably from the spontaneous or the radiation induced breakage in normal material, since the latter are random events. While the cause of such abnormal conditions is not apparent, the need for precise studies of unirradiated control material is evident, for only then can the radiation sensitivity of such material be properly interpreted.

It has been found possible to cultivate excised anthers and buds at various stages through meiosis. This not only makes possible the more accurate control counts of spontaneous breakage, but also allows the examination of the effects of various addition agents upon radiation sensitivity. Another improvement in technique is the use of colchicine to induce tetraploid pollen grains, which immediately reduces the variability in the material and allows studies at higher levels of radiation. Progress has also been made in establishing several Trillium colonies in the nearby woods. If these are successful, the work will be facilitated greatly. During the coming year, it should be possible to examine the effects of both neutron and cyclotron radiations on the chromosomes of this plant (A.H. Sparrow, R.C. Sparrow, E. Christensen, G.R. Davison, V. Pond).

The microphotometer which will permit photometric determinations of nucleic acids and proteins in individual nuclei and parts of cytological structures has been

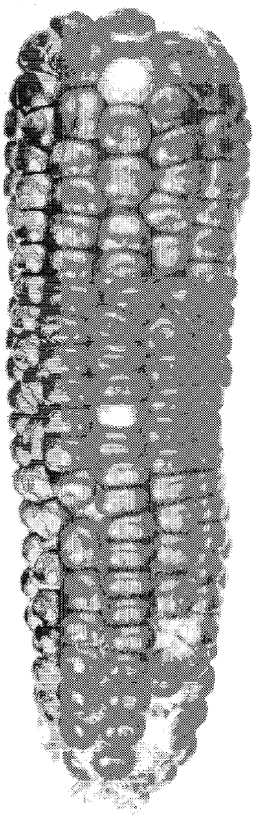
completed. This instrument allows examination in both the visible and ultraviolet ranges, and makes it possible to obtain the light absorption of structures as small as 0.5 μ in diameter. Standardizations of both the optical methods and chemical procedures are being carried out. Some of the results to date show that: a) The optical extinction of desoxyribose nucleic acid (DNA) in terms of regenerated fuchsin in the nuclei follows Beer's law and varies directly with thickness of absorbing sections and with the concentration. b) Nuclei of different sizes (different stages of prophase) have different concentrations and different distributions of DNA but contain the same amount of DNA per nucleus. c) The spectrophotometric curve of the dye in the nucleus matches that in the test tube. d) Mild acid hydrolysis of DNA is necessary before it regenerates color in the fuchsin reagent. The rate of hydrolysis of DNA in a nucleus is 2 to 5 times as fast as the rate of hydrolysis of DNA (depolymerized) in a test tube. These and other control observations will make it possible to estimate the number of sensitive molecules present in a cytological radiation target, and to describe in some degree the molecular organization in the cell.

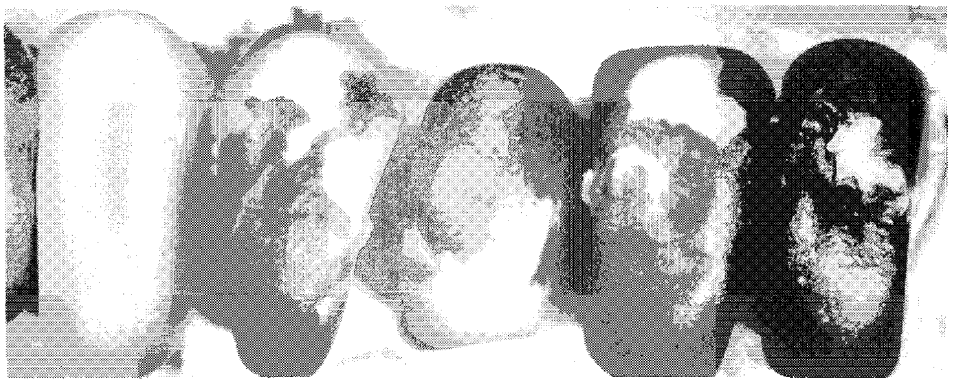
The quantitative microanalysis of DNA and RNA in Trillium pollen mother cells has shown that there is no change in the amount of DNA per pollen mother cell or, in other words, the change in radiation sensitivity is independent of the amount of DNA, as well as RNA, present. The cytochemical analysis of DNA in pachytene nuclei is in good agreement with other independent estimates, including those of Steele et al. of this Laboratory. There appears to be 340×10^{-9} mg of this substance per nucleus. Examination as to whether the sensitivity to radiation depends on concentration of DNA is under way. No striking differences in the nucleoproteins of cells after irradiation with X-rays have as yet appeared. Methods to determine the degree of depolymerization are now under way (M.J. Moses, G. Lindenblad, A.H. Sparrow, R. Steele).

Quantitative methods of determining genetic death in E. coli grown in the presence of high levels of radioactive phosphorus have been worked out. A simple synthetic medium has made it possible to obtain good growth levels independent of total phosphorus concentration. Also, methods for determination of the proportion of various streptomycin mutants produced are now at hand. It becomes increasingly clearer that the proportion of the various mutants changes with the different methods for producing mutants.#

Preparations are well in hand for determining the effects of X-rays on mutation frequency and on growth under the same time course of exposure and experimental conditions which the organisms receive when they are grown in solutions of radioactive phosphorus. This necessary control experiment is essential for the interpretation of the "transmutation effect" in producing mutations previously reported (B.A. Rubin, P. Steinglass, J. Ellington).

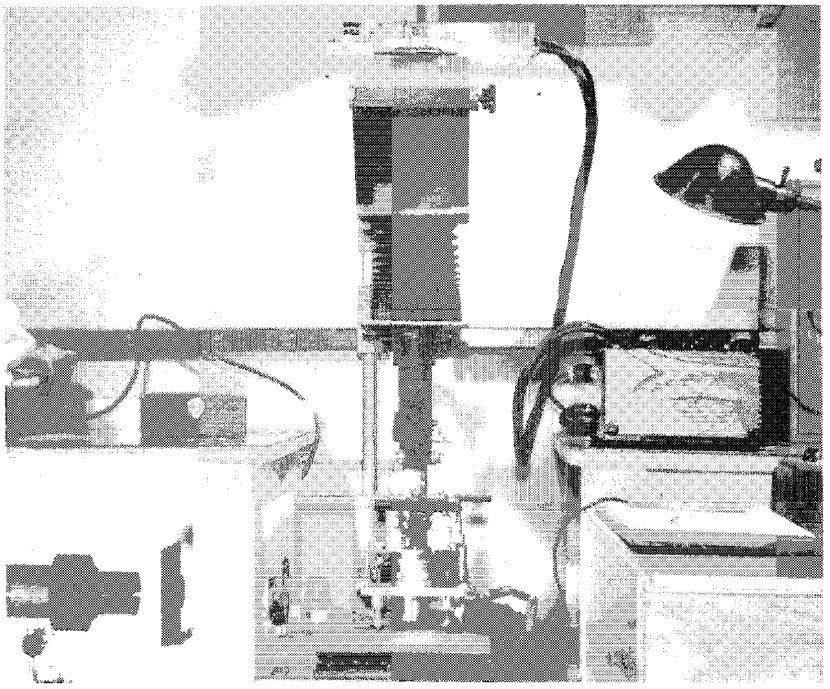
An extremely interesting mutant has been obtained from the Ceylon strain of Allomyces arbusculus by X-ray irradiation. This mutant is colorless instead of orange, and has an entirely new type of asexual reproductive structure. It completes its whole life cycle in 2 weeks, instead of the 6 weeks required by the wild type. With this mutant, an attempt is being made to see if a precursor for γ-carotene can be found which will allow the mutant to produce normal γ-carotene. It can then be seen what effect γ-carotene has upon sexual differentiation.





Above: Mutations in seeds from pollen of plants in the Co^{60} field, where growing plants were subjected to continuous gamma rays. Changes for one of the color genes, r, include entire kernel (one on left), and only partial kernels (four on right). Kernel on extreme right has a fractional mutation for sugar as well as for color.

Left: Ear of corn grown in the Co^{60} field under continuous radiation. Two mutations shown are for the r factor, one of three complementary genes which produce color.



Right: A microphotometer for the quantitative spectrophotometric analysis, in visible and ultraviolet light, of the chemical component of cytological structures. Top, photometer head containing photoelectric table. Center, microscope and reflex camera. Lower left, visible light source. Lower right, ultraviolet source and monochrometer.

The genetic picture of Allomyces arbusculus has been clarified using biochemically marked mutants. These studies greatly aid the conclusions drawn from recent cytological work which had been considered dubious by some workers. One of the mutants is believed to contain a semilethal factor which makes it only partially self-fertile but very cross-fertile and shows a strong temperature dependence for self-fertility. It turns out that the higher the temperature the greater the self-fertility becomes. This semilethal factor may give some idea as to how a heterothallic strain of a fungus could be produced if there were complete viability of the mutant strain at meiosis (K. Yaw).

Tracer Studies of Biochemical Problems

The rate of disappearance of subcutaneously injected tracer phosphate from the blood plasma has been found to be biphasic. The first phase, which is rapid, with a half-time of about 30 minutes, seems to correspond to the establishment of diffusion equilibrium between the blood plasma and the extracellular phase of the tissues, plus some additional component, which may be an exchange-adsorption equilibrium with the surface of bone salt. In two strains of rats studied, Carworth and Sprague-Dawley, the rate of this phase is the same. The second phase, which is much slower, probably corresponds to the over-all rate of phosphate transport into the tissue cells, plus excretion. The rate of this phase is about three times as high in the Carworth rats as in the Sprague-Dawley. Data on the liver indicate that the incorporation of the tracer phosphate into the adenosine triphosphate fraction shows a corresponding three-fold difference in rate in the two strains.

Experiments have been started on rats made diabetic with alloxan, in which the time course of the distribution of the tracer phosphate in the plasma and liver is compared with that in the normal animal. These experiments have been undertaken in the attempt to ascertain whether the defects in the utilization of carbohydrate which characterize diabetes can be accounted for by some defect in the operation of the phosphorylation cycle. At this time, no tracer data are at hand, but the amount of inorganic phosphate in the livers of these diabetic animals has been found to be about 50% greater than in the normal, and the amount of glucose-1-phosphate is reduced to little more than half the normal value# (J. Sacks, B. Damast).

In collaboration with J.R. Nickerson, W.S. Root, and M.L. Gregerson, of Columbia University, the blood volumes of a series of dogs has been simultaneously measured by three independent methods. The T-1824 dye method and the CO method give nearly identical values, while the mean blood volume obtained from the radioactive iron method is some 14% lower. A detailed examination is being made of possible sources of error in such determinations, and it appears that the lower values of radioactive iron method cannot be accounted for in terms of any analytical error (L.M. Sharpe).

Determinations of the blood volume of the rat by dye and radioactive iron give values which are further apart. The dye method gives values for the blood volume of 7 to 8 ml per 100 grams of body weight. Whereas, in confirmation of results obtained by the University of California investigators, the radioactive iron method has given a mean blood volume of 4.8 ml per 100 grams of body weight.

In studies of the iron pigments of the tissues, it is necessary to correct for the hemoglobin of residual blood. Radioactive iron is being used to determine the residual blood in perfused and nonperfused tissues of the rat.

It has been found that radioactive iron injected in the form of ferric ammonium citrate does not reach isotopic equilibrium in the tissues of the rat in two months at a dose level of 0.001 mg per kg body weight, or in three months with a dose level of 0.1 mg per kg body weight. With the lowest dose, 0.001 mg per kg body weight, at the end of two months, the relative specific activities of liver and leg muscle were 1.1 and 0.7, the activities of erythrocytes, kidney, plasma, and spleen were intermediate. The activities of heart muscle and brain tissue were about half that of muscle. Skin appears to take up injected iron relatively rapidly.

The studies on the mechanisms of transfer of iron from blood plasma to cells is still under study. It is found that transfer is maximal after 6 hours at 37°C for the duck erythrocyte. The protein, nonprotein, and cell debris fractions contained about 75%, 5%, and 20% of the radioactive iron, respectively. The protein and cell debris fractions of hemolyzed cells also combine with iron and, in contrast to the intact cell, this reaction is not inhibited by 0.025 M cyanide. It has not been possible as yet to establish that any transferred iron is synthesized into heme.

Studies on the rates at which radioiron appears in various hemochromogens will continue, and an examination of the effects of radiation on the hemopoietic system by tracer techniques is also contemplated (J.R. Klein, L.M. Sharpe, G. Culbreth, M. Kern, B.P. Baldwin, J. Gordon).

Tests for incorporation of radiocarbon dioxide into heart, muscle, and brain glycogen will be made in the abdominally eviscerated cat (G. Culbreth, J.R. Klein).

Studies on the photosynthetic processes in plants are continuing. An attempt will be made to separate the photosynthetic processes from respiratory processes by working with cyanide poisoned cells. Various supposed intermediates of the photosynthetic process are being fed to experimental plants, and the fate of the tagged carbon is being determined. Control studies of the reaction mechanism involved in the degradation of the tagged compounds produced by plants are being done to clarify the interpretation of nonuniform labeling which appears in some degraded compounds. With the cooperation of the Chemistry Department, the combined biological and chemical synthesis of C^{14}-tagged ascorbic acid is approaching completion (M. Gibbs, F.A. Bennett, R. Gastel).

The fate of ingested sucrose carbon in the mouse is being followed with the aid of uniformly C^{14}-labeled sucrose prepared photosynthetically. It has been found that 1% of the original activity of the sucrose is retained at the end of 5 weeks. The distribution of the tagged carbon as a function of time is being determined in about 30 of the mouse tissues. These studies have shown a relatively high content of C^{14} in brain and abdominal fat 5 weeks after injection, whereas blood serum, hair, and liver are lowest in C^{14} content. The radiocarbon of the red cells has the highest specific activity at the end of 5 weeks. This is perhaps due to the fact that red cells have a definite life span which is greater than 5 weeks.

The question of the origin of "endogenous" fecal fat is to be investigated in such mice. Also it is felt that the "essential" dietary constituents will become labeled with C^{14} in all molecular positions save those which represent the truly essential structures, i.e., those which cannot be synthesized in the body. One such structure, the essential methyl group of choline, is already known. It is hoped that others may be discovered (R. Steele, K. Kiyono).

A detailed study of uptake, distribution, and excretion of iron in Drosophila larva, making use of tracer and autoradiographic techniques, is well under way. The results to date provide the basis of extensive revision of descriptions of absorbing and excreting activities of the insect intestine. Several species of Drosophila will be used to determine the specific differences which appear in the various subfamilies in order to establish the physiological significance of the very diverse patterns that have been found by other investigators using histochemical methods.

Data are accumulating on the metabolism of barium, traced as Ba^{140}, in ants of two different families. In general, the ants appear to handle barium similarly to the vespid treatment, but detailed information awaits further study of the autoradiographs.

The technique for combined freezing-drying fixation and contact autoradiography is now well in hand and will greatly help in the study of the chemical affinities of radioisotopes held in tissues.

A pilot hydroponic setup has been completed, and the study of the uptake of the rare earths by hickory trees will soon be begun. This will be a long term study, since the metabolism of rare earths by plant materials is likely to be quite complex.

With Dr. J.C. Neess, an AEC Fellow who will be working at the Laboratory during 1950, an attempt will be made to establish a laboratory basis for the use of short-lived isotopes in a series of field experiments as indices of the efficiency of carbon transfer through the food chains of fresh water lakes. Doubly labeled organisms of known limnological photosynthetic significance will be prepared, and these will be fed to laboratory cultures of zooplankton, which in turn will be fed to higher organisms. The relative efficiencies of transfer at each stage will be determined (V.T. Bowen, A. Carbone, D. Sutton).

MEDICINE

As of December 31, 1949, personnel on duty in the Medical Department numbered 63, a 37% increase since June 30. Included are 8 physicians full time, 1 physician part time, 2 medical scientists, 1 hospital administrator, 12 registered nurses, 2 dieticians, 7 research laboratory technical assistants, 4 medical technicians, 1 X-ray technician, 1 occupational therapist, 1 pharmacist, 1 medical records librarian, 6 administrative and clerical personnel, 3 matrons, 2 animal caretakers, 5 orderlies, 4 kitchen staff, 2 supply and stock control assistants. In addition, one physician is on leave of absence because of illness. This staff is divided among the various divisions noted below. The Hospital Division is an administrative unit, but does not carry physicians on its roster, since the medical staff of the hospital comprises those members of the other divisions whose training and interests dictate their participation in the work of the hospital.

As work is progressing in readying the present temporary structures for use as laboratories, planning is going forward for permanent quarters for the Medical Department. The few months operation of the hospital has already taught valuable lessons which will be put to good use in the planning program. This future development is being insured from every possible angle. The hospital administrator is taking a course in hospital construction given under the direction of Dr. John E. Gorrell of Columbia University, one evening a week. The present planning schedule calls for a reasonable statement of needs by the Medical Department operating personnel at the end of this academic year. Thereafter, the hospital administrator will work closely with the architects and engineers to meet these demonstrated needs with facilities which will be adequate for future growth and development. Classical laboratory and hospital design will not meet the requirements for use with radioactive materials. A comprehensive study will also be made of desirable sites at varying distances from the nuclear reactor. A thorough study of building materials and their adaptability to the needs of the projected laboratory is also scheduled. Emphasis will be placed upon flexibility, economy, and efficiency in operation.

Division of the Hospital

During the six-month period under review, the hospital has been growing gradually and steadily. The staff included, as of December 31, 10 registered nurses and 4 technicians in other categories. The number of patients admitted totaled 30. Patients have been referred by private agencies, general hospitals, special hospitals, and individual physicians. A total of 1424 patient days was reached, with only 297 patient days charged to employees. There have been four deaths; autopsies were done on the three research patients in this group. The services and tests offered by the hospital have significantly increased during the interval.

On patients with thyroid carcinoma, studies are being carried out on the effects of thiouracil and thyroid stimulating hormone on instigating normal activity in distant metastases. All patients have previously been thyroidectomized; after a suitable interval on thiouracil and the hormone, test doses of I^{131} are given. When retention of the isotope is found to be satisfactory, a therapeutic dose is given. The process is

then repeated, and a patient may receive a number of therapeutic doses at suitably spaced intervals if no evidences of radiation damage are detected.

In addition, patients with Graves' disease are being studied with tracer doses of I^{131}. In those patients for whom surgical treatment is inadvisable, a partial destruction of the thyroid is accomplished with radioactive iodine. When the shorter-lived isotopes become available, they will be tried in place of I^{131} for estimation of function and for therapy. These patients, also, are being observed for any systemic evidences of radiation damage.

Several children with the nephrotic syndrome are patients in the hospital. General tests of renal function and protein utilization are being developed, looking forward to body water studies (sodium space) and sodium excretion studies at a somewhat later date.

Counting equipment has been obtained and set up to follow the iodine isotope in patients. This is being correlated with the equipment at Memorial Hospital in order to permit studies made at either institution to be continued at the other by suitably correcting the data for the instruments under consideration.

Division of Pathology

Remodeling of the hospital ward to provide the temporary pathology laboratory was scheduled for completion by August 15, but the work was not sufficiently complete to permit moving the Division until October 25. The building was occupied at that time without waiting for completion of chemical fume hoods or the installation of some major items of equipment. The facility was finished late in November, and, in December, a satisfactory autopsy room was completed. Work has continued throughout the period insofar as inadequate quarters would permit. As of December 31, staff included 2 physicians and 3 technicians, exclusive of clerical and service personnel.

Although work has continued on the problems of protein synthesis and breakdown following injury, little could be accomplished during the report period because of the dislocation resulting from moving to the new building. However, it was possible to check on certain specific aspects of the work largely completed elsewhere and involving tissue response to a chemical inflammatory process. It was learned that under these conditions synthesis of blood and body proteins does not appear to be inhibited in dogs. Although a considerable catabolism of protein has long been known to occur, it has not been determined whether any significant portion of this catabolism represents newly absorbed dietary aminoacids before their synthesis into body tissue and blood constituents. This present investigation showed that body protein uptake of radioactive sulfur, which had been given in the diet incorporated in methionine, was very similar in dogs with turpentine abscesses to that of the normal controls. For this type and degree of injury, there appears to be no inhibition of synthesis of protein at the height of the reaction. Preparations are almost completed for a similar study of protein synthesis after fractures and certain other disease states. When the nuclear reactor is in operation, the study will be extended to include various types of radiation injury.

A collaborative investigation has begun with Dr. Jean Oliver, Professor of Pathology, and his associates at the Long Island College of Medicine. This is an attempt at the further characterization of intracellular bodies previously described by Dr. Oliver as occurring in the renal tubule epithelial cells following single intravenous injections of egg albumen, homologous serum protein, and a number of amino-acids, including methionine.

The Consolidated-Nier isotope ratio mass spectrometer has now been placed in operation, and is ready for use in various studies.

Three autopsies have been performed by the staff members of the Division; and the tissue laboratory is now in operation (S.C. Madden, J.A. Fancher, Jr., R.S. Stone).

Division of Bacteriology and Virology

The Division was activated July 1, when its head, Dr. William M. Hale, reported for full-time duty. As of December 31, staff included 3 physicians and 3 technicians, exclusive of clerical and service personnel.

The first two months were spent largely in checking and ordering supplies and equipment. Additional staff were secured, and thought was given to the general program of the Division. An animal colony was begun with Swiss mice, and CFW mice were added later. When improved laboratory quarters became available, late in September, four transplantable tumors -- two carcinomas and two sarcomas -- were obtained, and breeding was begun in the animal colonies to supply experimental subjects.

In September, all experimental animals, together with the transplantable tumor specimens, were lost through an accident following failure of closure of a steam valve on an uncapped steam line. Another two months were required to grow sufficient experimental animals. Fortunately, the same transplantable tumors were yet available, and new specimens were secured. At the present time, work with transplantable tumors is being carried out, while a new infection-free strain of mice is being bred to replace the Swiss mice obtained previously, which were found to be not infection free. Within another two months, the breeding stock should be adequate for all experiments.

Work with yellow fever virus, and its growth in animals with transplantable tumors, is just beginning. It is planned to use, in addition, several of the other common and well defined viruses.

A 2-curie Co^{60} source has been obtained for use as a gamma-radiation source in studies on small animals. In addition, stainless steel needles providing a 70-millicurie source of Co^{60} have been ordered for local tissue irradiation. It is planned to study the effects of various types of radiation on resistance to viral and bacterial infectious agents, as well as antibody production. Particular attention will be devoted to virus-host relationships. This program will be greatly accelerated when the nuclear reactor comes into operation.

In the period up to December 1, the Division had reported 364 determinations on 91 bacteriological specimens sent from the hospital and the clinic. This service was severely handicapped by lack of a suitable laboratory, until the new remodeled ward building became available at the end of December.

Since the laboratories of the Division are now completed, it is planned to increase the technical and scientific staff to authorized numbers as soon as satisfactory personnel can be obtained. It is hoped that this will be accomplished by July.

Division of Biochemistry

The Division of Biochemistry began functioning on September 1, when Drs. Lee E. Farr and Wade N. Miller began their duties full time. Dr. Donald D. Van Slyke, head of the Division, arrived September 15. As of December 31, the Division included 2 physicians, 1 medical scientist, and 1 technical specialist. One more physician will join the staff February 1.

The space vacated by the Bacteriology Division in September was taken over as a temporary laboratory facility by the Division of Biochemistry. Efforts have been directed toward integrating the hospital work on research patients with laboratory procedures. Some equipment has been set up and placed in a functioning status; work has started on calibration of apparatus and establishment of methods suitable for the work planned. Counting equipment has been obtained and set up for the determination of radioactive materials in liquids. It is planned to begin study on the conditions affecting the renal excretion of iodine as soon as general methods are established for evaluation of renal function.

In the meanwhile, valuable experience is being gained from the patients with metastatic thyroid carcinoma under treatment with I^{131}. Observations are beginning on children with the nephrotic syndrome, which necessitates setting up several methods to assure requisite analytical accuracy on the small blood samples available. It is hoped that studies may begin on the selective function of renal tubules early in 1950.

It is planned to complement the observations on humans with studies carried out on animals. Studies on the latter, in addition to work on renal function mechanisms, will include certain problems of bone metabolism and structure, as it is likely that radioactive tracer materials can be used advantageously to elucidate these problems. The effects of various radioactive isotopes on growth will also be studied. Work cannot begin, however, until more laboratory space and facilities are available.

At the present writing, final approval has not yet been given to architectural drawings for remodeling of a building to house the temporary biochemistry laboratory. Construction is expected to begin February 15, and the laboratory should be available for work about July 1.

Division of Physiology

No appointment has yet been made to this Division. With the development of the other divisions of the hospital well under way, every effort is being made to speed

the selection of a proper individual to serve as head, so that the balanced program planned for the Medical Department may be established.

Division of Industrial Medicine

This Division was previously called the Medical Practice Division, but the new name was taken as being a more apt description of its activities, both present and planned. As of December 31, personnel of the Division comprised 2 full-time physicians, 1 part-time physician as roentgenologist, 3 registered nurses, 4 medical technicians, and 8 additional staff members in various capacities. This division is short 2 full-time physicians, but is otherwise fully staffed.

During the six-month period June 1 to November 30, there were 4127 visits to the clinic, of which 1260 were classified as occupational and 2867 as nonoccupational. Of the nonoccupational visits, 469 were by dependents of Laboratory staff members. Workers employed by contractors and subcontractors accounted for 154 occupational visits. The average number of visits to the clinic each day was 26. Required pre-employment, initial, special, and annual physical examinations totaled 707 during the six-month period. Eighteen clinic patients were hospitalized in Brookhaven National Laboratory Hospital during this interval; all were suffering from nonoccupational illnesses.

During this period, the clinic laboratory did all the work for both hospital and clinic in hematology and in urine analyses. It also did all the blood chemistry during the first five months until the biochemistry laboratory was able to establish some of the more necessary determinations which thereafter were carried out for the hospital patients as originally planned.

On June 18, a Workmen's Compensation Medical Bureau license was issued to the Laboratory to operate an employer's Workmen's Compensation Bureau to render medical care to injured employees under the provisions of Section 13-C of the Workmen's Compensation Law. The use of Workmen's Compensation Board Form C2.1 (5-48), "Notice That Employee Declines Right to Choose Own Physician," was begun. The patient must fill out one of these forms if he requires more than two visits to the clinic. During the six-month period under review, 230 injuries were treated in Laboratory employees. Three of the injuries were disabling, and 227 were nondisabling. A total of 553 clinic visits was required for treatment.

Pre-employment examinations were given to all nonscientific personnel; and most of the scientific personnel employed during this review period received physical examinations. A drop in the number of physical examinations, as compared with the previous six months, is due, in part, to a decrease in the full-time staff of the clinic from 4 to 2 physicians and, in part, to vacations taken by the physicians during this time. For the past two months, 2 physicians from nearby communities have been assisting in conducting physical examinations for a total of three half-days a week. It is now apparent that a minimum of 3 full-time physicians is necessary at all times to carry the load. When the Laboratory reaches full-scale operation, the minimum number of physicians required in the clinic will become 4.

During the past six months, the general health of Laboratory employees has been good. The anti-tuberculosis campaign has been continued, but no new cases were discovered. During the past summer, when poliomyelitis was epidemic in the northeast area, every effort was made to keep parents advised of proper measures to follow; the Personnel Division requested and received advice frequently about various general matters, such as swimming pool regulations. Despite all efforts, polio struck the Laboratory family, in the person of an employee who was on vacation. He was admitted to another hospital closer to his home, where his illness ended fatally. Efforts were made to allay the apprehensiveness among other employees following this episode. No epidemics developed in Laboratory personnel during the fall months.

The Division inspected the cafeteria, gave advice, and made recommendations on sanitary conditions, garbage disposal, and similar public health problems. Vaccinations and inoculations were given to those employees leaving the U.S. on Laboratory business.

The X-ray facility conducted 976 examinations during this period. Of these, 666 were in connection with the required physical examination, 108 were on employee out-patients, 69 on employees of subcontractors, 41 on dependents of employees, and 92 on patients in the hospital, the research group accounting for 80 of these. All routine and special roentgenological examinations were carried out with regard to radiation exposure of the patient; the photofluoroscopic method was not used on those exposed to radiation elsewhere. In each instance, the amount of exposure, which has been determined for our machines, was reported to Health Physics for inclusion in the employee's radiation exposure record.

When responsibility for operating the ambulance was transferred from the fire department to the police department, lectures and demonstrations were given to the police on first-aid procedures and use of first-aid equipment. The ambulance was inspected by the Medical Department once each week to insure maintenance of medical supplies.

Indoctrination in health physics procedures and radiation practices was started for Medical Department personnel. Personnel monitoring boards were installed for ionization chambers and pocket badges. Instruction in their proper use was given to the nurses and other staff members. A program was developed with Health Physics to set up waste containers for both dry and liquid waste materials, and to provide for the collection of accumulated wastes. Arrangements were made with Oak Ridge National Laboratory to examine each week up to three urine specimens obtained from employees working with fission products. The distance between the two laboratories and the difficulties of shipment have interfered with the success of this plan. It is anticipated that facilities for these analyses may be developed soon either on the site or in the vicinity.

During the review period, Health Physics did not report to the Medical Department any instances of overexposure to radiation requiring medical action. No injuries associated with radiation hazards required more than first-aid treatment. No cataract formations were found in employees previously exposed to neutron radiation. Steps are being taken to further strengthen protection against radiation as the day nears when the reactor becomes operative.

RADIATION PROTECTION

The following units are parts of different Laboratory organizations, but most of their work is concerned with various phases of radiation protection; therefore, they are grouped together in this report under the Laboratory's general radiation protection program.

Health Physics

Little change took place, during the review period, in the staff of the Health Physics Division or in the scale of routine activities. Additions to the staff concurrent with expansion of Laboratory operations are anticipated for the coming year. Special testing and development projects are continuing.

No formal program of research is projected in connection with the Division's program, but a number of research and development projects similar to those reported below will be continued simultaneously with normal operating responsibilities. Except for minor elaborations, the central facilities remain virtually unchanged, but decentralization of the building survey staff has continued with the activation of the health physics headquarters and staffs at the reactor, cyclotron - Van de Graaff, and new biology buildings, in addition to those previously established for the chemistry complex.

Training

The training plans projected in the last report have been carried out. These included assignment of newly acquired building surveyors to all parts of the health physics program, and sending a number of the more seasoned building surveyors to Oak Ridge National Laboratory for added training. Eight Atomic Energy Commission fellows in health physics spent two months at the Laboratory obtaining experience in each of the 11 subdivisions of health physics activities.

Extensive revisions have been made of those parts of the safety manual dealing with radiation safety; an indoctrination pamphlet, entitled ABC's of Radiation, written for employees of the Laboratory, has been well received. Outside interest in this pamphlet has been substantial.

Preparations are now being made to conduct a training course for safety engineers of insurance companies in February. This course is being sponsored by the Atomic Energy Commission at the request of the Association of Casualty Underwriters. Brookhaven National Laboratory was selected partly because of its convenient location and accommodations. Plans have also been initiated by the Commission for a civilian defense instructors' training course to be given this spring at several installations, including the Laboratory.

Waste Disposal

The Laboratory waste disposal problem is not expected to develop to substantial proportions until the middle of 1950. While the waste concentration group of the Reactor Science and Engineering Department is responsible for liquid waste operations within the reactor complex, the Health Physics Division is responsible for all other operations and for over-all coordination.

Steady progress has been made in providing facilities for control of liquid waste outside of the reactor complex. A hold-up and sampling system for the Chemistry Department's semi-hot laboratory has been completed and put into operation. A similar installation has been designed and is in process of construction for the new Biology Department laboratory. Designs for hold-up systems have been made for the Chemistry Department's hot laboratory at the cyclotron building, and for the mortuary at the Medical Department.

Design work has also been completed on flow measuring and sampling equipment for the discharge of the Laboratory's Imhoff tank. The effluent released from the Laboratory sewer system has shown no detectable activity, except for occasional concentrations of the order of 10^{-13} c/cc observed as a result of special experiments or minor accidents.

An experimental incinerator, consisting of a household type disposal unit equipped with high efficiency filters, has been set up for small volumes of biological waste. Adequate dark room facilities have been established for radioautographic studies of aerosols and dusts.

Building Survey

The usual routine surveillance of contamination and exposure conditions in laboratories continues. Building surveyors have assisted scientists in providing safety arrangements for a variety of activities. A major project has been the operation of the 20-curie Co^{60} field by the biologists, which was carried out with complete safety. Plans have been made to use a much stronger source in 1950, which will require further planning and supervision. The coming year will likewise see the start-up of the nuclear reactor, the 60-inch cyclotron, and the 3.5-Mev electrostatic accelerator, three major sources of radiation. Although plans for operation of these facilities have been made, they will require further elaboration and testing in practice.

During the past year, the bulk of radiation survey work centered on activities at the waste concentration laboratory, the semi-hot chemistry laboratory, the hot shop, the metallurgy laboratory, and the Co^{60} field. The emergency survey coverage has been continued, and has proved its value in several instances.

A variety of other projects originated during the past six months. An extensive series of tests was made of papers suitable for use as waste containers in laboratories. A polyethylene coated paper was found to be the best, and resistant to a wide variety of chemicals. A quantity of bags made of this material is being procured for use in standard treadle cans. Their utility will be proven in practice before standardization on this material.

A study of the sensitivity of present methods for assaying liquid waste is still in progress in order to establish the way in which sensitivity depends on statistical limitations and on the energy of beta radiation. Additional projects are completion of BF_3 type counters for neutron surveys, testing of a new precipitron dust sampler and completion of counting facilities for it, design of an arrangement for Co^{60} irradiation of animals in the Medical Department, construction of polonium alpha standards, construction of Co^{60} sources for calibration use, and the use of X-22 type ionization chambers for air monitoring.

A number of these projects will continue into 1950. If time permits, it is proposed to investigate special techniques for civilian defense and to make a study of the mechanism of filter paper collection of atmospheric activity.

Area Survey

All area monitoring stations now have complete 5-channel G-M counter installations, battery-operated ratemeters, dynamic condenser type electrometers, and automatic photographic recording equipment. The continuous air monitors, which collect dust from the air on filter paper and count it for alpha and beta activity, have been procured, and are installed in 6 stations. The balance will be installed shortly. The efficiency of station operation has ranged from 67% to 96%.

The accumulation of background data has continued and, with the addition of data from the continuous air monitors, constitutes an interesting mine of information in regard to naturally occurring radiations. A study has been made of peaks in background activity occurring as a result of rainfall. Such peaks increase the normal background by as much as a factor of 2, and have a duration dependent upon the type of precipitation. Plots of activity detected by the continuous air monitors are being made and correlated with meteorological conditions.

Personnel Monitoring

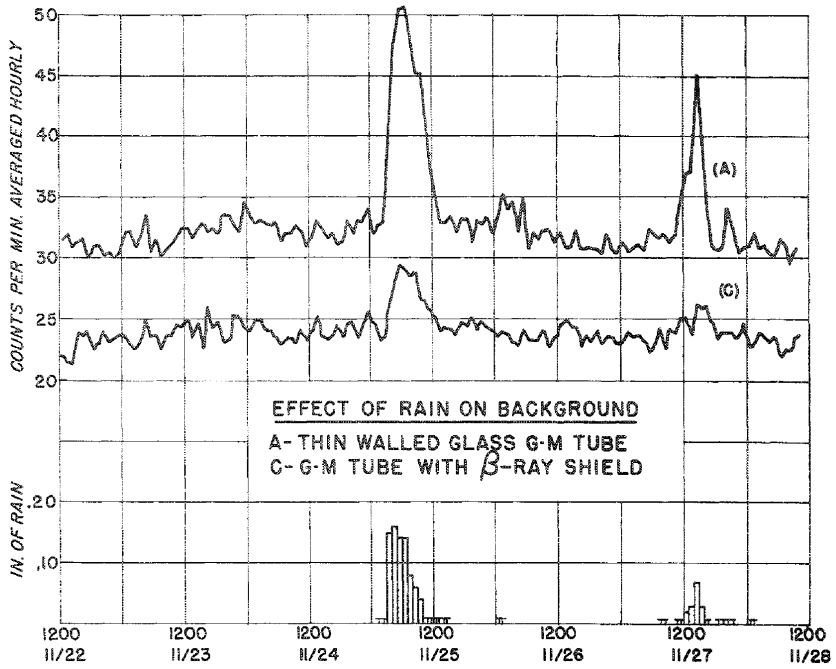
The use of personnel monitoring equipment has increased gradually; at present, about 450 film badges and 450 pairs of pocket chambers are being used per week. Monitoring equipment is distributed to boards provided at 24 locations throughout the site. An integrated system of security and personnel monitoring equipment control has been put into operation at the entrance lobby of the reactor building.

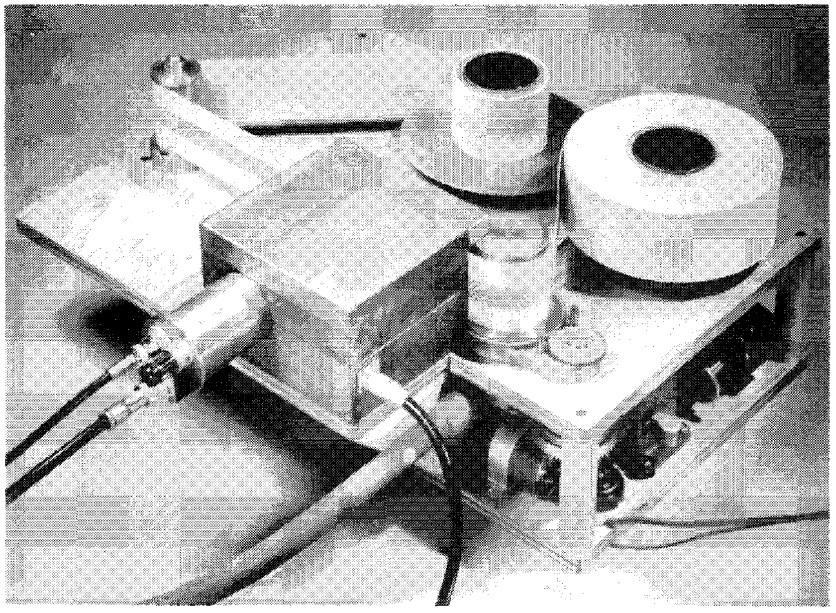
A stage attachment for the microscope used to count tracks for neutron monitoring has been designed, constructed, and put into service. This moves the film one field diameter laterally, and has 24 discrete positions, corresponding to the normal counting of 24 fields. An automatic device for timing exposures and removing sources in beta calibration of personnel monitoring films has been constructed and has proved to be very useful.

Meteorology

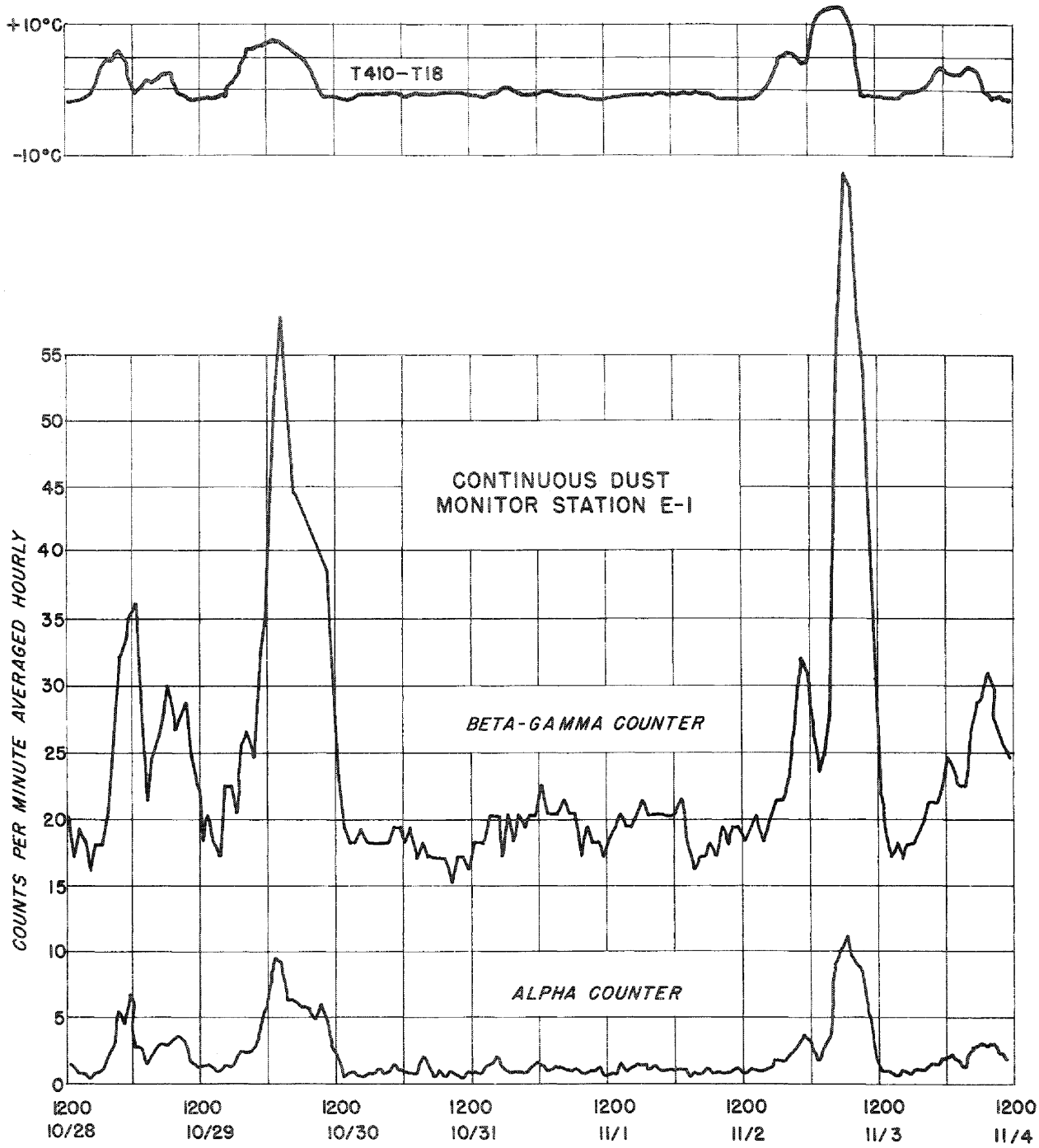
The operation and maintenance of the meteorological facility, which is still less than a year old, has been placed on a relatively stable basis in the past six months. A basic change in instrumentation has been the addition of the Friez wind gradient

Right: Curves showing influence of rain on natural radioactive background level. Curve A, counting rate of unshielded thin wall counter; curve C, counter shielded to exclude beta rays. Note that axtivity peaks coincide with periods of rainfall.





Left: Monitoring equipment for recording activity of airborne dust. Air is pumped through strip of filter paper which is moved at rate of one inch per hour and passes in front of beta-gamma and alpha counters (in lead shields).



Typical record of the natural radioactivity associated with dust, obtained with equipment shown opposite. The peaks, which in this case are due principally to natural thorium B and its daughters, occur during periods of still air accompanied by a temperature inversion, as indicated by the difference in air temperature between the 410' and 18' levels of the meteorology tower (top curve).

recorder, which was a part of the original plan. Actually, this unique instrument was installed prior to July 1, 1949, but an adjustment period was required before minor difficulties were completely eliminated by the manufacturer.

Members of the Meteorology Group have been active in many cooperative projects within the Laboratory. A summary of pertinent meteorological data was prepared for the Instrumentation and Health Physics Department to assist in the analysis of fluctuations in normal background radiation. The miniature oil-fog generator has been used to test the efficiency of filters proposed for certain Health Physics Division installations. In addition, data and assistance have been provided for a number of specialized problems to members of the Biology, Chemistry, and Reactor Science and Engineering Departments.

In September, 1949, after conferences with the Suffolk County Agricultural Agent and members of the Laboratory's Biology Department and Meteorology Group, the New York Office of the U.S. Weather Bureau established a special agricultural forecast for eastern Long Island. Climatological and current data are being provided the Weather Bureau to assist in this venture.

A number of inquiries have been received concerning the availability of unclassified meteorological data, primarily from organizations interested in atmospheric pollution, and at least two programs specifically involving utilization of data from the Laboratory facility are currently under consideration.

The most significant accomplishment of the Meteorology Group during the past six months has been the completion of a sufficient number of oil-fog test runs to permit the estimation of radiation dosage from the nuclear reactor cooling air effluent. Data from thirty-one processed runs are now available, covering all standard meteorological situations. The tests have revealed extremely important variations in the rate and character of atmospheric dispersion.

On the basis of available information, templates have been prepared for a variety of combinations of wind speed and atmospheric turbulence, so that it is now possible to classify and evaluate any given meteorological situation in terms of reactor operations.

Daily forecasts of micrometeorological conditions are also made routinely on the basis of the synoptic weather analysis. The micrometeorological forecasts are converted into radiation dosage values by means of the templates referred to above, and the practice prediction for Reactor Operations is completed by the addition of a short summary explaining the significance of the current meteorological situation and a recommendation concerning continued operation.

Future plans of the Group center on the theme of improving and refining the meteorological control system as it is now formulated. Oil-fog tests will continue to form an active portion of the program, both to increase our knowledge of the less common meteorological situations, and to provide simultaneous comparisons between oil-fog and radiation measurements after the reactor becomes operative.

The Group plans to effect improvements in meteorological instrumentation. For example, equipment available at the present time does not include any device suitable for the remote recording of vertical wind and turbulence. Such an instrument has already been completed, and it will be improved and revised within the coming months.

Improvement in forecasting techniques will go on continuously. The accomplishments of the past six months serve to establish the basic method suitable for the problem. An increasingly lengthy microclimatological record will be fully exploited to improve the techniques, as will operational experience with the particular problem.

Geological Studies

During the past six months, emphasis has shifted from putting the wells and other physical facilities into operation to using them for the collection of data. These data, while still incomplete, have permitted the construction of a series of exact water table maps, from which can be derived many of the details of the movement of the ground water in the area. They have also served to call attention to the lack of adequate information on the relation between ground water and surface water.

The water sampling program has furnished by now a partial picture of chemical and radioactivity background conditions in both surface and ground water. Rather unexpectedly, the chemical analyses of the ground water have called attention to a possible important water pollution hazard arising from the leaching of nitrate from fertilizer in farm areas near the Laboratory. This is being investigated further, not only for its own sake, but also for the light which it may throw by analogy on the water contamination problems of the Laboratory.

The most important construction job completed was the installation of five test wells, each about 200 feet deep, from which, with the help of cores, a detailed record of glacial deposits was obtained. This study made it possible to define with some precision the distribution and nature of the glacial formation, through which moves most of the ground water in this area.

While no additional data of value were obtained by the use of tracers, new and much better equipment was designed and built for this research.

Two projects of less obvious application to the problems of ground water contamination, but actually of importance because they attack fundamental problems of Long Island geology, have been continued. One of these is a study of the micro fossils of the Gardiners clay. This formation has been used as a key horizon in the study of Long Island geology, both because it is one of the very few formations that contains fossils, and also because of its general importance to water supply problems. No systematic study of the formation, however, has ever been made, nor has any proper correlation ever been attempted between the several areas of Gardiners clay on Long Island and the type area on Gardiners Island. Second, a detailed grain size analysis of the cores from the two deep wells is being made with the hope that it will give not only a quantitative picture of the composition of the sands and clays, but also a better picture of their conditions of origin. These deeper beds do not contain the types of fossils normally used for correlating formations or interpreting their geologic histories.

DIRECT SERVICES

Information and Publications

Within the last year, the staff of the Information and Publications Division has decreased from 41 to 31. However, the work load of the Division, reflecting the progress of the research program, has shown a steady increase in a number of respects. To handle the current volume of work with its present staff, the Division has postponed several less critical phases of its program.

The Research Library will shortly be in need of additional space. The stack area has already been extended one and one half ranges, an alteration expected to solve the Library's worst space problem for another year. After that time, either an extension to the existing premises or removal to a larger building will be essential. Another means of temporarily alleviating the need for space has been the storage of duplicate and little used material in an adjacent unoccupied building. Since the basic collection is estimated to be 80 to 85% complete, the volume of new acquisitions has been reduced. Only those items which are urgently needed are now being procured, mainly current periodicals and textbooks.

Other Library services are in greater demand. The cataloging program has progressed steadily, and is now approximately 85% accomplished, with the branch library in the Medical Department completely cataloged and supplied with card indexes. The circulation desk reports an average of over 660 loans per month, 30% higher than that of the previous period. Activity at the reference desk has increased noticeably, but is still well within capacity. The conduct of literature searches has been confined to the fulfillment of special requests from the Biology Department.

An increasing number of translations from the Russian have been requested, notably by the Physics Department. Some of these will appear in an early issue of the Guide to Russian Scientific Periodical Literature. The repository of translated Russian scientific documents, established at the Laboratory a year ago, now contains over 200 titles, including items contributed by industrial and scientific laboratories in many parts of this country and abroad. Over 100 outside requests have been received for loans from this repository. Lists of titles of newly received translations will appear in the Guide as soon as possible, and complete lists will be published semiannually.

The Classified Library has expanded into adjacent space, vacated when the Reactor Science and Engineering Department staff moved into its new building. The holdings of this library now average 4 copies of over 8000 classified reports, 700 of which were added during the past six months. Approximately 30,000 classified documents, over which the Laboratory has accountability control, were recently inventoried. Such inventories will, in the future, be conducted on a continuous basis, so as to approach completion at the end of each calendar year. Inventories of the classified files of properly authorized staff members are made at more frequent intervals. Circulation of classified reports, books, and periodicals, is increasing steadily.

During the past six months, the Publications Group has edited and otherwise prepared for reproduction some 30 major documents, not including the Weekly Bulletin and the Weekly Selected Reading List. Under a recent policy decision by the Atomic Energy Commission, the reproduction and distribution of reports to non-project recipients must be handled by the Technical Information Division at Oak Ridge. Accordingly, after sufficient copies of a document to take care of on-project requests have been run off at the Laboratory, the plates are now shipped to Oak Ridge, where the document is placed on a sales basis.

The Guide to Russian Scientific Periodical Literature, under the direction of John and Ludmila Turkevich of Princeton University, is now receiving sufficient material to warrant its issuance on a monthly basis with an annual index. Since its somewhat modest inception in March, 1948, it has grown considerably in scope and significance. Whereas it formerly contained a mere listing of translated titles from the major Russian scientific journals, it now also publishes the outstanding abstracts and articles in nuclear physics. A plan is presently under way to give translations for all articles in this field appearing in the U.S.S.R. Academy of Sciences, Reports, the Journal of Technical Physics (U.S.S.R.), and the Journal of Experimental and Theoretical Physics (U.S.S.R.).

Two more compilations in the series Properties of Atomic Nuclei have been published: Nuclear Energy Levels, Z = 11 - 20, and a revised edition of Spins, Magnetic Moments, and Electric Quadrupole Moments. An additional document in this series, Neutron Cross Sections, is in progress.

In addition to the publication of reports, the Division is responsible for the review, clearance, and processing of manuscripts prepared by Laboratory staff members for publication in the professional literature. During the past six months, over 90 such papers have been received covering research conducted at the Laboratory under the auspices of the Atomic Energy Commission. This compares with a figure of 70 for the previous period.

The Information Group, in cooperation with the Research Library and the Public Education Office of Associated Universities, Inc., has begun to compile a selective annotated bibliography of popular literature on atomic energy. Outside requests for specific information on various aspects of the subject have increased, and there is a definite need for bibliographical materials suitable for distribution to schools and adult groups.

Due to the growing interest of surrounding communities in atomic energy in general, and in the Laboratory in particular, a 30% increase occurred during the past six months in the number of public film showings arranged by the Division from its library of audio-visual aids. A collection of unclassified photographs of various phases of work in other atomic energy installations, both here and abroad, is now on exhibit in the Research Library.

Photography and Graphic Arts

In the period under review, the Photography and Graphic Arts Group, as a service unit, has found that its work reflected the general development of the Laboratory. A generally increasing load has become more and more the by-product of research.

A program of standardizing repeat operations and training personnel for greater flexibility has allowed the load to be carried by the existing personnel. An exception was the requirement for over seven thousand prints resulting from the Cosmotron testing program, which, added to an increasing darkroom load, has necessitated the addition of a darkroom technician, bringing the personnel of the Group to 19.

In photo-offset operations, a definite campaign to standardize report design has resulted in greatly increased efficiency of operation. The design and production of preprinted typing guides has assisted in cutting down preparation time. Although the printing of copies for public distribution has been transferred to Oak Ridge, the increase in the number of reports and the growth of "job printing" has meant an increase of 12% in the offset output.

The design and illustration of an informal booklet, ABC's of Radiation, was a new and successful project for the Group.

In photography, there has been a greater use of color, particularly by the life sciences, and a noticeable increase in the use of special camera installations for recording data. At the suggestion of Dr. Borst, a subminiature camera was converted and used in an effort to photograph some inaccessible details of the reactor structure.

Drafting

The Drafting Group, comprising 30 persons, and organized into a small central drafting section and several "task forces" detailed to various projects in the Laboratory, performs the drafting requirements of the Laboratory.

The Accelerator Section has witnessed a steadily increasing load. Two additional persons were assigned to cover the drafting work on the current phase of electrical and electronic equipment design details. Finalizing of the magnet coils and their attendant cooling, as well as further design studies of the vacuum tube and its pumping system, have been worked on. Seven men are assigned to this project.

Design work is proceeding on target probes and target handling equipment in the Cyclotron Section, with two men assigned.

The Reactor Section has completed most of its projects, with two pending, and has carried some of the design and drafting load incidental to the general reactor adjustment program. The urgency of this program has tended to delay the usual amount of work on experimental equipment and apparatus, but it is anticipated that this will revert to normal in the near future.

The Tool Design Section has continued with apparatus and equipment for the Biology, Chemistry, and Physics Departments; this section has also felt the impact of the repair and test program of the Reactor Department, and has designed several pieces of apparatus for them.

The Central Headquarters Section has been engaged on work for Physics, Meteorology, and Chemistry, and has also handled some of the urgent overflow of work from

the cyclotron and reactor projects. Detailing of the cyclotron work has been done here to expedite the design program of the Cyclotron Section.

Shops

The Shops Division consists of 90 persons, and comprises two main central shops, besides a sheet metal, welding, and lead shop, a graphite shop, and a special materials shop. With the installation of the 74-inch Bullard lathe and the setting up of the large new power brake in the sheet metal shop, the facilities of the Division are now felt to be well rounded.

In addition to the main Shops Division, several scientific departments maintain small staff shops to handle minor, immediately required, short-run needs.

The workload of the Division has increased since the last report. The following table shows the trend in the past 18 months.

	Six-Month Period Ending		
	12/31/48	6/30/49	12/31/49
No. jobs completed	742	851	929
No. hours	42,037	50,580	47,789
Average hours per job	56.7	59.5	51.5
No. jobs in process	124	128	143
Est. hours work in process	16,550	26,305	32,261
No. jobs subcontracted	26	9	10

ADMINISTRATION AND MAINTENANCE

Architectural Planning and Plant Maintenance

Personnel of the Architectural Planning and Plant Maintenance Department now number 400, a net decrease of 11 from the total as of June 30. This decrease is accounted for by reductions in the Fire Department, Transportation Group, and Janitor Section, which was partly offset by minor increases in the maintenance shops.

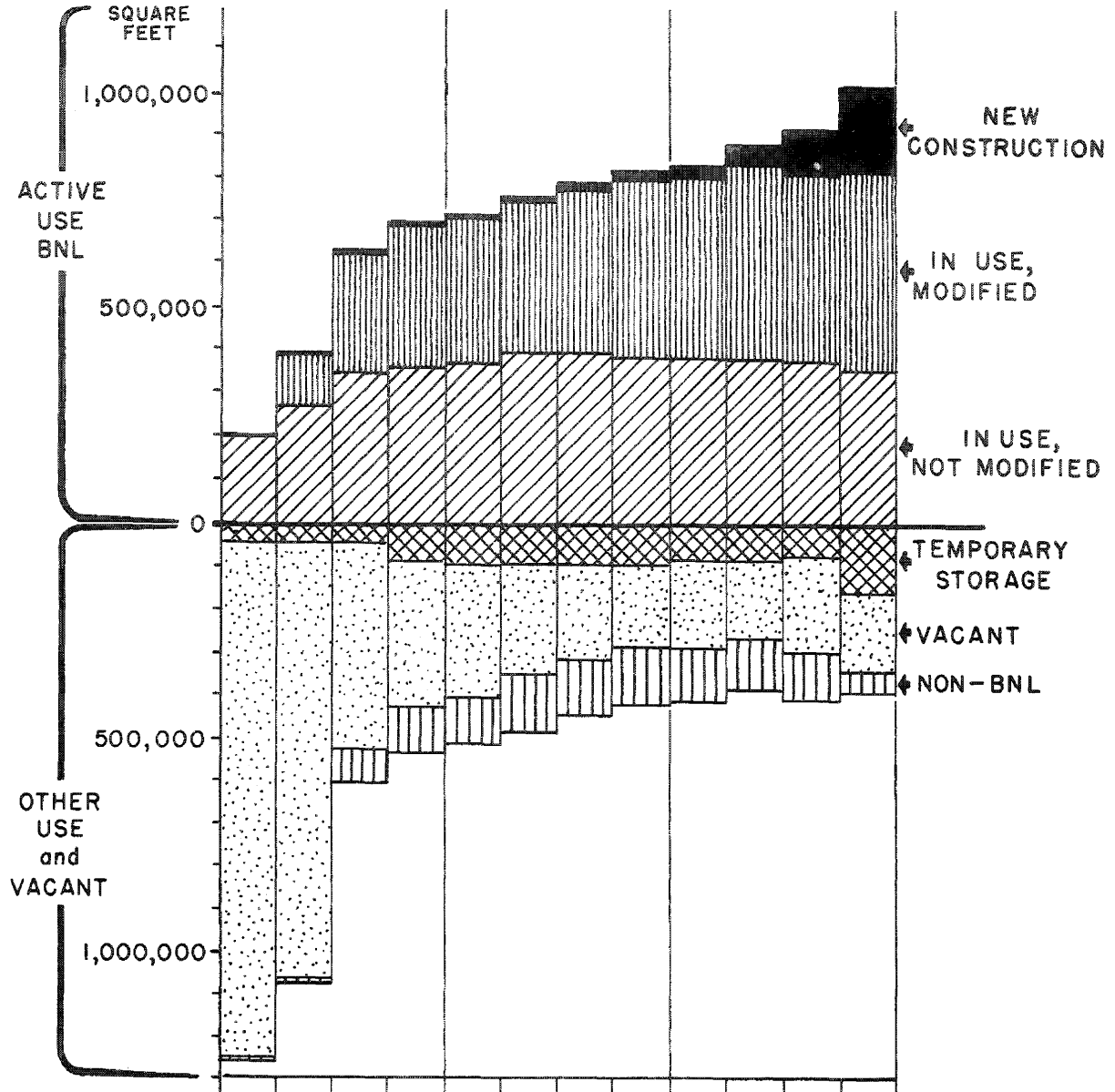
During the past six months, there was a net gain of 138,600 square feet of new modified, and unmodified building facilities in use, made up as follows:

Change in Building Facilities	Area (square feet)
Added by new construction	152,900
Added by modification	42,900
Added without modification	21,400
Total	217,200
Withdrawn from use	-78,600
Net gain	138,600

Complete architect-engineer services for approximately 50,000 square feet of this modification and new construction were furnished by the Architectural Design Group. This group is now working on design of new construction or modification involving 19 buildings and 7 utility installations, and is supervising current work on 10 buildings and 2 major utility installations. The largest single project in the current work load is the Cosmotron building and related services, progress on which is approximately on schedule.

In the Buildings and Grounds Division, a Motor and Compressor Section, recruited from, and still part of, the Utilities Group, has been formed to maintain the increased tonnage of refrigerating and air-conditioning equipment. Since the end of September, there have been 3 riggers (increased to 5 in November) from the Grounds Group on permanent detail with the Cosmotron project to move the magnet sections for testing. The Grounds Group has also detailed men to the Biology Department for work on field crop experiments as required. The plumbing, electric, and carpenter shops have each had large areas of direct responsibility for the installation of the 60-inch cyclotron and the Lectrodryer unit in the electrostatic accelerator chamber. Routine maintenance functions of the Department are being carried on as outlined in previous reports. No new maintenance facilities have been added.

Continued use of vehicles by self-drivers and lower maintenance due to lower average age of vehicles has permitted a small reduction in the Transportation Group, with the same average number of miles driven. This group provided an unusual service by trucking the major cyclotron components from Cedar Rapids, Iowa, to the Laboratory at appreciably less cost than by common carrier.



	1947 1	1947 2	1947 3	1947 4	1948 1	1948 2	1948 3	1948 4	1949 1	1949 2	1949 3	1949 4
NEW CONSTRUCTION	0	-	1	1	1	1	1	1	2	3	8	15
MODIFIED	-	8	22	27	28	29	31	33	34	36	33	35
NOT MODIFIED	14	19	29	29	29	31	32	32	31	30	28	25
TEMPORARY STORAGE	3	3	3	7	8	8	8	8	7	7	6	12
VACANT	83	70	39	27	25	20	17	15	16	14	17	13
NON-BNL	-	-	6	9	9	11	11	11	10	10	8	4

Percent of total area

TOTAL AREA OF BUILDINGS BY STATUS
(Quarterly Averages)

The Fire Department strength has been reduced from 65 to 52 officers and men. Organization and functions of the Department are as last reported, but in addition, a program of instruction in the use of extinguishers for all Laboratory employees has been inaugurated. Responsibility for operation of the Laboratory ambulance has been transferred to the Police Department.

The Radio and Alarms Maintenance Section has been reduced from 3 to 2 men, despite the fact that its area of responsibility continues to increase as more fire alarm systems are added to our circuits and more intercommunication units are installed in offices and laboratories.

Business Management

Business Office Administration consists of the business management functions, technical services supervision, budget and financial planning, and contract negotiation. The staff comprises 5 administrative and 3 secretarial personnel.

Purchasing

The Purchasing Group, with 22 members as of December 31, handles all Laboratory buying, except for a number of special contracts negotiated by the Contract Negotiator in the Business Office.

Buying is taking on a somewhat different aspect as the Laboratory progressively shifts emphasis from construction to operation of machines and to research. Supplies are required which, in many cases, are not common to vendors used during the construction period, and which thus require more than ordinary search for sources of supply.

Requisitions Processed by Purchasing Group			
July:	981	October:	991
August:	1010	November:	876
September:	968	December:	850 (projected)
Purchase orders issued, July 1 - December 1, 1949:			4,991
Change orders issued, July 1 - December 1, 1949:			665

In order to locate quickly the cheapest and most reliable sources for a wide variety of supplies, a card catalog file of items, indicating vendor and price, is being regularly compiled. Since January, 1949, some 23,000 items have been recorded in this record. The records supply a quick reference for the buyers as to sources, prices, availability, etc.

Another useful tool of the Purchasing Group is the library of suppliers' catalogs. This source of information is consulted by the buyers and by members of the scientific staff.

Receiving, Warehousing, and Distribution

The functions of the Receiving, Warehousing, and Distribution Group comprise the processing of purchase requisitions against the inventory records, the receiving,

inspecting, and warehousing of goods, including the preparation of the necessary receiving reports, the issuing of stores, maintenance of inventory records, and the disposal of salvage by sale. A further contraction in employment has taken place, reducing the Group from 71 on June 30, 1949, to 68 as of December 31, 1949.

Activities have continued on a high level during the past six months. The number of stores issues and stores turn-in slips has increased steadily in the past 18 months, as the Laboratory has come to depend more and more on its inventory of stores for new supplies.

The Salvage and Disposal Section has been engaged in disposing of the surplus of the H.K. Ferguson Company, the contracting firm which is completing the reactor. To date, this section has disposed of materials and equipment amounting to $502,000 in original cost. This is in addition to the disposal in about two years of surplus materials and supplies of an original cost of $435,600, which arose mainly from the "take-over" inventory.

Fiscal

The Fiscal Division handles all the accounting of the Laboratory, which includes payrolls, bookkeeping, audits of vouchers, payment of bills, activities of the cashier, etc. Personnel increased from 49 at the start of the report period to 51 at present.

The Division experienced a slightly increased work load in all sections except the Bookkeeping Section, where the increase was large. The increase in work load and in number of employees resulted primarily from the capitalization of assets and the change from a cash to an accrual basis of accounting.

During the report period, the usual auditing agencies examined the accounts of the Laboratory maintained by the Fiscal Division. The audit engagements were conducted by the public accounting firm of Haskins and Sells, by the General Accounting Office, and by employees of the Atomic Energy Commission.

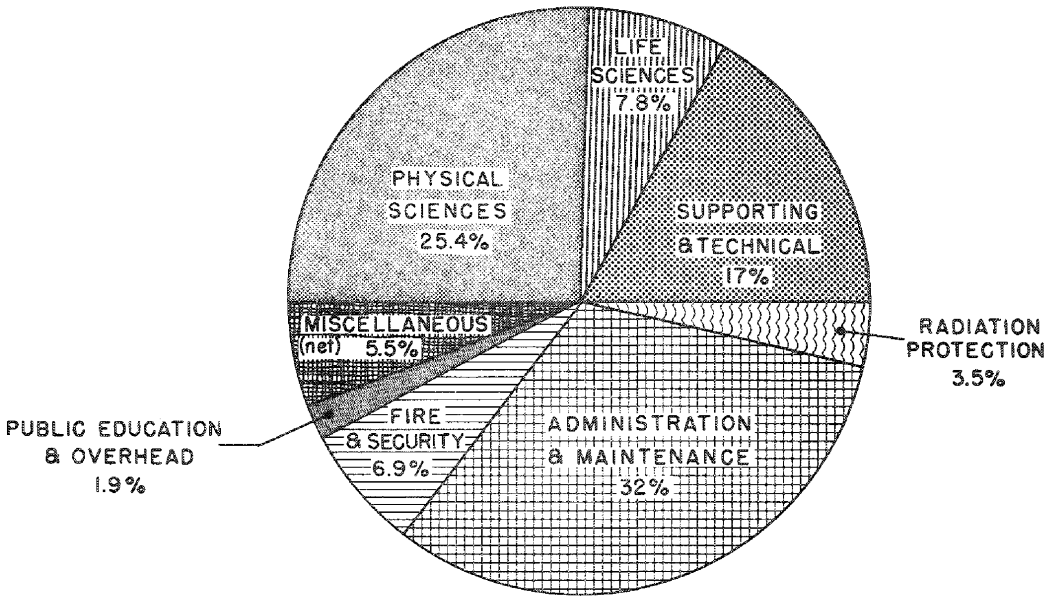
Routine operations were maintained, including the issuing of monthly financial statements, auditing of subcontractors' accounts, and the preparation of accounting information for budget study and revision.

Office Services

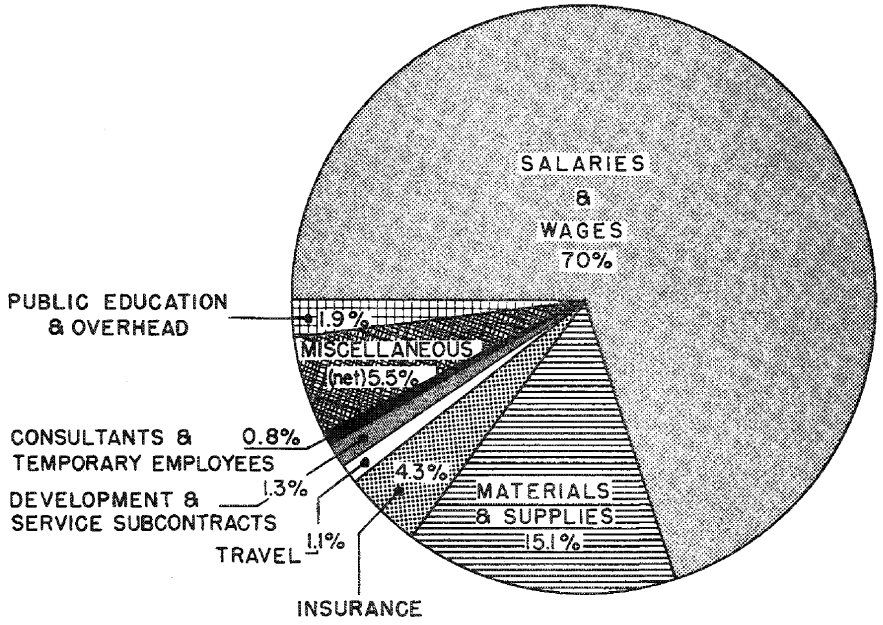
The Office Services Group is charged with the maintenance of a small stenographic pool, collection and distribution of Laboratory mail, repair of office machines, and the operation of a mimeograph section and the telephone service for the Laboratory. The personnel of the Group dropped from 34 to 30 during the report period.

The work load of the various sections has shown little change from previous periods; in addition, several new activities have been undertaken.

A records retirement program has been established to provide systematic storage for unclassified Laboratory records. Space has been prepared for the files. An adequate fire alarm and sprinkling system has been installed, and files are being brought to the building.



OPERATING BUDGET
Total $ 7,688,000 Fiscal Year 1950



MAJOR CATEGORIES
of EXPENDITURES
Total $ 7,688,000 Fiscal Year 1950

A file has been set up, and is being maintained, for continuous comparison and study of existing and new Laboratory forms. Significant savings have been obtained by simplification, consolidation, and elimination of forms, and also by the use of mimeographing rather than printing.

A periodic inspection of all office machines is now established to provide preventive maintenance and reduce repair charges.

A review of each department's telephonic installation is presently in progress, involving the use of a Cardex file which lists each phone extension in the Laboratory by location, department, and charge. It is expected that more economical and more efficient service will result.

Personnel

The number of Laboratory employees on December 31, 1949, was 1447. This is a net gain of 36 over the number employed on June 30, 1949. It compares with a net gain of 69 during the first six months of 1949, and a net gain of 25 during the last six months of 1948. The average monthly rate of net accessions for the last six months of 1949 was 0.42%. This can be compared with a rate of 1.1% for the first six months of 1949 and a rate of 0.3% for the last six months of 1948.

The average monthly turnover rate for the year 1949 was 1.4%. This was likewise the rate for both the first and the last six-month periods. It may be compared with the rate of 2.2% for the last six months of 1948.

The frequency rate of disabling injuries for the year 1949 was 2.72. This represents a reduction of more than 65% over the year 1948, during which the rate was 8.00. This reduction is a continuation of the trend, established during that year, which resulted in a 50% reduction in 1948 over 1947. From July until November of 1949, a new record was established; the Laboratory completed a period of more than 900,000 consecutive man hours without a single disabling injury. The low injury frequency rate achieved in 1949 was accompanied by a similarly low severity rate of 0.05, as compared with 0.26 for 1948. During the past six months, the Safety Group has been instrumental in effecting approval and implementation of a Laboratory-wide basic emergency plan.

The Housing Office assisted employees in arranging for 12 purchases of houses and 51 leases of houses, apartments, and rooms. Lease authorizations for properties controlled by the Laboratory amounted to $47,323. This compares with a total of $37,209 during the first six months of 1949, and $44,323 during the last six months of 1948.

Participation in the Laboratory Blue Cross Plan has continued to increase, despite the fact that members bear the full cost of the plan. Present participation is more than 87% of those eligible, as compared with 76% at the end of 1948. This increase was the more remarkable, as the premium charges for hospitalization were increased approximately 25% late last spring. Participants in the group insurance plan continue to exceed 90% of the total staff. Approximately 50% of the eligible staff have become members of the retirement plan; there were nearly twice as many members at the end of 1949 as there were at the end of 1948.

Security and Plant Protection

The growth and development of the Laboratory is reflected in the evolution of the security and police organization, with respect not only to the number of staff members, but to the concept of operations as well. The pace of Laboratory expansion poses the constant problem of meeting additional security and police requirements within present personnel and budgetary limits.

The Security Office is concerned with problems of personnel clearances, plant protection, security of restricted data and of restricted areas, and other similar items. Its program is now stabilized; and plans are in prospect for a reduction of personnel made possible by the development of more efficient and less costly operating methods. The work load and the scope of responsibility remain unchanged.

The objective of the Office is to provide security and plant protection in line with Commission requirements. The performance of these functions in a laboratory where freedom and restriction are interwoven raises new problems requiring new solutions. An attempt is being made to impose as little restriction as possible on the time and energies of Laboratory personnel by maintaining a realistic balance between the requirements of security and those of individual freedom of action. This requires constant attention to details and a constant search for new methods.

The operations of the Police Group, as distinct from those of the Security Office, present a different problem. Within the past four months, the security and protection of the reactor complex has become the responsibility of the Laboratory. This has necessitated the establishment of additional fixed police posts. These are being manned, at present, by readjusting police duty schedules, by maintaining a high degree of flexibility in extra duty assignments, and by reducing the number of patrolmen required for duty in the local Atomic Energy Commission office. However, the addition of the new facilities to the operating plant will require some expansion of the police organization to discharge contractual obligations to provide adequate protection, as well as to comply with security requirements of the Atomic Energy Commission.

The Police Group assumed the operation of the Laboratory ambulances in August, to be continued until the Medical Department can provide the necessary manpower. Since then, there have been a total of 19 calls; 12 in connection with the Laboratory medical program, and 7 accident calls outside the Laboratory site, involving 19 injured persons. The Laboratory policy of responding to calls for assistance off-site has helped to maintain friendly relations with citizens in surrounding communities, and with their police and fire departments, with whom the Laboratory has arrangements for reciprocal aid.

Training and indoctrination of security and police personnel is focused on services which they can render the Laboratory. These are positive contributions over and above the regulatory and restrictive functions commonly associated with police organizations. They include such activities as operating the Laboratory ambulances, providing emergency transportation, attending to the personal needs and difficulties of the individual Laboratory employee, and providing an information service to employee and visitor alike, all illustrating a new and broader concept of police functions.

Sixty-five Laboratory police officers have completed the American Red Cross Basic First Aid Course as a requirement for operating the ambulances, thereby providing first aid in ambulance work and creating a reservoir of trained men ready to meet disasters and emergencies when needed.

The future scope of security and police operations will be determined largely by the needs of the Laboratory, the security requirements of the Atomic Energy Commission, and the usual run of unpredictable requests which are made of service organizations of this kind.

APPENDIX

A. UNCLASSIFIED PUBLICATIONS, JULY 1 - DECEMBER 31, 1949

This list includes official Laboratory publications, publications by staff members and consultants, which resulted from work done at the Laboratory, and abstracts, submitted during the report period, of papers which were or will be presented at scientific meetings. In addition, publications listed as "in press" in the previous progress report (BNL-AS-2) are listed again in cases where complete publication information is now available. (A) indicates abstract; (L) letter to the editor; (N) note. (In press.) indicates acceptance for future publication.

General Publications

Progress Report, January-June, 1949 (BNL-AS-2)

Guide to Russian Scientific Periodical Literature 2, #4-12 (BNL-L-61 to 69)

Weekly Bulletin 2, #49-52; 3, #1-22

Weekly Selected Reading List 2, #17-43

Staff Publications and Abstracts

Accelerator Project

Blachman, N.M.
The counting volume of a cylindrical ionization chamber
Rev. Sci. Instruments 20, 477-9 (1949)

Blachman, N.M. and Courant, E.D.
The dynamics of a synchrotron with straight sections
Rev. Sci. Instruments 20, 596-601 (1949)

Blewett, J.P.
Radio frequency problems associated with particle accelerators (A)
Proc. I.R.E. (In press.)

Blewett, J.P. (See Livingston, M.S.)

Courant, E.D. (See Blachman, N.M.)

Green, G.K. (See Livingston, M.S.)

Haworth, L.J. (See Livingston, M.S.)

Livingston, M.S., Haworth, L.J., Blewett, J.P., and Green, G.K.
Design study for a 3-Bev proton accelerator
Rev. Sci. Instruments (In press.)

Architectural Planning and Plant Maintenance Department

Hunter, E.J.
Results of seeding rate test sections
N.Y.S. Turf Assoc. Bull. (In press.)

Biology Department

Acher, F. (See Gibbs, M.)

Christensen, E. (See Sparrow, A.H.)

Damast, B. (See Sacks, J.)

Dumrose, R. (See Gibbs, M.)

Edelmann, A.
The adrenal cortex and survival of rats after X-irradiation (A)
34th Annual Conv. of the Fed. of Amer. Socs. for Exptl. Biology, Atlantic City, N.J., April 17-21, 1950

Gibbs, M., Dumrose, R., and Acher, F.
The biosynthesis of radioactive starch
Book - "Biochemical Preparations" (In press.)

Gibbs M.
On the mechanism of the chemical formation of lactic acid from glucose studied with C^{14}-labeled glucose
J. Am. Chem. Soc. (In press.)

Gibbs, M.
The reliability of the bacterial degradation of C^{14}-labeled glucose (A)
The Botanical Soc. of America, Annual Meeting, New York, December 27-31, 1949

Gibbs, M.
The use of tracers in plant physiology
Teaching Scientist 6, #2, 28-9 (December, 1949)

Gibbs, M. (See Udenfriend, S.)

Holt, M.W.
A semiautomatic injection apparatus for use with radioactive solutions
Science (In press.)

Klein, J.R. (See Sharpe, L.M.)

Krishnan, P.S. (See Sharpe, L.M.)

Moses, M.J.
Nucleoproteins and the cytological chemistry of *Paramecium* nuclei
Proc. Soc. Exptl. Biol. Med. (In press.)

Rubin, B.A.
The effect of growth in a radioactive culture medium on the mutation rate of *E. coli* to streptomycin resistance
Microbial Genetics Bull. (In press.)

Rubin, B.A.
The pattern and significance of delayed phenotypic expression of mutations induced in *E. coli* by absorbed P^{32}
Genetics (In press.)

Rubin, B.A.
A rapid method for the determination of mutation rate of *E. coli* to streptomycin resistance
Microbial Genetics Bull. (In press.)

Rubin, B.A.
A source of error in tracer experiments with P^{32}
Science (In press.)

Rubin, B.A. and Steinglass, P.
The effect of absorbed radioactive phosphorus (P^{32}) on the genetics of E. coli
Proc. Soc. Amer. Bacteriologists (In press.)

Rubin, B.A. and Steinglass, P.
The genetics of streptomycin resistance induced by absorbed radioactive phosphorus (P^{32}) (A)
Bull. N.Y. Branch of Soc. of Amer. Bacteriologists (In press.)

Rubin, B.A. and Steinglass, P.
The significance of phosphorus in the metabolism of E. coli in studies with P^{32}
Proc. Soc. Amer. Bacteriologists (In press.)

Sacks, J.
An all glass filtration apparatus for radioactive tracer experiments
Analytical Chemistry 21, 876 (1949)

Sacks, J.
A fractionation procedure for the acid-soluble phosphorus compounds of liver
J. Biol. Chemistry 181, 655-66 (1949)

Sacks, J. and Damast, B.
Phosphate turnover in the liver of alloxan diabetes (A)
34th Annual Conv. of the Fed. of Amer. Socs. for Exptl. Biology, Atlantic City, N.J., April 17-21, 1950

Sharpe, L.M. and Klein, J.R.
Distribution in the duck of intraperitoneally administered radioiron in erythrocytes, muscle, cytochrome C of muscle, and plasma
J. Biol. Chemistry (In press.)

Sharpe, L.M., Krishnan, P.S., and Klein, J.R.
In vitro transfer of radioiron across the nucleated and non-nucleated erythrocyte membrane (A)
Amer. Soc. of Zoologists (In press.)

Singleton, W.R.
Breeding for sucrose in corn stalks
Agronomy Journal (In press.)

Sparrow, A.H. and Sparrow, R.C.
The frequency of spontaneous chromosome breakage in Trillium (A)
Genetics (In press.)

Sparrow, A.H. and Christensen, E.
Nonrandom distribution of chromosome fragmentation in unirradiated Trillium (A)
Genetics (In press.)

Sparrow, A.H.
Tolerance of Tradescantia to continuous exposures to gamma radiation from $cobalt^{60}$ (A)
Genetics (In press.)

Sparrow, R.C. (See Sparrow, A.H.)

Steinglass, P. (See Rubin, B.A.)

Udenfriend, S. and Gibbs, M.
The preparation of C^{14} uniformly labeled fructose by means of photosynthesis and paper chromatography
Science (In press.)

Yaw, K.E.
Irradiation effects on Allomyces arbusculus (A)
Mycological Soc. of Amer., N.Y. Meeting, December, 1949

Chemistry Department

Bigeleisen, J.
Dissociation and exchange equilibria of the tritium halides
J. Chem. Phys. (In press.)

Bigeleisen, J.
The relative reaction velocities of isotopic molecules
J. Chem. Phys. 17, 675-8 (1949)

Bigeleisen, J. and Friedman, L.
C^{13} isotope effect in the decarboxylation of malonic acid (L)
J. Chem. Phys. 17, 998-9 (1949)

Bonner, F. and Turkevich, J.
Study of the carbon dioxide - carbon reaction using C^{14} as a tracer (A)
Am. Chem. Soc., Atlantic City Meeting, September, 1949
Abstracts of Papers, 116th Meeting, 39P

Bonner, F. and Turkevich, J.
Study of the carbon dioxide - carbon reaction using C^{14} as a tracer
J. Am. Chem. Soc. (In press.)

Brookhaven conference report:
Nuclear fission and radiochemical research associated with nuclear reactors
July 14-15, 1949 (BNL-C-9)

Burtt, B.P.
The standardization and use of radium E sources for absolute beta counting
Nucleonics 5, #2, 28-43 (1949)

Dodson, R.W.
Some studies in reaction kinetics with isotopic tracers (A)
Am. Chem. Soc. Lecture, Buffalo, December 13, 1949

Dodson, R.W. (See Harbottle, G.)

Elliott, N.
The magnetic susceptibilities of some tetravalent uranium fluorides (L)
Phys. Rev. 26, 431-2 (1949)

Friedman, L. and Turkevich, J.
The infrared absorption spectra of propane-D-1 and propane-D-2
J. Chem. Phys. 17, 1012-5 (1949)

Friedman, L. (See Bigeleisen, J.)

Friedman, L. (See Turkevich, J.)

Gryder, J.W.
Electronic exchange and oxidation-reduction reactions in inorganic systems
Trans. N.Y. Acad. Sci. (In press.)

Harbottle, G. and Dodson, R.W.
Exchange reactions between the oxidation states of thallium in perchloric acid solutions (A)
Am. Chem. Soc., Atlantic City Meeting, September, 1949
Abstracts of Papers, 116th Meeting, 29P

Hutchinson, E.
A note on the direct determination of adsorption from solution (N)
J. Colloid Sci. (In press.)

Kennedy, J.W.
The hydrolysis of iodine and a reaction with "propanol," December, 1949 (BNL 30 (T-14))

Kennedy, J.W.
A proportional ionization chamber, December, 1949 (BNL 31 (T-15))

Rubinson, W.
Nuclear developments in chemistry
Teaching Scientist 6, #1, 3 (September, 1949); #2, 31 (December, 1949)

Samos, G.
Some observations on exchange of CO_2 between $BaCO_3$ and CO_2 gas
Science 110, 663-5 (1949)

Schultz, R.D. and Taylor, H.A.
The photolysis of methyl iodide
J. Chem. Phys. (In press.)

Taylor, H.A. (See Schultz, R.D.)

Thompson, S. and Turkevich, J.
Fischer-Tropsch reaction using deuterium and carbon monoxide (A)
Am. Chem. Soc., Atlantic City Meeting, September, 1949

Turkevich, J. (See Bonner, F.)

Turkevich, J. (See Friedman, L.)

Turkevich, J. (See Thompson, S.)

Turkevich, J. (See Townes, C.H.)

Electronics and Instrumentation Division

Ballentine, R. (See Bernstein, W.)

Bernstein, W. and Ballentine, R.
Gas phase counting of low energy beta emitters
Rev. Sci. Instruments (In press.)

Bernstein, W., Brewer, H.G., Jr., and Rubinson, W.
A proportional counter X-ray spectrometer
Nucleonics (In press.)

Brewer, H.G., Jr. (See Bernstein, W.)

Chase, R.L.
A device for making point by point measurements of varying frequency
Electronics (In press.)

Kuper, J.B.H.
Desirable improvements in nucleonics instrumentation
Elec. Eng. (In press.)

Madansky, L. and Pidd, R.W.
Preparation of a parallel plate spark counter
Rev. Sci. Instruments (In press.)

Madansky, L. and Pidd, R.W.
Some properties of the parallel plate spark counter. II
Phys. Rev. (In press.)

Pidd, R.W. (See Madansky, L.)

Rubinson, W. (See Bernstein, W.)

Health Physics Division

Weiss, M.
Area survey manual, September 1, 1949 (BNL-I-8)

Information and Publications Division

Stanford, S.C.
A guide to the Russian scientific periodical literature (A)
Am. Chem. Soc., Atlantic City Meeting, September, 1949
Abstracts of Papers, 116th Meeting, 13F

Stanford, S.C.
A guide to Russian scientific periodical literature
J. Chem. Education (In press.)

Physics Department

Alburger, D.E.
Gamma radiation from Na^{22} and Co^{60} (L)
Phys. Rev. 76, 435 (1949)

Alburger, D.E. and Hafner, E.M.
The properties of atomic nuclei. III. Nuclear energy levels Z = 11-20, July, 1949 (BNL-T-9)

Alburger, D.E., Hughes, D.J., and Eggler, C.
The β spectrum of Be^{10} (A)
Bull. of Am. Phys. Soc. 25, #1, 10, C4 (1950)

Alburger, D.E. (See Sunyar, A.W.)

Bird, G. (See Land, E.H.)

Blau, M., Block, M.M., Friedman, H., and Nafe, J.E.
Charged particles of low energy associated with the ends of μ meson tracks (L)
Phys. Rev. (In press.)

Blau, M., Block, M.M., and Nafe, J.E.
Heavy particles in cosmic ray stars (L)
Phys. Rev. 76, 860-1 (1949)

Blau, M. and Ruderman, I.W.
Photographic methods of measuring neutron intensities
Rev. Sci. Instruments (In press.)

Block, M.M. (See Blau, M.)

Burgy, M.T. (See Hughes, D.J.)

Cohen, V.W. and Knight, W.D.
The nuclear gyromagnetic ratio of V^{51} (L)
Phys. Rev. 76, 1421 (1949)

Cohen, V.W., Koski, W.S., and Wentink, T., Jr.
Nuclear spin and quadrupole coupling of S^{35} (A)
Bull. Am. Phys. Soc. 24, #7, 7 (1949)

Cohen, V.W., Koski, W.S., and Wentink, T., Jr.
Nuclear spin and quadrupole coupling of S^{35} (L)
Phys. Rev. 76, 703-4 (1949)

Curtis, N.W., Hornbostel, J., Lee, D.W., and Salant, E.O.
Photodisintegration of rhodium (L)
Phys. Rev. (In press.)

der Mateosian, E. and Goldhaber, M.
Photoneutron production (A)
Bull. of Am. Phys. Soc. 25, #1, 19, A5 (1950)

der Mateosian, E. (See Scharff-Goldhaber, G.)

Dollmann, E.M.
Variation of grain density with temperature of exposure in nuclear emulsions
Rev. Sci. Instruments (In press.)

Eggler, C. (See Alburger, D.E.)

Foley, H.M. (See Townes, C.H.)

Friedlander, G. (See Sunyar, A.W.)

Friedman, H. (See Blau, M.)

Goldhaber, M. (See der Mateosian, E.)

Goldhaber, M. (See Sunyar, A.W.)

Goudsmit, S.A. (See Richards, P.I.)

Hafner, E.M. (See Alburger, D.E.)

Hays, E.E. (See Richards, P.I.)

Hornbostel, J. and Salant, E.O.
Energetic events in emulsions at high altitude (L)
Phys. Rev. 76, 859-60 (1949)

Hornbostel, J. and Salant, E.O.
High energy events at high altitude (A)
Phys. Rev. 76, 468 (1949)

Hornbostel, J. (See Curtis, N.W.)

Hughes, D.J., Ringo, G.R., and Burgy, M.T.
Coherent neutron-proton scattering by liquid mirror reflection (L)
Phys. Rev. (In press.)

Hughes, D.J. (See Alburger, D.E.)

Johnson, G.W.
Oriented overgrowth of alkali halides on Ag, Bi, Sb, and Fe (A)
Bull. Am. Phys. Soc. 25, #1, 7, A6 (1950)

Johnson, G.W.
Some observations of the epitaxy of sodium chloride on silver
J. Applied Phys. (In press.)

Johnson, G.W.
Some observations on the epitaxy of sodium chloride on silver (L)
J. Chem. Phys. (In press.)

Knight, W.D.
The effect of electronic paramagnetism on nuclear magnetic resonance frequencies in metals (A)
Bull. Am. Phys. Soc. 24, #7, 13 (1949)

Knight, W.D.
Nuclear magnetic resonance shift in metals (L)
Phys. Rev. 76, 1259-60 (1949)

Knight, W.D. (See Cohen, V.W.)

Knight, W.D. (See Pound, R.V.)

Koski, W.S. (See Cohen, V.W.)

Land, E.H., Bird, G., and Shurcliff, W.A.
Detection of tracks and stars in nuclear track plates
Phys. Rev. (In press.)

Land, E.H. and Shurcliff, W.A.
Rotating illumination method of locating stars in nuclear track plates
Phys. Rev. (In press.)

Lee, D.W. (See Curtis, N.W.)

Low, W. (See Townes, C.H.)

McKeown, M. (See Scharff-Goldhaber, G.)

Nafe, J.E. (See Blau, M.)

Piccioni, O.
Local production of mesons at 11,300 feet
Phys. Rev. 77, 1-5 (1950)

Piccioni, O.
On the secondary particles of local penetrating showers
Phys. Rev. 77, 6-10 (1950)

Poss, H.L.
The properties of atomic nuclei. I. Spins, magnetic moments, and electric quadrupole moments (Revised), October, 1949 (BNL 26 (T-10))

Pound, R.V. and Knight, W.D.
A radio-frequency spectrograph and simple magnetic-field meter
Rev. Sci. Instruments (In press.)

Richards, P.I., Hays, E.E., and Goudsmit, S.A.
Magnetic time-of-flight mass spectrometer (A)
Phys. Rev. 76, 180 (1949)

Richards, P.I. and Hays, E.E.
Scintillation-type ion detector (Laboratory and shop notes)
Rev. Sci. Instruments (In press.)

Ringo, G.R. (See Hughes, D.J.)

Ruderman, I.W. (See Blau, M.)

Salant, E.O. (See Curtis, N.W.)

Salant, E.O. (See Hornbostel, J.)

Scharff-Goldhaber, G., der Mateosian, E., McKeown, M., and Sunyar, A.W.
Low energy photons from radioactive nuclei (A)
Bull. of Amer. Phys. Soc. 25, #1, 18, H3 (1950)

Scharff-Goldhaber, G. (See Sunyar, A.W.)

Schwartz, H.M.
Basic electromagnetic theory and the correspondence principle (A)
Phys. Rev. 76, 192 (1949)

Schwartz, H.M.
Contributions to existence theory of ordinary differential equations in the real domain. II (A)
Bull. Am. Math. Soc. 55, 672 (1949)

Scott, W.T.
Correlated probabilities in multiple scattering
Phys. Rev. 76, 212-9 (1949)

Scott, W.T.
The distribution of arc-chord differences in scattered particle tracks (L)
Phys. Rev. 75, 1763-5 (1949)

Scott, W.T. and Snyder, H.S.
Multiple scattering of fast charged particles
Phys. Rev. 76, 220 (1949)

Shurcliff, W.A. (See Land, E.H.)

Smith L.G.
Magnetic electron multiplier for detection of positive ions
Rev. Sci. Instruments (In press.)

Snow G.
The cross section of (n,2n) reactions near the threshold (A)
Bull. Am. Phys. Soc. 25, #1, 14, E8 (1950)

Snyder, H.S.
Comparison of calculations on cascade theories
Phys. Rev. 76, 1563-71 (1949)

Snyder, H.S.
Quantum electrodynamics: the self-energy problem
Phys. Rev. (In press.)

Snyder, H.S.
The self-energies of electrons and photons (A)
Bull. Am. Phys. Soc. 25, #1, 42, V9 (1950)

Snyder, H.S. (See Scott, W.T.)

Sunyar, A.W., Alburger, D.E., Friedlander, G., Goldhaber, M., and Scharff-Goldhaber, G.
Isomerism in Pb^{204} and radiations of Bi^{204} and Bi^{206} (A)
Bull. Am. Phys. Soc. 25, #1, 19, H4 (1950)

Sunyar, A.W. (See Scharff-Goldhaber, G.)

Townes, C.H. and Turkevich, J.
Hyperfine structure and exchange narrowing of paramagnetic resonance (L)
Phys. Rev. 77, 148 (1950)

Townes, C.H., Foley, H.M., and Low, W.
Nuclear quadrupole moments and nuclear shell structure (L)
Phys. Rev. 76, 1415-6 (1949)

Wantuch, E.
Scattering of 4.5 and 5.5-Mev neutrons by deuterons (A)
Bull. Am. Phys. Soc. 25, #1, 19, H8 (1950)

Wentink, T., Jr. (See Cohen, V.W.)

Reactor Science and Engineering Department

Barad, M.L.
Diffusion of stack gases in stable atmospheres (A)
Amer. Meteorological Soc. Meeting, St. Louis, January 3-6, 1950

B. OFFICERS AND SCIENTIFIC STAFF

Leland J. Haworth, Director

Robert A. Patterson, Assistant Director, University Liaison

Donald D. Van Slyke, Assistant Director, Biology and Medicine

Leland J. Haworth, Acting Chairman, Accelerator Project*
Leslie F. Nims, Chairman, Biology Department
Richard W. Dodson, Chairman, Chemistry Department
J.B.H. Kuper, Chairman, Instrumentation and Health Physics Department
Lee E. Farr, Chairman, Medical Department
Thomas H. Johnson, Chairman, Physics Department
Lyle B. Borst, Chairman, Reactor Science and Engineering Department
J. Georges Peter, Manager, Architectural Planning & Plant Maintenance Department
James M. Knox, Manager, Business Department
H. Russell Cort, Acting Head, Business Office
Lewis R. Burchill, Controller
Charles F. Dunbar, Legal Counsel
Lawrence R. Swart, Personnel Officer
Frederick H. Williams, Security Officer

Scientific Staff

Accelerator Project

Leland J. Haworth, Acting Chairman
Nelson M. Blachman
John P. Blewett
M. Hildred Blewett
James G. Cottingham
Ernest D. Courant
Edward W. Dexter
Serge E. Golian
George K. Green
George J. Hoey
Donald F. Howard
David D. Jacobus
Ralph Kassner
Joseph M. Kelly
Joseph A. Kosh
William Liben
John S. Medd
John J. Mede
Walter W. Merkle
William H. Moore, Jr.
Martin Plotkin
Irving J. Polk
Abraham I. Pressman
Fred J. Seufert, Jr.
Lyle W. Smith
Lincoln D. Stoughton
Clarence M. Turner
Milton J. White (part time)
Abraham N. Wise
Luke Chia-Lui Yuan

Biology Department

Leslie F. Nims, Chairman
Vaughan T. Bowen
George C. Culbreth
Rosalind J. DuBow
Abraham Edelmann
Martin Gibbs
J. Raymond Klein
Mary L. Koester
Montrose J. Moses
Benjamin A. Rubin
Jacob Sacks
Leon M. Sharpe
W. Ralph Singleton
Arnold H. Sparrow
Rhoda C. Sparrow
Robert Steele
Paul Steinglass
Robert Van Reen
Jackson S. White
Katherine E. Yaw

Chemistry Department

Richard W. Dodson, Chairman
James A. Amick
Augustine O. Allen
R. Christian Anderson
Jacob Bigeleisen
Aksel A. Bothner-By
Charles M. Cook, Jr.
Lester M. Corliss
Raymond Davis, Jr.
Lois J. Eimer
Norman Elliott
Simon Freed
Gerhart Friedlander
Lewis Friedman
Garman Harbottle

*As of April 1, Dr. George B. Collins will join the staff as Chairman of the Accelerator Project.

Beers, N.R.
General aspects of meteorology in the air pollution problem (A)
Symposium on Air Pollution, Pasadena, Calif., November 11, 1949

Keyes, J.J., Jr.
Ventilation studies on a radiochemical "semi-hot" bench, September, 1949 (BNL 27 (T-11))*

Liben, W.
Evaporating jig for Geiger-Mueller tubes (L)
Rev. Sci. Instruments (In press.)

Lowry, P.H.
Micro-climatic factors in smoke pollution from tall stacks (A)
Amer. Meteorological Soc. Meeting, St. Louis, January 3-6, 1950

Selvin, G.J.
A sealer and cutter for plastic tubing, September, 1949 (BNL 28 (T-12))

Selvin, G.J.
A totally sealed rotating funnel, September, 1949 (BNL 29 (T-13))

Selvin, G.J. (See Stang, L.G., Jr.)

Smith, M.E.
The forecasting of micrometeorological variables (A)
Amer. Meteorological Soc. Meeting, St. Louis, January 3-6, 1950

Stang, L.G., Jr. and Selvin, G.J.
An improved method of directing liquid flow in a closed system (N)
Rev. Sci. Instruments (In press.)

---

*For official use only.

Julius Hastings
Jerome J. Howland, Jr.
Adolph P. Irsa
Everett R. Johnson
Seymour Katcoff
Arthur Levy
Avrom I. Medalia
Warren Miller
John A. Miskel
Morris L. Perlman
Herbert C. Prosser
William Rubinson
Kenneth M. Sancier
Oliver A. Schaeffer
Morris Slavin
Joseph Silverman
Raymond W. Stoenner
Sydney O. Thompson
Elizabeth D. Wilson

Instrumentation and Health Physics Department

J.B.H. Kuper, Chairman
Ramon L. Ashley
David Balber
William Bernstein
Seymour Block
William F. Burditt
Robert L. Chase
Frederick P. Cowan
Edward H. Foster
Lee Gemmell
John S. Handloser
Saul J. Harris
William A. Higinbotham
Richard C. Jacobsen
Byron E. Keene
Stanley I. Kramer
Calman Lasky
John C. Logue
Marilyn H. McKeown
John H. Michel
Cornelius F. Murphy
Casimir Z. Nawrocki
John V. Nehemias
Peter Prentky
Oliver H. Perry
Seymour Rankowitz
William C. Reinig
Charles F. Stearns
Max M. Weiss

Medical Department

Lee E. Farr, Chairman
Ruth M. Drew
James A. Fancher, Jr.
William M. Hale
Sidney C. Madden
Wade N. Miller
Robert A. Love
John H. Prodell, Jr.
Alma W. Richards
Wilma C. Sacks
Donald D. Van Slyke
Louis J. Zeldis

Physics Department

Thomas H. Johnson, Chairman
David Alburger
Charles P. Baker
Ira B. Bernstein
Rodney L. Cool
Victor W. Cohen
Nancy W. Curtis
Charles C. Damm
Theresa Danielson
Edward der Mateosian
Elsie Dollmann
Charles B. Fisk
Earle C. Fowler
Gertrude Goldhaber
Maurice Goldhaber
Samuel A. Goudsmit
Everett M. Hafner
Earl E. Hays
John Hornbostel
William F. Hornyak
Donald J. Hughes
Alfred C. Hunting
Allan L. Johnson
Gerald W. Johnson
David A. Kleinman
Dorothy Lee
Allen J. McMahon
Andrew W. McReynolds
Henry T. Motz
John R. Pasta
Simon Pasternack
Oreste Piccioni
Howard L. Poss
William R. Rate, Jr.
Paul I. Richards
Edward O. Salant
Frederick G.P. Seidl
Ralph P. Shutt
Joseph E. Smith
Lincoln G. Smith
Jean H. Snover
George A. Snow
Hartland D. Snyder
Andrew W. Sunyar
Alan Thorndike
Stanley H. Ungar
Ernest Wantuch
Richard J. Weiss
Tunis Wentink, Jr.
William L. Whittemore
A. William Wotring

Reactor Science and Engineering Department

Lyle B. Borst, Chairman
James E. Atherton, Jr.
David W. Bareis
George A. Bennett
John E. Binns
Randolph H. Bretton
Gloria D. Brown
William F. Charlesworth
Jack Chernick
Melville Clark, Jr.
Harry C. Cook
David Dropkin
Dietrich H. Edel, Jr.
John J. Floyd
Marvin Fox
Robert C. Garth
William S. Ginell
David H. Gurinsky
Loranus P. Hatch
Franklin A. Heasley
Raymond J. Heus
Guy M. Inman
Sheldon E. Isakoff
Otto F. Kammerer

Irving Kaplan
Justin Karp
John W. Kunstadter
Paul H. Lee
Walter Lones
Philip H. Lowry
Bernard Manowitz
Daniel A. Mazzarella
Lowell McLean
Francis T. Miles
Charles L. Osborne
William R. Page
Jack E. Phillips
Robert W. Powell
Olaf J.S. Pruss
Alonzo C. Rand
Chad J. Raseman
Vance L. Sailor
William F. Scully
Gerald J. Selvin
Thomas V. Sheehan
Maxwell M. Small
Maynard E. Smith
Louis G. Stang
Gerald Strickland
Robert J. Teitel
Walter D. Tucker
Clarence M. Turner
Robert L. Turner
Edward J. Vanderman
George Vassilopoulos
William T. Warner
Clarke Williams
Warren E. Winsche
Richard H. Wiswall, Jr.