BNL 74 (AS-4)

BROOKHAVEN NATIONAL LABORATORY

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Annual Report
July 1, 1950

Associated Universities, Inc.
under contract with the
United States Atomic Energy Commission

Annual Report
July 1, 1950

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 July 1, 1949 - June 30, 1950. It is the first annual report, and it covers the entire progress of the Laboratory. However, since a report (BNL 39 (AS-3)) was issued for the period July 1 - December 31, 1949, this report is, for the most part, a review of work done during the first half of 1950. It contains both a summary of research in progress at Brookhaven National Laboratory and an outline of the Laboratory's future program.

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

September, 1950 1500 copies

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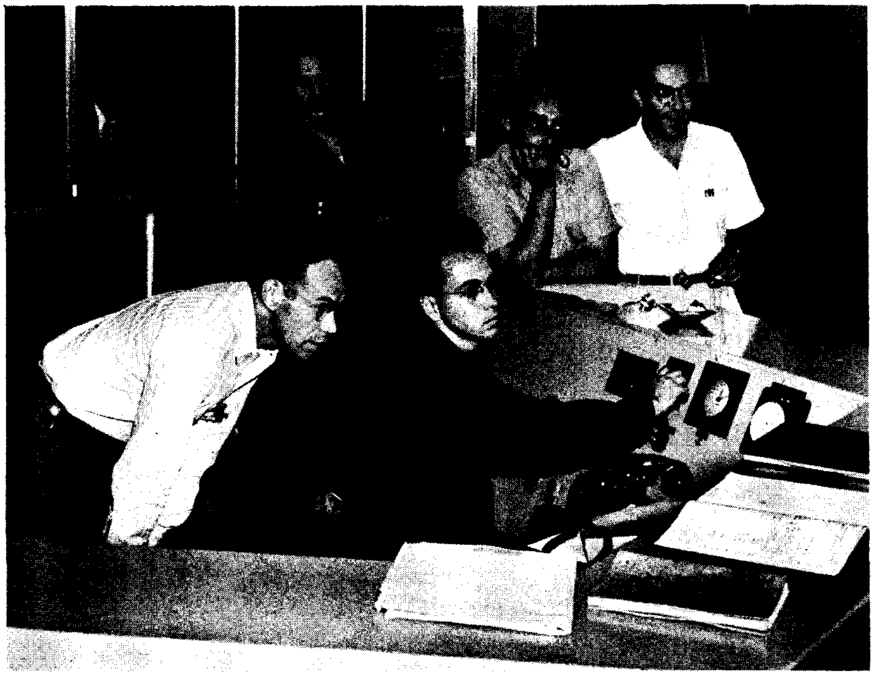

An important event in the history of Brookhaven National Laboratory is recorded in this picture, taken a few minutes before the reactor became critical at 2:30 a.m., August 22, 1950. The scene is the console desk in the control room, with all eyes turned toward the indicating instruments. Although the date on which criticality was reached was later than the actual period covered by this report, the event was such a milestone in the Laboratory's development that early start-up information available at the time of printing was included.

PART ONE

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Introduction

The purpose of this introductory section is to record the subjects to which the Trustees, their committees, and the Officers of Associated Universities, Inc. have given particular attention during the past six months. The second part of this report will provide a full account of the progress of Brookhaven National Laboratory during the period and its plans for the future.

As in the past, the Trustees have maintained their lively and direct interest in all of the affairs of the Laboratory, and have substantially assisted its management through funneling their institutions' intellectual resources into the project.

At regular monthly meetings of the Executive Committee and quarterly meetings of the Board of Trustees, detailed reports of the Officers and Director have been considered and acted upon. The value of their knowledge of the Laboratory's work and their guidance on major matters of policy and procedure have been augmented by visits of individual trustees to Brookhaven National Laboratory, by service on special committees, and by conferences at their respective universities with the Director and Officers. Of great importance, also, is the perspective which they bring to those engaged closely in the daily operation of the Laboratory.

Trustees Report

In July, 1949, the Trustees authorized a committee to prepare a report summarizing and appraising the experience of AUI as a contractor with the AEC during the first three years of the contract relationship. The report was submitted in April. It found that steady progress was being made toward realization of the fundamental purposes of the participating universities, and that, on the whole, the contractual relationship with the AEC was satisfactory, the exceptions being matters of procedure more than of principle. In the report itself, and in subsequent considerations of major policies, the Trustees expressed their judgment on several important matters.

1. It is the wish of AUI to provide an environment in which promising fundamental research can flourish, but also to render service to the country by undertaking other projects of immediate practical value to the Commission's other programs. Fundamental research is the foundation upon which future scientific development rests. In the national interest and for the good of science, the Laboratory's role as a center for fundamental nuclear research and development must be protected. Also in the national interest, however, problems of immediate practical concern must be solved. To the extent consistent with its primary purpose, Brookhaven National Laboratory should seek ways in which to assist the AEC in solving them. Therefore, in light of the increasingly grave international situation, the Trustees concurred in the plan of the Director of the Laboratory to explore with the AEC ways in which the Laboratory can now be especially useful in the national interest.

2. Without relaxing the effort to recruit a first-class staff and initiate fruitful programs of research, primary operating emphasis should be given to the earliest possible completion of major facilities.

3. The resources of equipment and staff at the Laboratory are intended to be used in cooperative projects and in training by qualified scholars or engineers from any educational or research institution in the northeastern area.

Contract Negotiation

The Corporation's contract with the Atomic Energy Commission provides for expiration on December 31, 1950, unless renewed. Early completion of negotiations for renewal is desirable. The President appointed a committee of Trustees to assist the Officers of the Corporation in negotiating renewal of the contract with the AEC. During July, the contract was extended for six months to June 30, 1951, in order to bring its term into conformity with the AEC's fiscal year, and to provide more time for discussion of certain features to be embodied in the new contract. This committee, with some of the Officers and the Laboratory Director, has met with a group of representatives of the AEC in a preliminary discussion of some aspects of the contractual relationship. Thereafter, the Trustees reaffirmed their view that the best interests of the AEC and of the universities will be served by preserving a substantial measure of administrative autonomy in AUI as the representative for the universities.

Organization and Personnel

Dr. George B. Collins, representing the University of Rochester, resigned from the Board of Trustees to assume his new post as Chairman of the Accelerator Project at the Laboratory. At its April meeting, the Board elected Dr. William S. McCann of the Rochester School of Medicine and Dentistry to take Dr. Collins' place.

Meetings of the Visiting Committees

The following meetings of the visiting committees were held between January 1 and June 30, 1950:

For the Biology Department:

April 22, 1950. To review the current and future program of the Biology Department, and to consider the choice of a new Department Chairman. The committee approved Dr. Howard Curtis, who will assume this post on October 1.

For the Chemistry Department:

June 29-30, 1950. To review and appraise the work of the Chemistry Department. In its report, the committee was most complimentary about the Department's work, staff, and leadership, and emphasized the importance of postdoctoral fellowships as a means of training nuclear scientists.

For the Medical Department:

April 6-7, 1950. To review the Medical Department's program and to become better acquainted with its staff. The committee found that a splendid start has been made in gathering a well-qualified staff, and in beginning an important research program. The committee's findings emphasized the desirability of bringing the Medical Department into closer touch with other scientific departments, particularly the Biology and Physics Departments, as soon as possible, and the importance of avoiding delay in building permanent hospital facilities for medical research at the Laboratory.

For the Physics Department:

May 1-2, 1950. To review the work and plans of the Physics Department and of the Accelerator Project. It was the committee's judgment that the present work is highly commendable and the plans thoroughly in keeping with the proper aims of the Laboratory.

For the Reactor Science and Engineering Department:

January 9, 1950. To review plans for repair and reinforcement of the reactor. The committee found that the plans were sound and urged their prosecution without delay.

March 13, 1950. To review the Department's research program and the progress of repair and reinforcement of the reactor. The committee expressed satisfaction with the research programs described and with the progress made in completing the reactor.

Conference with Representatives of Other University Contractors

In May, another of the series of meetings of representatives of the principal university contractors with the Atomic Energy Commission was held at Argonne National Laboratory. A wide range of administrative subjects was reviewed, particularly including organization, personnel administration, accounting, budgeting, patent management, and communication between the national laboratories and their university sponsors. Such conferences are valuable because they permit an exchange of experience whereby each institution is better enabled to solve problems which the others may have encountered already.

Fiscal

Fiscal developments of extra routine interest during the period included:

1. Preparations were completed for the introduction on July 1, 1950, of a detailed cost accounting system, providing for compilation and distribution of direct and indirect costs on an accounting basis. A new chart of accounts and rearrangement of the organization of several of the Laboratory's departments were necessary features of the new system.

2. On June 23, the Liberty Mutual Insurance Company rendered its accounting for the second interim adjustment of the premium account for the Corporation's coverage of workmen's compensation and general liability risks. The adjustment was retroactive to April 15, 1947, and included a recalculation of reserves for all open claims. A substantial return premium was paid to the Corporation by the carrier and was applied to the cost of other Laboratory programs.

3. Negotiations were completed with the Liberty Mutual Insurance Company to increase the limits of insurance coverage against claims arising from occupational disease, public liability, and property damage.

4. Messrs. Haskins and Sells, the Corporation's auditors, did not, as in previous years, make an audit as of December 31, 1949. A complete audit will be made as of June 30, 1950.

Public Education

After three special showings at Wallingford, Connecticut; Manhasset, Long Island; and Stratford, Connecticut, all but one or two locally useful parts of the Nuclear Energy Exhibit were transferred to the American Museum of Atomic Energy at the Oak Ridge Institute of Nuclear Studies. This transfer was proposed by AUI because the Trustees felt the exhibit program could more appropriately be administered by another agency, and because to do a thorough job of exhibit promotion would call for a larger staff and expenditure of more money than they were willing to approve. During the three years since AUI purchased its first component, the exhibit has been shown twenty-five times to a total estimated audience of 370,800 persons at a total cost of $91,200 for the whole program.

The staff of the Public Education Office was brought up to strength. There has been noticeable improvement in the quantity and usefulness of the output. In particular, news stories concerning some of the more significant developments at the Laboratory were prepared and released as a service to the press and radio. Also, an increasing service was rendered to reporters and special writers who asked for aid in preparing their own stories. These services must be a part of AUI's program because the central news gathering agencies of New York City depend upon nearby Brookhaven National Laboratory, as well as upon the New York Office of the AEC, for current information about nuclear developments in general.

The experimental Educational Services Program developed still further. A conference of members of the Association of Secondary School Administrators was held under the joint auspices of New York University and AUI to acquaint them with the broad outlines of recent atomic developments, because they affect the planning and administration of school curricula. The deans or department chairmen, and one president, of the eleven New York state teacher training institutions attended a conference at the Laboratory. This meeting was arranged by AUI and the Executive Dean of the State University of New York, Dr. Hermann Cooper, to explore the part they might play in developing atomic education, especially in the social science areas. At Hartford, Connecticut, with the assistance of AUI, the Connecticut Department of Education conducted a three-day institute for secondary school teachers in Connecticut and adjacent states to acquaint them with nuclear developments and how they may be introduced into the classroom. Similar institutes are being planned in Pennsylvania and in other parts of New York.

In addition, efforts continued to expedite and encourage the production by others of teaching materials in the atomic energy field and to find financial sponsors for other educational projects, including the production of motion pictures and workshops or in-training conferences for teachers.

Administration of AEC Predoctoral Fellowships

Acting upon the request of the AEC, and as an emergency measure, Associated Universities, Inc. undertook administration of the AEC Predoctoral Fellowships in the northeastern region for the academic year 1950-51. Although the announcement of the fellowships was unusually late, 142 completed applications were received from students seeking to undertake advanced study in the physical and life sciences. After careful review of their academic qualifications by Fellowship Panels, and "fellowship approval" by AEC, as required by law, 37 appointments were made by Associated Universities, Inc. and accepted. These men will study toward advanced degrees in 15 universities in the northeastern area.

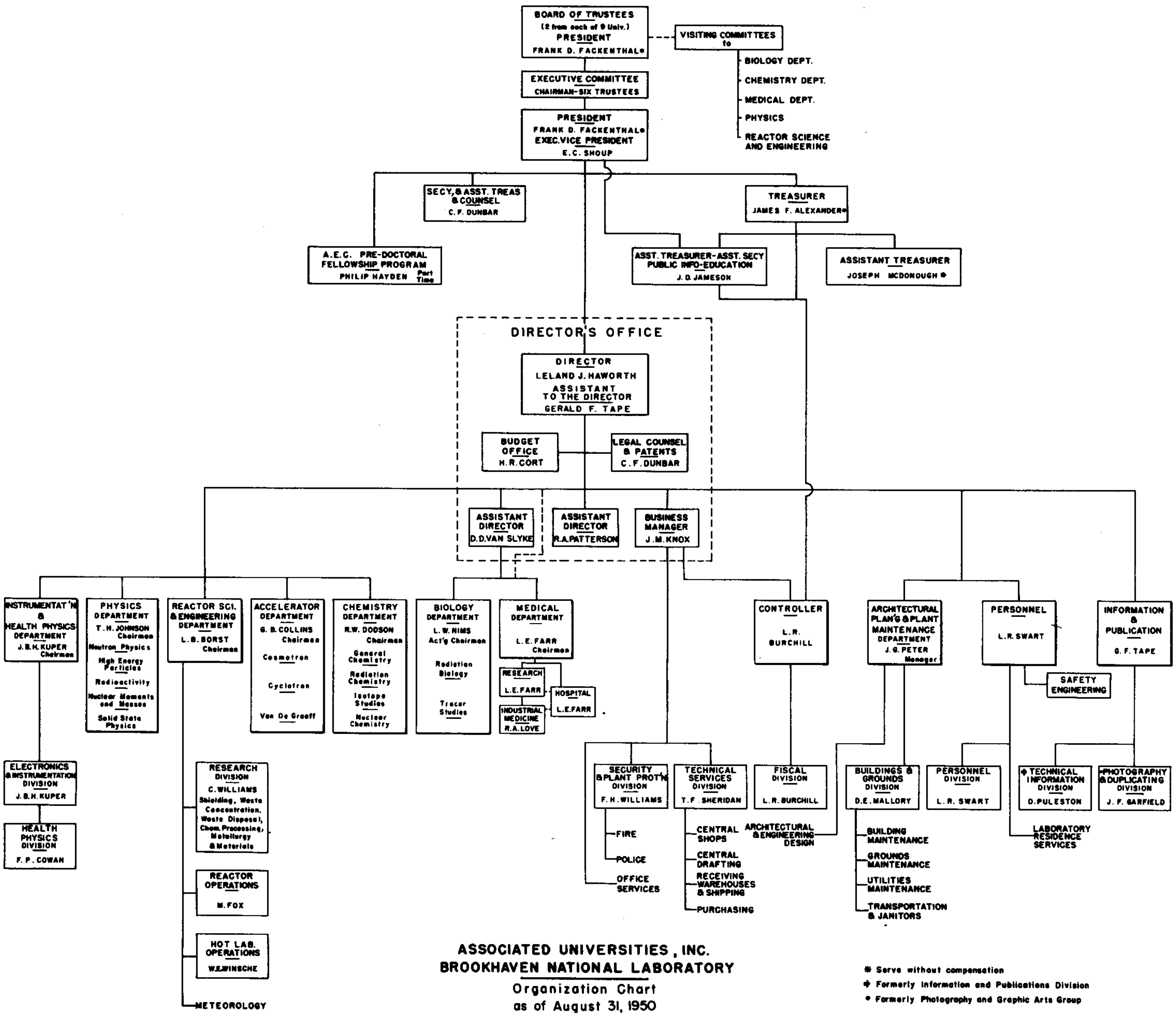
Invaluable assistance was received from the National Research Council in establishing administrative procedures and in examining and ranking the qualifications of applicants. AUI also acknowledges with sincere thanks the service of the members of the AUI Fellowship Panels:

Physical Sciences

- Dr. T.B. Drew, Executive Officer, Department of Chemical Engineering, Columbia University
- Dr. R.W. Dodson, Chairman, Chemistry Department, Brookhaven National Laboratory
- Dr. J.C. Boyce, Chairman, Department of Physics, New York University

Biological Sciences

- Dr. D.D. Van Slyke, Assistant Director, Brookhaven National Laboratory
- Dr. H.H. Rossi, Assistant Professor of Radiology, Columbia University
- Dr. L.F. Nims, Chairman, Biology Department, Brookhaven National Laboratory



ASSOCIATED UNIVERSITIES, INC.
BROOKHAVEN NATIONAL LABORATORY
Organization Chart
as of August 31, 1950

* Serve without compensation
◆ Formerly Information and Publications Division
• Formerly Photography and Graphic Arts Group

PART TWO

REPORT OF BROOKHAVEN NATIONAL LABORATORY

INTRODUCTION

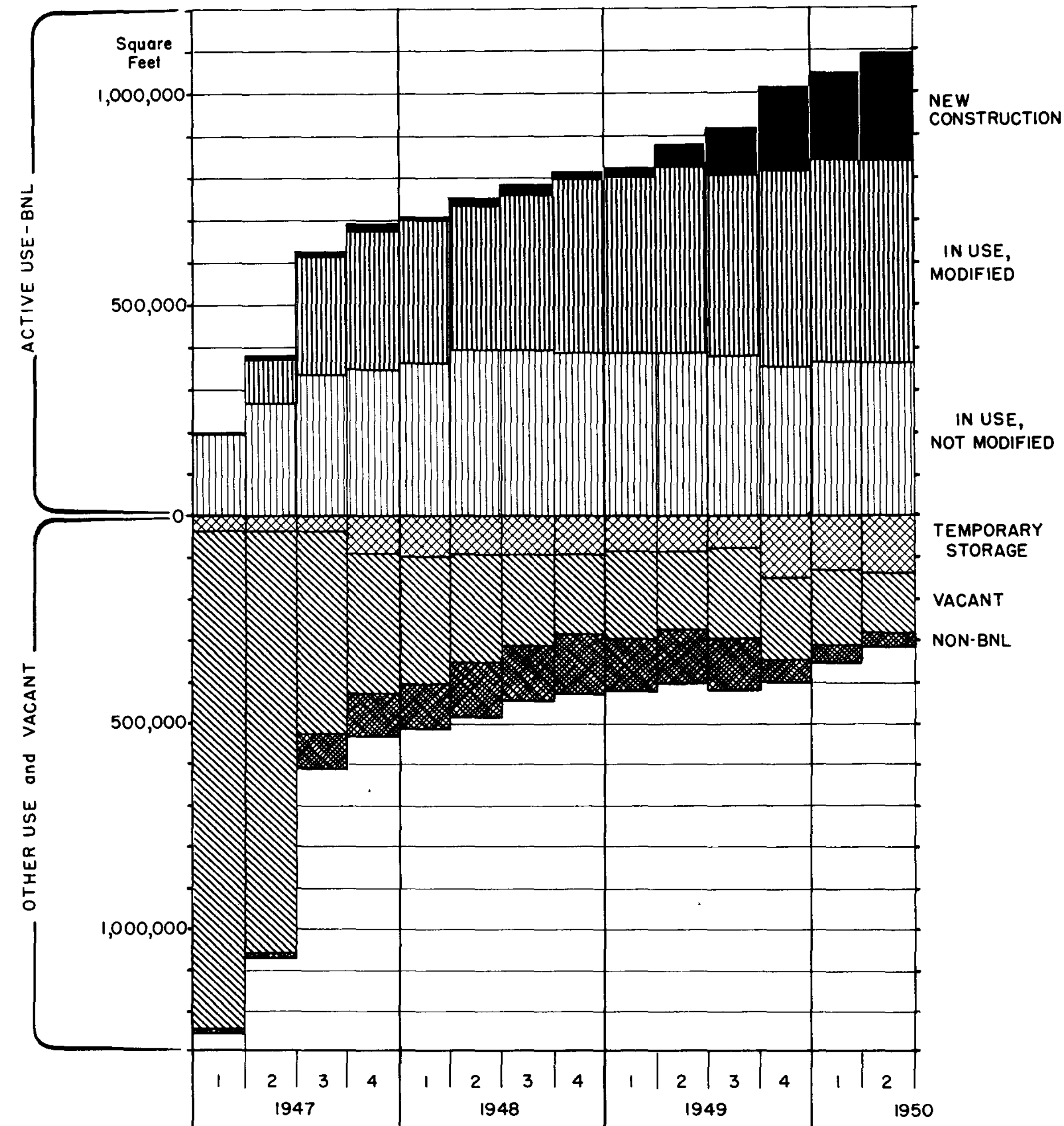
This report for fiscal year 1950 concentrates on the work of the last half of the year, since a semiannual report was issued on December 31, 1949 (BNL 39 (AS-3)). With the adoption of the new procedure of issuing an annual report at the end of the fiscal year, this report of an interim nature emphasizes the scientific research progress of the past six months and reviews the administrative aspects of Laboratory operation for the entire fiscal year. For detailed reports on the research progress of the various scientific departments, attention is called to the quarterly scientific progress reports of the Laboratory.

July 1950 saw the completion or near completion of many of the initial facilities planned for Brookhaven National Laboratory. The reactor complex was complete, except for the reactor alterations; these were scheduled for August completion. The Accelerator Project realized the completion of the cyclotron - Van de Graaff building and the installation of the two machines. The Cosmotron building was completed. The fabrication of components and their assembly into the Cosmotron continued.

The greatest effort toward the completion of facilities was spent on the nuclear reactor. This maximum of effort plus the diversion of considerable funds made possible the virtual completion of the reactor in August. It is to be noted, parenthetically, that the alterations were completed by the H.K. Ferguson Company on August 11, 1950, at which time the reactor was turned over to the Laboratory. Loading of the uranium proceeded until criticality was reached on August 22, 1950.

The first phase of the Biology building was completed and put into active use. The Chemistry complex was completed, with the exception of part of one wing which will be finished in 1951. The Physics Department, although scattered through many temporary buildings, carried its work through to a productive research phase. The Medical Department, the last unit to implement its research program, saw the completion of pathology, bacteriology, and biochemistry laboratories and of the research hospital within the structure of the former camp hospital. Thus, for the present time, each department has reasonably good, though limited, laboratory facilities. However, the Medical and Physics Departments are in temporary quarters, and Biology Department facilities need to be extended. Appropriations for the second phase of the Biology Department construction are available and plans are under way.

The over-all construction status of the Laboratory is shown in the accompanying chart (Figure 1). The total area in use is shown by quarters. New construction occupied during the past year includes the Cosmotron building (partial only), the hot laboratory, reactor laboratories, and the cyclotron - Van de Graaff building.



	1947-1	1947-2	1947-3	1947-4	1948-1	1948-2	1948-3	1948-4	1949-1	1949-2	1949-3	1949-4	1950-1	1950-2
NEW CONSTRUCTION	0	—	1	1	1	1	1	1	2	3	8	14	15	19
MODIFIED	—	8	22	27	28	29	31	33	34	36	33	33	34	33
NOT MODIFIED	14	19	29	29	29	31	32	32	31	30	28	25	27	26
TEMPORARY STORAGE	3	3	3	7	8	8	8	8	7	7	6	11	10	10
VACANT	83	70	39	27	25	20	17	15	16	14	17	13	12	10
NON-BNL	-	-	6	9	9	11	11	11	10	10	8	4	2	2

percent of total area

TOTAL AREA OF BUILDINGS by STATUS
(Quarterly Averages)

Figure 1.

The 2-Mev electrostatic generator, purchased from the High Voltage Corporation, was installed and is operating for the Chemistry Department. The Accelerator Project's 3.5-Mev General Electric accelerator operated generally at 2.0 Mev with an occasional top voltage of 2.5 Mev. Work on this machine was centered on bringing it up to specification by the manufacturer and the Laboratory, and on the starting of research, using proton or deuteron beams. The cyclotron was installed by the Collins Radio Co. and the Laboratory. The usual debugging and shakedown period is now in process. The Cosmotron is in process of assembly; the steel for its magnet is in place. The 4.0-Mev Van de Graaff injector was under test at the manufacturer's plant and is scheduled for shipment to the Laboratory in September. The over-all schedule for the Cosmotron calls for the assembly of all parts for test as a 2 to 3-Bev proton accelerator early in 1951.

With emphasis on the completion of facilities and the implementation of the research program, the trend in personnel has been toward an increase of scientists, engineers, and supporting technical help, while the number of general and administrative personnel has shown a sharp decline. This latter reduction was achieved as a result of a detailed study of certain Laboratory operations and a reorganization in several groups. On June 30, 1950, there was a ratio of 4.8 employees to every scientist. This number would have been less had not employment of scientists been deliberately delayed in order to keep in step with delays in certain facilities, and as an economy move. The over-all trends in Laboratory personnel, which show a net reduction of 6%, are summarized in the accompanying table.

The following key people have joined the Laboratory staff: Dr. George B. Collins became chairman of the Accelerator Project on April 1. Dr. Howard Curtis, now chairman of the Physiology Department, Vanderbilt University, will arrive on October 1, 1950, to assume the chairmanship of the Biology Department; Dr. Leslie F. Nims, who resigned as chairman in December, 1949, was asked to continue until then. Dr. Gerald F. Tape became Assistant to the Director on July 1.

In July, 1950, a new contract with the AFL labor union was concluded. The contract extends to June 30, 1955, with provisions for a wage adjustment for annual improvement and for cost of living changes. The Laboratory also adopted a new vacation policy for wage employees, the main feature of which is the change of vacation schedules to one day per month with pay, while maintaining the option of the old schedule of two days per month, the second day without pay. Adjustment of wage scales to compensate for the additional 12 working days was made.

The research activities continue to be directed toward stabilization within the departments and toward the use of the reactor and accelerators during the next year. An increasing number of research projects has been completed or has reached the stage where reports of significant progress could be made. This is indicated by an increasing number of technical publications submitted by the scientists. The results of classified work are published only as classified reports with limited distribution.

The programs of the Chemistry and Physics Departments are well stabilized around researches utilizing nuclear techniques, both within and outside the field of nuclear energy. Where a moderate program using sources supplied from outside the Laboratory now exists, expansion is about to take place because of the availability of a greater variety of sources supplied from the Laboratory. Also, the chief expansion of all research programs will be in connection with the actual use of particle beams from the accelerators and the reactor. In this area of research are included all of the experiments with the electrostatic generator, time-of-flight slow neutron velocity work with the cyclotron, and the many proposed experiments with reactor neutrons for studies with neutron optics, interactions with nuclei, and shielding studies, as well as general irradiation work.

Personnel Changes

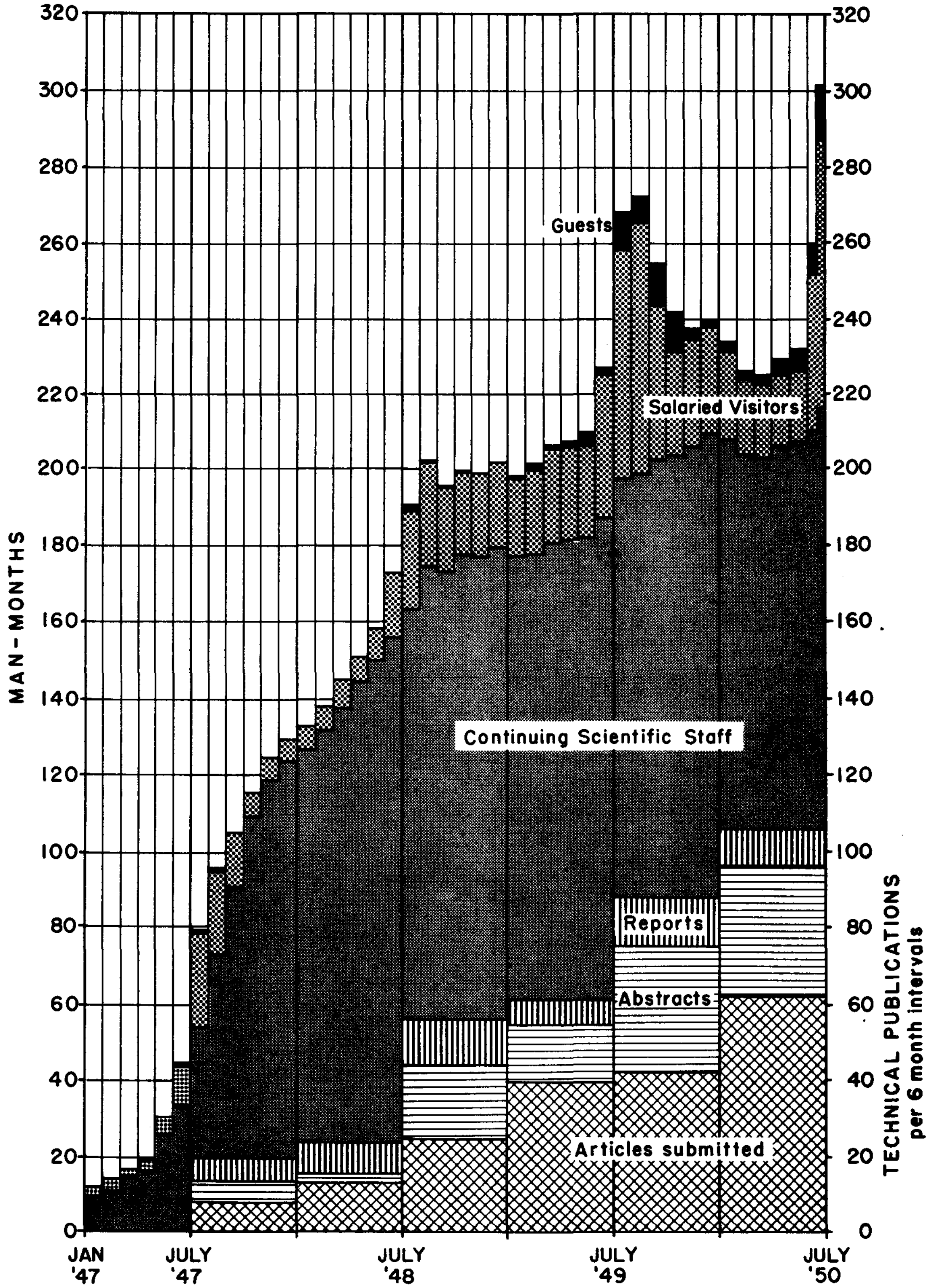
Employees	June 30, 1949	June 30, 1950	Change
Scientific Departments			
Continuing scientists	193	210	+ 17
On-leave scientists	25	19**	- 6
Total	218	229**	+ 11
Technical helpers*	223	274	+ 51***
Others	60	58	- 2
Technical Services			
Technical helpers*	125	132	+ 7
Others	41	29	- 12
General and Administrative			
All classes	744	603	-138
Total Scientists	218	229	+ 11
Total Technical Helpers	348	406	+ 58
Total Others	845	690	-155
Grand Total	1411	1325	- 86

*Technical helpers include technicians, mechanics, etc., who work on scientific equipment.

**Does not include temporary (less than three months) paid appointees who worked a total of 9.3 man-years during fiscal year 1950, consultants who worked a total of 2.8 man-years, nor guests without stipend who worked a total of 6.1 man-years.

***Largely accounted for by increments in the Medical Department (including the hospital) and major facilities.

Applied physics and chemistry research and engineering studies have been carried out in the Reactor Science and Engineering Department. Most of the work in metallurgy and chemical engineering has been directed toward reactor design studies, fuels, and fission products. The Electronics Division has been concerned with the development of instruments and equipment for specialized research and for health physics use. The general electronics problems center around the design of equipment having greater precision and stability, ability to measure short times (fractions of a microsecond), simplification of monitoring equipment, etc. The Accelerator Project has solved many basic and applied problems in the design of the Cosmotron.



BROOKHAVEN NATIONAL LABORATORY
Scientific Staff and Publications

Figure 2.

The life sciences programs, biology and medicine, are progressing. The first phase of the Biology building program for permanent quarters was completed, and the building is occupied. The second phase of this building program for additional permanent facilities to accommodate the staff still housed in temporary structures, the additional continuing staff, and the on-leave staff will be started this year. The expanding research program now in progress emphasizes radiation biology and tracer studies.

The Medical Department contains the research divisions encompassing the fields of bacteriology, biochemistry, pathology, and physiology. This staff is the most recent addition to the Laboratory research staff, having been organized in 1949 and not yet up to full strength. In fact, the Physiology Division is to be activated in the fall of 1950. The medical research program overlaps the biology program in part, but is directed specifically toward man. In cooperation with New York hospitals, studies using selected research patients are in progress. Atomic techniques are applied in attempts to improve on diagnosis, to effect cures, and to determine an understanding of certain specific afflictions.

Individual research programs are rounded out by technical conferences on specific subjects. Experts in the fields are invited as speakers, and interested scientists from other institutions are welcomed as participants. Seminars in physical and life sciences are scheduled regularly during the summer months, when a large number number of the summer visitors are represented on the programs.

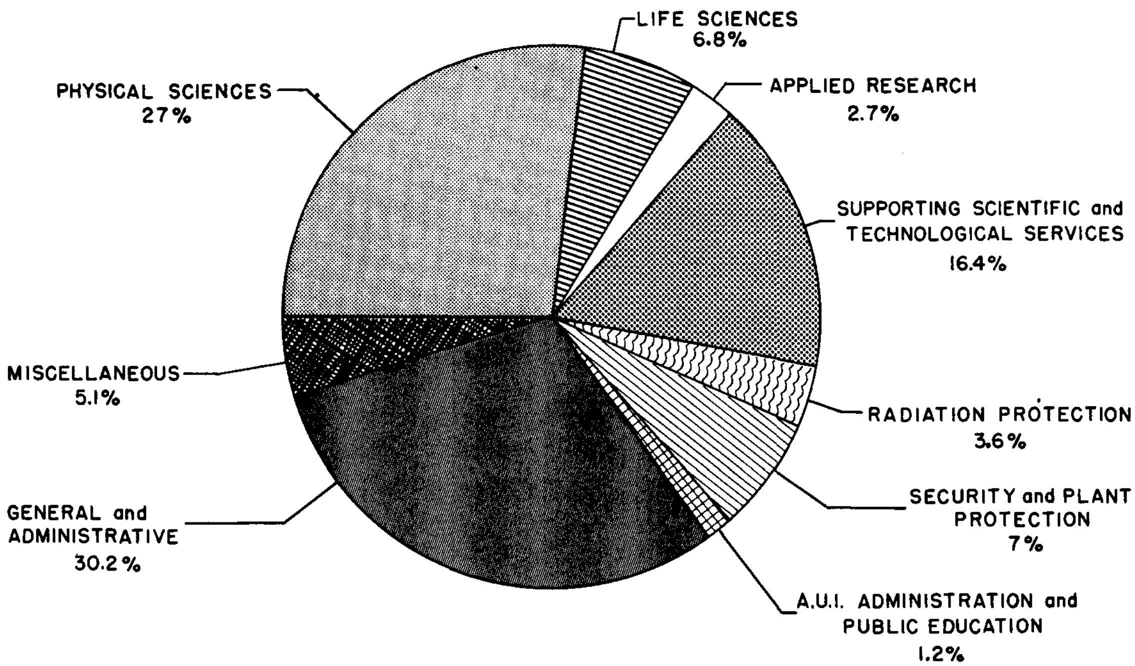
The operating expenditures for fiscal year 1950, totaling approximately $7,500,000 are shown in detail in Figure 3. The capital equipment expenditures of $477,664 are also shown. Figure 4 indicates the relative fractions of the operating expenses by programs in one case, and by major category in the second case. During the course of the year, stringent reductions in all Laboratory activities and curtailment of expansion resulted in a transfer of $1,269,112 from the Operating and Capital Equipment Budgets to the Facilities Budget for application to the reactor alteration program and to increased cyclotron costs. An operating budget of $7,863,700 for Laboratory operations and $132,000 for AUI administration and public education (total AUI-BNL, $7,995,700) has been approved for fiscal year 1951.

At the present time, the Laboratory has contractual arrangements with seven industrial companies for performance of work necessary to construction, operation, and maintenance. These contracts are usually let on a lump sum basis after competitive bidding. Where the work involved is research and development or where personal services are sought, other criteria of selection are naturally used. These arrangements are normally made on a cost plus fixed fee, or other cost reimbursement basis. Where the contract is with another nonprofit organization such as a university, the contract is designed simply to cover all direct and indirect costs of the work. Six such contracts have been negotiated with northeastern educational institutions.

A second category of contracts includes those designed to assist other institutions to solve specific scientific problems, in line with the Laboratory's research program. This type is still small numerically, but is hoped to increase as more and more major research facilities are completed. The arrangements for these contracts differ from case to case. In making these arrangements, especially where services of Laboratory personnel are involved, great care is exercised to avoid conflicts with work of the Laboratory staff or with the policies of the AEC.

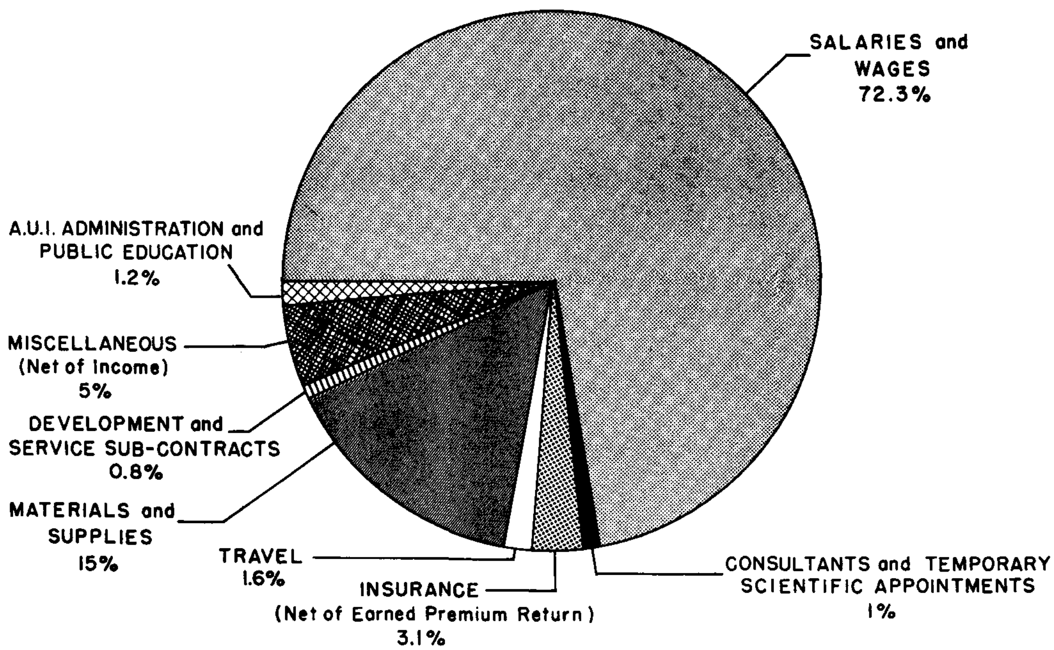
EXPENDITURES - FISCAL 1950										
	Salaries & Wages	Consultants & Temporary Appointments	Insurance	Travel	Materials & Supplies	Research & Development Subcontracts	Special Power	Miscellaneous	Total Direct Operating Costs	Capital Equipment Expenditures
Physical Sciences	1,282,683	47,281	56,110	67,064	450,377	28,514	62,130	21,411	2,015,570	232,435
Life Sciences	338,388	4,835	14,476	13,729	134,473	-	-	406	506,307	66,405
Applied Research	111,394	5,955	5,061	6,031	45,808	1,947	-	9,672	185,868	19,665
Radiation Protection	190,225	490	8,257	3,135	41,979	24,145	-	2,696	270,927	56,364
Supporting Scientific & Technical Services	921,481	10,945	39,448	11,525	280,371	4,805	16,318	2,564	1,287,457	79,088
Security, Police, and Fire Protection	494,276	-	20,691	152	5,286	-	-	(101)	520,304	1,142
Miscellaneous (net of income)	-	-	-	-	-	-	-	297,864	297,864	8,295
General & Administrative	2,038,440	4,634	86,028	15,947	163,914	-	-	(25)	2,308,938	14,270
Laboratory Total	5,376,887	74,140	230,071	117,583	1,122,208	59,411	78,448	334,487	7,393,235	477,664
A.U.I., Administration, and Public Education	11,378	-	470	1,235	5,068	-	-	71,000	89,151	-
Grand Total: A.U.I. and B.N.L.	5,388,265	74,140	230,541	118,818	1,127,276	59,411	78,448	405,487	7,482,386	477,664

Figure 3.



OPERATING BUDGET

Total $ 7,482,386 Fiscal Year 1950



MAJOR CATEGORIES
of EXPENDITURES

Total $ 7,482,386 Fiscal Year 1950

Figure 4.

A constant effort has been maintained by the staff to keep the neighboring communities informed about the general aspects of the research work done at the Laboratory. Forty speakers addressed 65 neighborhood organizations during the last year. In response to a large number of inquiries from all types of organizations, a "Visitors Day" was held at the Laboratory, at which time approximately 2000 individuals representing 43 organizations visited the major unclassified installations.

PHYSICAL SCIENCES AND ENGINEERING

Three broad categories of investigation are emphasized in the physical science program at Brookhaven National Laboratory. These are basic research in chemistry and physics; applied research in chemistry, metallurgy, and physics; and design and development of particle sources, including such devices as cyclotrons and nuclear reactors.

The Chemistry and Physics Departments are each deeply involved in basic research in nuclear and atomic fields or on problems in which nuclear and atomic techniques lend themselves to a solution. In many instances, these problems require the use of high speed particles from such machines as the cyclotron, the electrostatic generator, or the Cosmotron, or the use of neutrons from a nuclear reactor. The establishment of the particle accelerators is in the hands of the Accelerator Project, whose chief function at this time is the design and construction of the Cosmotron, a 2-3 Bev proton accelerator. The Accelerator Project is also the procurement and operating group for the 60"-cyclotron and the 2-3 Mev electrostatic generator, both of which were purchased from outside contractors.

Although some applied research is done by the Chemistry and Physics Departments, the chief interest in this work centers in the Reactor Science and Engineering Department. Their researches in the fields of chemical engineering and metallurgy are, in general, directed toward those problems connected with the design and use of reactors, fuels, and fission products. Up to the present, a large portion of their efforts has been directed toward the completion of the Brookhaven National Laboratory reactor which actually became critical on August 22. A few of the researches are unclassified and are reviewed in this report. However, most of the work of this Department is reported in the classified progress reports of the Reactor Science and Engineering Department.

In the Electronics Division is centered the design and construction of experimental electronics equipment for all departments of the Laboratory. The Division yields valuable service in several categories. By careful analysis of commercially available equipment it can recommend the units most satisfactory for given operations. Many experiments require new and commercially unavailable equipment. These are designed, constructed, and developed by this Division. It is also ready to assist in problems of use and maintenance. The use of electronics equipment is of Laboratory-wide necessity and is required by the biologist, chemist, and physicist, as well as the applied scientist.

Since the particle accelerators and the nuclear reactor have not been available for use by the various departments to date, the general research programs have been centered around the development of research techniques and the construction of equipment which will be applicable to use with these machines in the future. Work has been done and results achieved by undertaking studies requiring similar techniques but not requiring artificial sources, e.g., cosmic ray studies, stable isotope studies, etc., by the procurement of sources for use at the Laboratory, and by the use of facilities at other institutions by Laboratory research staff members. Emphasis is now being placed on the use of Laboratory facilities. The GE electrostatic accelerator, although not yet up to its 3.5-Mev specification, is being used in part for physics research. The 2-Mev electrostatic generator in the Chemistry Department is being used for chemical and biological studies which employ its electron or X-radiation. Both the nuclear reactor and the cyclotron are in the stage of completion and should be useful in direct research and in the production of sources during the coming year.

PHYSICS

The staff of the Physics Department now totals 90 persons, a decrease of 5 during the report period. Forty-nine of the staff are scientists, 8 of whom are on leave from universities. They are supported in their work by 36 technicians. The additional 5 are administrative and clerical personnel.

The physics research program of the Laboratory places major emphasis on problems associated with the atomic nucleus. Although the work of the Laboratory constitutes but a small fraction of the total effort in this field, its contribution will be especially significant in view of the unique combination of facilities at Brookhaven. The researches of the Physics Department have, therefore, been planned to use these facilities effectively in advancing knowledge, specifically in the field of nuclear physics, and, more generally, throughout the whole field of physics wherever nuclear techniques are applicable.

Many empirical facts about the nucleus are already known and much progress has been made in systematizing this knowledge. However, most of the basic principles are still lacking for a complete understanding of the complex structure of the many known species of nuclei which have been produced or occur in nature, and of the factors which determine their stability and dynamical behavior when excited with additional energy. The Laboratory's program includes studies of both the dynamical and the stationary properties of nuclei. This program is carried out in the hope, on the one hand, of developing a more satisfactory understanding of the laws governing the interactions between neutrons and protons when combined structurally to form complex nuclei, and, on the other hand, of acquiring additional factual knowledge which will be useful throughout the atomic energy program. Twenty-one of the scientific staff are working on dynamical properties, 5 on stationary properties. The program also includes studies of nuclear effects produced by particles accelerated to energies high compared with nuclear binding; these engage 11 of the scientific staff. These studies may be expected to shed light upon the forces between elementary particles and upon the nature of the particles themselves. Finally, investigations are being undertaken by 4 of the scientific staff of other problems in the more general field of physics, especially those concerned with the solid state, which involve for their prosecution the use of nuclear techniques. In all phases of the program, attention is given to theoretical interpretation and the fundamental significance of the experimental results. A strong interest in basic theory not directly related to the experimental program is also developing; both types of theoretical activity engage 6 of the staff.

Dynamical Properties of the Nucleus

For studies of the dynamical properties of nuclei, the reactor, the cyclotron, and the electrostatic generator are used as sources of bombarding particles, while details of the induced reactions are observed by a variety of techniques. Such observations include the energies and intensities of emitted and scattered particles, dependencies upon angle, and the cross sections for the various reactions as function of the energy of the bombarding particle. In the case of the radioactive nuclei, studies are made of the emitted radiations from nuclei produced by bombardments or from those few which occur in nature. The common objective of all studies in this category is to determine the energy and other characterizing parameters of the excited levels of the various nuclear species. In analogy with the electronic states of the atom, a complete characterization of a nuclear level would involve assignments of not only its energy, but also its angular momentum and parity (characterization of the symmetry of the wave function).

In the experiments with radioactive nuclei, energy differences are measured by determining the energy of the quanta of radiation emitted when the nucleus makes a transition from one level to another. It is necessary to know what transitions occur in sequence in order to arrive at the energy of any particular level. Likewise, the change of angular momentum and of parity is related to the probability of the transition (the sum of the transition probabilities from any level to all lower levels is the reciprocal of the lifetime in that level). The change of angular momentum is also equal to that carried away by the radiation. The latter is related to the relative probabilities for ejecting electrons from the various atomic orbits by so-called internal conversion. Nuclear levels which have a measurable lifetime, the so-called isomeric states, assume considerable importance because of the possibility of determining changes of angular momentum from measured lifetimes and conversion coefficients, and of making a complete characterization of those levels. For this reason, a careful survey of the system of elements is being made to discover new isomeric states and to determine their lifetimes, their energies, and their relative internal conversion coefficients.

So much of the earlier work in this field was in the nature of a rough survey that reported gamma rays are frequently in error and many have not yet been discovered. Furthermore, when one tries to assemble accumulated information in the form of level diagrams and other tabulation schemes, inconsistencies often require a search for missing rays or an investigation of suspected errors.

In experimental work at the Laboratory, special attention has been given to the very soft gamma rays which might have been confused with X-radiation. For these, a proportional ionization chamber, aided by a series of critical X-ray absorption filters, has been used to determine the energy of the radiation. Gamma rays of about 20,000 ev energy were recently found by this method in Sm, Tb, and Pa. High energy gamma rays of low intensity, easily obscured by large intensities of lower energy radiation, are detected by the photoneutrons ejected from Be or D. With this method, new gamma rays were discovered in Ag^{110}, Bi^{206}, Pr^{144}, Ru^{106}, and Ni^{57}. Unknown gamma spectra are also explored and the energies accurately measured by permanent magnet spectrometers, a set of which has been constructed with overlapping ranges. In these instruments, electrons produced by the gamma rays within the source by internal conversion are brought to a focus on a photographic plate after their orbits have been bent through 180° in the magnetic field. Energies and relative intensities of the conversion electrons from different atomic levels are also measured in a magnetic lens spectrometer, or with the use of a scintillometer, consisting of a scintillating crystal, a photomultiplier, and a pulse height selector. In sources where many different gamma rays are emitted, scintillometers serving as energy selectors are connected in coincidence, in order to determine which gamma rays are emitted in the same sequence.

In the measurement of lifetimes, a variety of techniques are employed. In general, lifetimes greater than 10^{-8} sec can be measured; in special cases, still shorter times have been estimated. If the lifetime is less than several μsec, electronic circuits are used to measure the delay between scintillation pulses or G-M counter pulses from the first ray, indicating the occupation of the state, and the second ray emitted in transition to a lower state. For times longer than 1 sec, the lifetime can be measured by timing the rate of decay of activity with a clock. In the intermediate range of times, few measurements have been made. For this reason, a spinning disk has been constructed at the Laboratory to transport the activity induced in a foil by a beam of neutrons from the reactor past a pair of counters. By changing the distance between the counters, or by changing the speed of the disk, the rate of change of activity with time of transport will be observed.

Besides the measurements of half-lives and energies, attention is also directed to the angular and polarization correlations between successively emitted gamma rays. As an example, one nucleus, Pb^{204}, has been found in which a metastable state of half-life of 0.3 μsec follows a gamma transition from a still higher level, the latter having a life of 68 min. An asymmetric angular correlation between these two gamma rays shows that the nucleus can retain memory of its orientation for at least 1/2 μsec, which is a very long time on the nuclear scale. Attempts will soon be made to observe the precession of the excited nucleus in a magnetic field. This experiment will provide important confirmation of the spin of this state which now has been only predicted on the basis of an approximate theory from the half-life, the internal conversion coefficient, and the ratio of electrons converted in the K and L shells.

Systematic attempts to interpret nuclear structures as a series of shells of neutrons and protons have been partially successful in explaining the relative abundance, the neutron capture cross sections, and the angular momenta in the ground state of the stable nuclei. These theories also predict that no isomeric levels should occur in nuclei having an odd number of neutrons less than 39. Reported isomerism in Ti^{51} (29 neutrons) was, therefore, inconsistent with theory and was thoroughly investigated. The activity formerly attributed to this isotope was found to be due to impurities and the theory of shell structure was upheld.

Although none of the techniques described above for gamma ray studies is unique to the Laboratory, their combination with the reactor and the cyclotron should result in very substantial progress being made with the problems. Since chemical separations and source preparations are needed at every step of this type of work, the nuclear chemists at Brookhaven National Laboratory also play a vital role.

The magnetic lens spectrometer has been used for measurements fundamental to the theory of beta decay. In the case of the usual "allowed" or short-lived beta emitters, the distribution in energy of the beta rays is well explained by the theory.

However, no adequate test had ever been made of corresponding theories of the very few long-lived or "forbidden" emitters. Recent measurements at the Laboratory of the beta spectra of two of these -- Be^{10}, which seems to be "second forbidden," and K^{40}, which is probably "third forbidden" -- have provided important confirmation of those theories.

As an example of another type of study with the magnetic lens, a gamma ray of 803 kev has been found to accompany the alpha particle disintegration of Po^{210}. These gamma rays are only weakly excited to about 1 in 10^5 alpha rays, and the other levels of the product nucleus Pb^{206}, which are known from studies of K-capture in Bi^{206}, are not excited at all. The rules governing the excitation of levels by particle emission are the subject of interest in this and in other parts of the program.

Two magnetic lenses, referred to above, have been built at the Laboratory for the study of nuclear gamma and beta rays. Thus far, they have been used in a temporary laboratory, but one is now being installed at the electrostatic generator and the other in the reactor building. The first will be used for studying gamma rays from levels excited by charged particle bombardment, while the second will analyze the beta and gamma radiation of short-lived isotopes, or the gamma rays resulting when a nucleus captures a neutron. Since the latter spectra range up to many million ev and can only be measured through the mechanism of electron-positron pair production, the lens at the reactor will be adapted for use as a pair spectrometer by a new method suggested by Siegbahn and Johannson.

Another attack on the problem of determining the energy levels excited by particle bombardment is to measure the energies of inelastically scattered protons or deuterons. For this work, a magnetically focused spectrometer for heavy particles has been constructed and installed in front of the electrostatic generator. This instrument, which is unique in design, will enable one to determine the energy lost to the excited nucleus as well as the dependence of such energy losses on the angle through which the particle is scattered. When analyzed, the data will determine the spin of the excited state, as well as its energy.

Another instrument, nearly completed, for studying energy levels excited by particle bombardment, consists of a row of 10 small counters located within the same gas-filled envelope and connected in a circuit which records separately the number of particles stopping in each counter. Thus, the instrument makes a simultaneous record of the particles whose ranges fall into 10 different intervals. It will be used for analysis of inelastically scattered protons, deuterons, and alpha particles, and for determining the energies of particles emitted during reactions.

During the report period, the electrostatic generator has been completed to the point where it can be used for experiments at voltages up to 2.5 million. The first use has been to check the voltage calibration against the resonance for radiative capture of protons by Al and against the proton threshold energy for neutron emission from Li.

Investigations using the facilities of other laboratories are in progress. The betatron at the Picatinny Arsenal has been used as a source of 20-Mev X-rays for studies of the angular distribution of photoprotons and photoneutrons. The interaction of radiation with the nucleus, involved in these experiments, is, in a sense, the inverse of gamma ray emission, and the results have an intimate connection with the gamma ray studies already described. Although no very definite conclusions can be drawn until both theoretical and experimental studies have been carried further, the experiments are the first to show a nonuniform distribution of both protons and neutrons ejected at high energy. The distribution is consistent with the direct photoemission resulting from the interaction between the radiation and an electric dipole. Low energy particles are also emitted, but these come off uniformly in all directions as though by evaporation.

In another experiment, the Van de Graaff accelerator at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington has been used to measure the angular distribution and differential cross sections for the scattering of 5-Mev neutrons in deuterium. This experiment, which is the forerunner of other work planned in this field, has shown that a thorough experimental investigation of this scattering will be necessary, since the results at 5 Mev are not in accord with present theoretical predictions. Both the theoretical and the experimental work on this problem will be pushed, and a comprehensive program is envisaged to study both elastic and inelastic collisions of protons and neutrons at all energies with the isotopes of H and He.

Through the use of various targets, the electrostatic generator can produce neutrons of several energies, the highest being 18 Mev from a tritium target. It is perhaps worthy of note that a tritium target has already been used; a system for monitoring the alpha particles resulting from the D,T reaction has been constructed and will be used to determine the absolute yield of neutrons, there being one neutron for each alpha particle.

For one phase of the neutron scattering problem, a large cloud chamber is filled with H or D, and the angles and ranges of the protons or deuterons are observed when neutrons of various energies are passed through the chamber. This chamber is now in operation; methods for analysis of the tracks have been developed.

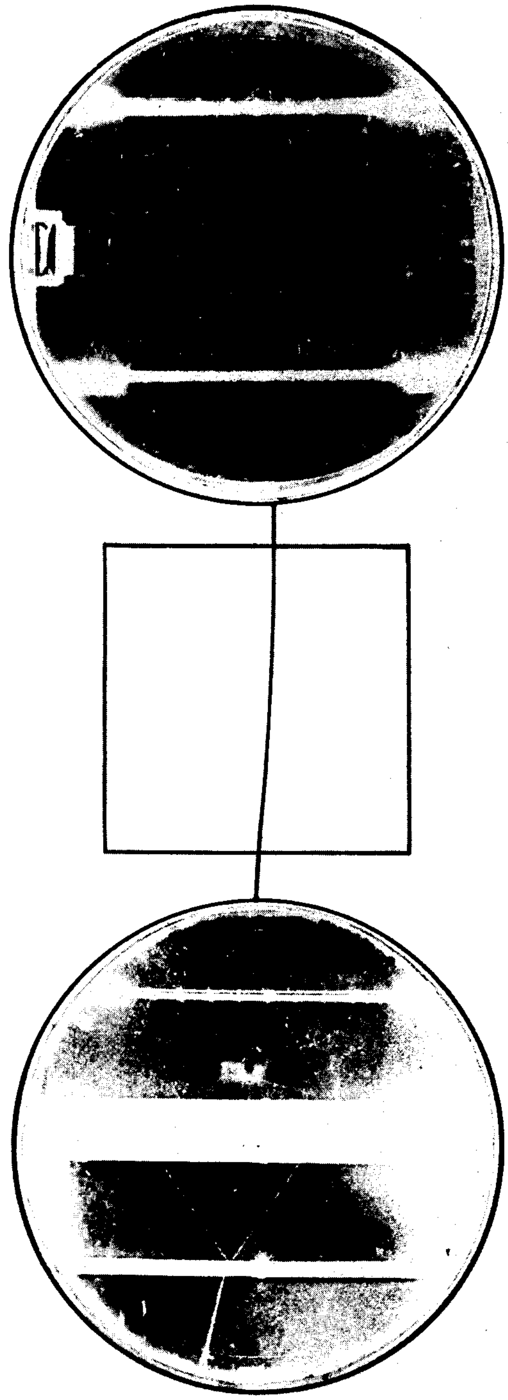


Figure 1 (Above). Photographs taken in two cloud chambers, with an intermediate field showing a 2-Bev particle of the cosmic radiation deflected in the field and then reacting to disrupt a lead nucleus in the lower chamber. Note that the particle is undeflected in the first 5-cm thick lead plate.

Neutron Interactions

Although reactors have been operating for a number of years, there is still much to be learned about the interaction between neutrons and matter. The magnitude of this interaction varies with the energy of the neutron and is different in different materials.

Three types of interaction can be distinguished: (1) A neutron may be captured by a nucleus, producing a new isotope which may be either stable or radioactive. In this case, the binding energy of the neutron in the new nucleus and its initial kinetic energy are given off as gamma radiation, or, if a particle is emitted, the energy may be balanced without gamma radiation. (2) In another type of interaction, the neutron may excite the nucleus, thus losing energy, but escape without being captured. In this category are included scatterings in which the neutron flips its spin axis. (3) Again, the neutron may make an elastic collision with an atom or a group of atoms, even an entire crystal or a large mirror. In this case, it loses only the energy required to conserve the momentum of the center of gravity of the interacting system. Such losses may or may not excite the lattice vibrations of the crystal. Interactions of the first two types are essentially nuclear in character. The third type, if collision is with the crystal as a whole, results in the coherent scattering of the de Broglie waves of the neutron and may be partly nuclear and partly dependent upon molecular constitution and arrangement of the atoms; such interactions may contain a component attributable to the force between the magnetic moment of the neutron and the magnetic field of the material or one associated with forces between neutrons and electrons. The major part of this interaction however, is nuclear.

All of these interactions are being studied at the Laboratory, although many of the experiments done during this report period have been carried on with the use of the reactors at Argonne National Laboratory or Oak Ridge National Laboratory.

In collaboration with Argonne National Laboratory, the magnetic interaction between neutrons and the field inside of ferromagnetic materials has been studied using magnetized mirrors. The coherent scattering either increases or decreases the index of refraction of the material for the neutron waves from its value of unity in the surrounding air; if it is less than unity, there will be a critical reflection close to grazing, below which the neutrons are totally reflected, just as light is totally reflected inside a glass prism. The critical angle depends upon the orientation of the neutron with respect to the direction of magnetization. By a proper choice of angle, neutrons of one orientation (or state of polarization) may be totally reflected, while those of opposite polarization pass through the mirror. Experiments on this effect have already revealed several important facts: (1) From a mirror of magnetized cobalt, one can reflect a beam of 100% polarized neutrons. (2) The magnetic interaction effective in coherent scattering of neutrons is equal to the product of the magnetic moment of the neutron and the magnetic induction B (not the magnetizing force H or something between B and H). (3) The reflected neutron waves are formed by coherent superposition (in the sense of the Huygens theory of diffraction) of wavelets from areas of the surface which are large compared with the domain size. In continuation of this work at the Brookhaven National Laboratory reactor, new mirrors are being prepared and magnets are being constructed. The technique seems to have potentialities for studies of the nature of ferromagnetism, and it may have useful applications in metallurgy.

One of the most significant results obtained with the mirror technique was the measurement carried out, in collaboration with Argonne National Laboratory, of the coherent scattering cross section of the proton. In this work, the undisturbed surface of a liquid hydrocarbon was used and the reflection of neutrons from the surface was studied as the composition (ratio of carbon to hydrogen) was varied. Since C tends to increase the index of refraction, while H decreases it, a mixture was found in which the index was exactly unity and there was no reflection at any angle. The scattering cross sections for H and C were then in the inverse ratio of the concentrations, and, since the cross section for C was already known, that for H was determined.

There has long been an interest in a possible interaction between electrons and neutrons. If nuclear forces are due to the exchange between nucleons of charged mesons, then a neutron must be thought of as continually emitting and absorbing virtual mesons which might result in the mean square of its charge differing from zero. The best chance of detecting such an effect would seem to be in the coherent cross section of atoms containing, on the one hand, a great many electrons and, on the other, a nucleus having a small and accurately measured cross section. Since the most promising substance is Bi^{209}, work has been started to prepare bismuth mirrors and to measure accurately the nuclear cross section of this material. Preliminary results indicate a difference of a factor of 2 between the total cross section for absorption of pile neutrons and the cross section for the capture process resulting in Bi^{210}. There is indication that Bi^{210} neutron capture sometimes results in a long-lived alpha-emitting isomer of Bi^{210} but further study will be required to resolve the discrepancy.

An illuminating clue to the structure of nuclei is obtained from a systematic study of the cross sections for capture of fast neutrons by all of the various stable nuclei. Such a study may also have cosmological significance, since it is generally assumed that the elements were formed in their creation by a sequence of fast neutron captures. In order to understand the relation of these cross sections to the nuclear structure, it is necessary to realize that a nucleus has a series of virtual excited levels in which the energy exceeds the binding energy of the last neutron. If a fast neutron is to be captured, it must possess the energy and angular momentum appropriate to one of these levels. If it does conform to such a level, a gamma ray will be emitted and the neutron will fall into the nucleus. The probability for capture is therefore proportional to the level density in the region of the energy of excitation (equal to the sum of the energy of the incoming neutron and the binding energy of the last neutron in the ground state). It is also true that the level density increases with the energy of excitation. Nuclei which are made up of closed shells may be supposed to bind the next added neutron with less than average energy, and in these nuclei the capture probability should be low. Extensive work by Hughes and collaborators at Argonne National Laboratory have shown that "magic number" nuclei containing 50, 82, or 126 neutrons have, in fact, low cross sections for capture of unmoderated fission neutrons, as compared with normal nuclei whose neutron numbers differ considerably from the "magic numbers."

This work is now being extended at the Laboratory to other nuclei -- both normal and those near to the "magic numbers." A new and more intense source of fast neutrons is being prepared for the BNL reactor, and some new counting techniques have been developed which will make it possible to measure low activities associated with low capture cross sections and long half-lives. One result from recent work, for which irradiations were made at Argonne National Laboratory, is evidence found in Ru^{102} that a closed shell is formed at 58 neutrons.

In their reflection and scattering from material objects, neutron beams are treated by the methods of classical optics and many of the familiar experiments with light have their neutron analogs. Although experiments of this kind with neutrons are not expected to settle any basic problems, they may result in useful techniques for determining neutron optical properties of matter. For example, recent work done by Laboratory personnel, and utilizing the Oak Ridge reactor, has resulted in a very simple method of determining whether the nuclear interaction in a material results in an increase or a decrease of the phase velocity of the de Broglie waves of the neutrons (whether the index of refraction of the material is less or greater than unity). In this work, the material is in the form of a fine powder; it is placed in a finely collimated neutron beam and the broadening of the beam due to scattering at small angles is observed. This scattering is the result of refraction of the de Broglie waves of the neutron as they enter and leave the powder granules. The breadth of the beam is measured with the dry powder and again with a paste made by wetting the powder with carbon bisulfide. The carbon bisulfide has an index of refraction less than unity, and if that of the powdered material is also less than unity the beam will be less scattered in the paste than in the dry state. A few substances are found to have indices greater than unity; for those, the scattering is greater in the paste.

In connection with the preceding work, the theory of small angle scattering in finely divided powders has been reviewed and generalized. Previous treatments were based upon 2 extreme assumptions -- one valid for very fine granules and the other for coarse granules. The new theoretical treatment is valid throughout the range of particle size.

In another experiment, the reflection of neutrons from a liquid surface has been used to measure the index of refraction of compressed gases. The liquid is contained in a tray which is placed inside a cylinder containing the gas at high pressure, and the intensity of the reflected neutron beam is measured as a function of the gas pressure. The reflection from the surface depends upon the relative index of refraction which may be either increased or decreased by raising the gas pressure, depending upon the nature of the gas and of the liquid. A decreasing relative index with rising gas pressure has been found for He, A, O, and N, when reflected from ethylene glycol and from triethylene glycol.

Another experiment, with neutrons reflected from a cadmium mirror, has shown evidence for a rapid variation of the index of refraction with neutron wave length in the vicinity of the well-known cadmium resonance at 0.7 Å, an effect analogous to the anomolous dispersion of light near absorption resonances.

Inelastic Scattering from Crystals

When neutrons are scattered inelastically from a crystal, energy is transferred between the neutrons and the various modes of vibration of the lattice. The probability of an energy exchange dE can be represented to first approximation as the number of modes of vibration of the crystal lattice which require the energy increment dE for their excitation times the cross section for an inelastic scattering process in which a single quantum of energy is exchanged between the neutron and a lattice vibration. In a theoretical study, the cross sections are being calculated so that a measurement of the spectrum of neutron energy losses could determine the distribution in energy of the lattice vibrations.

The cross sections of nuclei for neutron interactions as a function of the neutron energy are basic facts of nature which are useful in planning experiments and in designing reactors and shields. They also reveal the positions and characteristics of some of the highly excited levels of the nucleus and are of interest in connection with theories of nuclear structure. Several methods have been developed for making monoenergetic beams of neutrons which can be used for cross section studies. Some of these methods are being adopted with improvements at the Laboratory. In the low energy range, a crystal reflects strongly only the neutrons whose wave length (energy) satisfies the Bragg condition for constructive interference. Previously, nonmetallic crystals had been used for producing monoenergetic neutron beams from a reactor. However, it now appears, from work in which the Oak Ridge reactor was used, that metal crystals, for example, lead and nickel, can give more intense monoenergetic beams. Based on these findings, a new crystal spectrometer for neutrons is being designed for the BNL reactor.

Also for low energy work, a mechanical shutter employing cadmium vanes has been constructed. With this shutter, short pulses of neutrons are allowed to pass along the beam toward the detector. The energy of the neutrons is determined from the flight time between the shutter and the detector. This instrument has been constructed and put in final adjustment for experiments.

In the intermediate energy range, up to 100,000 v, 2 techniques will be used. The cyclotron will be used as a pulsed source of neutrons and the flight time to the detector will be measured by electronic circuits. These circuits have been constructed with help from Columbia University and are now installed in the cyclotron laboratory. Measurements can begin about two weeks after the cyclotron is in operation. Also, for the intermediate range of neutron energies, a fast mechanical shutter is under design in which the beam is transmitted in pulses of 1 μsec duration by a rotating slit system of hydrogenous material. This shutter is intended to operate in a neutron beam from the reactor, and will have two advantages over the cyclotron system just described. First, it will use only one of the many holes from the reactor and, hence, will not monopolize a major research facility. Second, it will allow the use of very small quantities of the material whose absorption or scattering cross section is being measured, so that separated isotopes or other rare materials can be analyzed.

Many nuclei exhibit strong resonances at certain neutron energies where the scattering or absorption cross section increases to many times the normal value. The spread in energy of such a resonance is closely related to the stability of the corresponding excited level, and is a measure of an important dynamical property of the nucleus. In a program utilizing a beam from the reactor, measurements of resonance widths will soon be started with an apparatus which has just been completed. This apparatus has been described in previous reports where it has been referred to as a rotating foil holder.

Stationary Properties of the Nucleus

In this section are included studies of nuclear masses and nuclear moments. Although neither the mass nor the moment of a nucleus is a stationary property in the sense of being unchangeable, the techniques employed lend themselves more readily to the measurement of the masses and moments of the stable isotopes or of the very long-lived radioactive species. The process of measurement does not depend upon a change occurring in the state of the nucleus.

The mass of a nucleus is fundamentally significant because from it one can determine the energy with which the nucleons are bound together. This is a quantity which hopefully should be calculable from any satisfactory theory of nuclear structure. The mass of a nucleus can be determined from the inertia of a free ion in a deflecting field; mass differences between adjacent or nearly adjacent isotopes can be determined in many cases from the energy given off or absorbed in nuclear transmutations. The presently attainable accuracy in energy measurements is in the order of 10 kev, or 1 part in 100,000 of the proton mass. Comparable accuracy in mass measurement by the inertia method has already been achieved in the light elements, and a careful study is being made of the consistency of measured masses with reaction energies. If a reaction leaves a nucleus in an excited state of long life, this fact shows up as a discrepancy between the reaction energy and the mass difference. In the heavy elements, the inaccuracies of present inertia methods do not permit useful comparisons and there is need for improvements in technique.

In view of the great advances made during the last war with electronic timing methods, improved accuracy in mass determination might be achieved if the time of flight of a pulse of ions were measured during a certain number of completed loops of a helical path in a uniform magnetic field. A preliminary experimental test of this method has been made at the Laboratory in an instrument known as the "Chronotron;" it does, indeed, show considerable promise, although some minor difficulties have been met because of disturbances produced by electric fields set up by surface contaminations. However, these difficulties can be minimized by cleaning the walls of the apparatus very carefully. In order to realize ultimate precision, the timing technique developed for Loran navigation systems is to be used.

Another embodiment of the time-of-flight principle is known as the "mass synchrometer." Here, the ion orbits are confined to a plane circular orbit in a uniform field between the poles of an iron magnet. In this instrument, 2 electric pulses are generated between a pair of grids, the first forming an ion pulse of the correct velocity from a continuous stream of faster ions from a source, and the second, which occurs after the ions have completed a certain number of revolutions in the magnetic field, deflects the ions into the detector. The value of the time interval between pulses, when adjusted for maximum current to the detector, is proportional to the mass. Both of these instruments are being tried at the Laboratory, and it has become clear that the principle of time measurement as compared with deflection measurement has some advantageous features.

Another very accurate method of comparing the masses of the various isotopes of an element is to measure the rotational frequencies of isotopic molecules by their absorption of radiation in the radio-frequency band. The frequencies at which absorption occurs depend upon the moments of inertia of the molecules. In the case of molecules containing different isotopes, the relative masses of the isotopes can be evaluated. A new microwave spectrometer, which allows the absorption frequencies to be determined to one part in a million, has been completed. In view of the very small quantities of material required in this method, it will be possible to measure masses of some of the longer-lived radioactive isotopes produced in the reactor. Four isotopes of sulfur, including radioactive S^{35}, are being measured by this method in the molecule COS; the values should be accurate to about one thirty-thousandth of the proton mass.

Other stationary properties of nuclei within reach of experimental measurements are the moment of momentum, or spin, the magnetic dipole moment, and the electric quadrupole moment. These quantities, when measured, may be compared with values predicted by the various nuclear models based upon shell structure. Techniques for the measurement of all these quantities are employed at the Laboratory. Attention is directed especially to radioactive isotopes or to isotopes more readily available to the Laboratory because of its relations with the AEC. Among the recent accomplishments, some of which have already been reported, are measurements of the spin and electric quadrupole moment of the radioactive isotope S^{35}, and of the gyromagnetic ratio (from which the magnetic moment was derived) of Sb^{121}, Sb^{123}, and V^{51}. The current investigations are described in the following paragraphs.

From the point of view of recent theories of nuclear shell structure, the nucleus S^{35} lacks one neutron to complete a theoretical shell of 20, and may, therefore, be expected to conform closely with a simple "one particle" model of the nucleus. A measurement of the magnetic moment of this nucleus is therefore of additional special interest. In carrying out this measurement, further refinements have been made in the techniques previously used in the spin determination, mentioned above, to concentrate the molecule COS^{35}. Apparatus is being prepared for measuring the fine structure of the rotational molecular absorption spectrum due to the interaction of the nuclear magnetic moment with an external magnetic field. This apparatus will employ a radio-frequency modulated component of the external field to facilitate the amplification of the microwave absorption frequencies, rather than the Stark modulation, previously used, which, although providing better sensitivity, introduces a complicated and irrelevant fine structure of its own.

In order to determine the spins and electric quadrupole moments of certain nuclei which cannot be placed in suitable gaseous molecules for study of the microwave absorption, a new method is being developed in collaboration with Iowa State University involving the use of a crystal, which may be as small as one cubic mm, or a salt containing a paramagnetic ion of the nucleus in question. The crystal is placed in a suitably tuned cavity between the poles of a magnet. The absorption of radiation in the cavity is measured as the magnetic field is varied. In this case, the frequency at which absorption occurs is determined primarily by the interaction between the magnetic moment of the electronic configuration of the ion and the applied magnetic field, but the absorption at this frequency is expected to show a pattern of fine structure due to interactions between the nuclear moments and the electromagnetic field of the crystal. These include the interaction of the electric quadrupole moment of the nucleus with the gradient of the electric field of the crystal lattice, and the interaction between the magnetic moment of the nucleus and the magnetic field of the crystal. Also, there will be a superposed structure due to the Stark effect associated with the electric interaction between the electronic structure of the ion and the electric field of the crystal. Although the resulting pattern of absorption frequencies is expected to be complex, it may be possible to resolve and interpret the various components. In a preliminary exploration of the method, a broad and unresolved resonance has been found in powdered crystals of Gd_2O_3, but no absorption has been found in Er_2O_3 nor in PrF_3. A small single crystal of $(Gd)_2(SO_4)_3 8H_2O$ also gave a broad unresolved absorption, and there is hope that a reduction of the temperature of the sample to that of liquid He or a dilution of the paramagnetic ion in a diamagnetic lattice may result in a resolvable structure. Work along these lines is being continued.

The nuclear magnetic resonance at radio-frequencies measures the interaction between the magnetic moment of the nucleus and an externally applied magnetic field. Absorption of the radiation occurs at the frequency of the precession of the nucleus induced through this interaction; this frequency is proportional to the ratio of the magnetic to the mechanical moment, or the gyromagnetic ratio of the nucleus. To find these absorption frequencies, the material is placed in a coil excited at radio-frequency in a constant magnetic field. The resistance of the radio-frequency circuit then measures the absorption of power in the material. Besides the resonances in V and Sb already reported, searches for resonances of this type have recently been made in Rh, As, and Bi. A new apparatus, specially designed, with a permanent magnet for searching resonances is being constructed. With it, other naturally occurring isotopes which have not yet been studied will be searched, and when resonances are found the gyromagnetic ratios will be determined. If the spin is also known the data lead to the value of the magnetic moment.

Effects of High Energy Particles

When protons or neutrons collide with nuclei at energies in excess of a few hundred million electron volts, a variety of new particles called mesons is created. These include both positively and negatively charged π-mesons with a mass of about 300 electrons and a mean life of the order of 10^{-8} sec, neutral mesons of about the same mass but a shorter mean life, and possibly other heavier particles. Mesons may be created singly or several of each type may be produced in a single collision. In addition, the π-mesons decay in the formation of charged μ-mesons with a mass of about 200 electrons and a life of about 1 μsec. At the Laboratory, principal interest in the study of these effects centers upon the mechanics of meson production and upon the properties of the mesons themselves. Preliminary to the operation of the Cosmotron, these studies are making use of the cosmic radiation. The observations are made by 3 different methods: the examination of tracks produced in special photographic emulsions, the counting of variously selected events with arrangements of G-M counters and pulse ionization chambers, and photographs obtained with cloud chambers. The emulsions have been exposed to primary cosmic rays at the top of the atmosphere through the use of balloons. The G-M counter work has been done at sea level, on a mountain, and in a B-29 airplane, and cloud chambers are being operated at sea level and on a mountain.

The work with photographic emulsions has been directed toward a study of the dependence on primary energy of the nuclear cross sections for proton-produced disruptions of various complexities, and for meson production in various multiplicities. The primary proton energy has been varied in this work by exposing the emul-

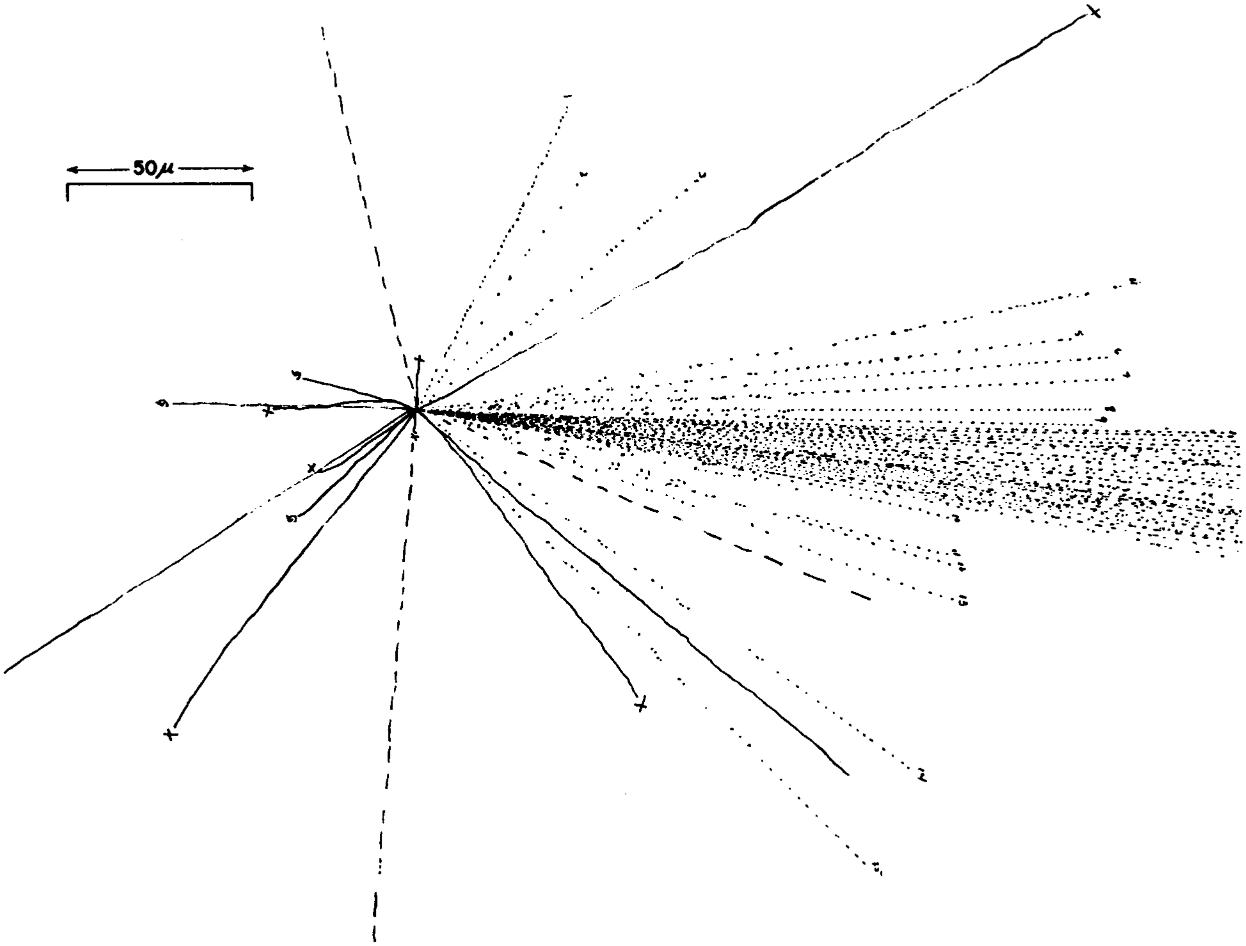


Figure 2. Disruption and meson production in a heavy nucleus found in an emulsion flown to 90,000 feet above the Caribbean Sea. Over 60 emitted particles were observed. 31 relativistic particles are in the 8° cone. The particle initiating the event is believed to be either a fast neutron or, possibly, a relativistic alpha particle making the track nearly vertical above the cone. The energy released is estimated to be of the order of 100 Bev.

sions at different latitudes. With regard to the disruption of nuclei into protons and heavier particles, the number of such events in all degrees of complexity was found to be just proportional to the total flux of incoming cosmic ray protons. The measurements of the cross sections are not significantly different for the regions of the cosmic ray spectrum above 2 Bev and for the region above 8 Bev, and in all energy ranges the total cross section for disruption is about equal to the projected area of the nucleus, or to the geometrical cross section.

Mesons produced in nuclei by incident protons have been distinguished by their lightly developed tracks in the emulsion. The experiments have led to the theoretically significant result that in a single nucleon-nucleon collision where the energy is in the range 2 to 8 Bev, usually only a single meson is produced. Protons can produce several mesons from the same nucleus, but they do this by colliding with several nucleons, not by making several mesons in a collision with a single nucleon. Multiple production of mesons in single nucleon-nucleon encounters may also occur at very much higher energies than those which can be distinguished in the latitude effect. These conclusions are strongly supported by the experimental results, which show a higher meson multiplicity and a wider angular distribution of the mesons from encounters with heavy nuclei, where multiple collisions are more probable, than from encounters with light nuclei. Also, there is evidence that the number of mesons produced by this process in the heavy nuclei increases with the energy of the incident proton, whereas no such increase is observed in collisions with light nuclei. This result suggests that an incoming proton of less than 8 Bev can spend most of its energy within a single heavy nucleus, depleting its power to produce mesons, but in a light nucleus it will escape before its meson productivity has been completely exhausted. In comparing observed meson multiplicities with the meson intensity measured in the lower atmosphere, it appears that the average number of mesons produced in the first encounters of primary protons with nuclei is insufficient to account for all of the mesons observed in the atmosphere if data on the primary cosmic ray intensity are accurate. It is possible that some mesons are produced in cascade at a lower level in the atmosphere by mesons or protons which have emerged from a nuclear disruption at a higher level. Evidence for meson cascades at high energy is cited later in this report. Plans have been made to extend these experiments to considerably higher energies, possibly to 30 Bev, through the use of oriented emulsions to be flown by balloons at the equator. An orienting device has been developed for this purpose; it is hoped that the cooperation of the U.S. Navy can be enlisted to make the flights. Exposures made in this way would provide data needed to firmly establish the conclusions already drawn, and might indicate at what energies single nucleon-nucleon collisions begin to produce mesons in multiple. Other investigations in progress include a study of nuclear disruptions produced when material is placed above the emulsions. Here, there is evidence that mesons produced in the material can also produce disruptions in the emulsions and a measurement of the nuclear cross sections for these events is of interest.

Because of the unique properties of emulsions as a research tool for use with the Cosmotron, as well as with cosmic rays, several new developments are in progress. In order to be able to identify particles by their scattering in the emulsion, distortions in the emulsion itself are being reduced and microscopes are being better adapted to the measurement of such scattering. Special emulsions are being made with which to better identify the nucleus which undergoes disruption, and a magnet is being designed with which to determine whether the mesons are positive or negative.

Experiments with G-M counters and pulse ionization chambers have been used, both to study the intensity of the nucleonic component (includes both protons and neutrons of high energy) of the cosmic radiation in its variation with latitude and depth in the atmosphere, and also to study the details of meson production and behavior with respect to nuclear interactions.

In the first category, 2 researches, referred to in earlier reports, have been finally analyzed during this period and reported for publication. In both of these experiments, the apparatus was able to distinguish showers of particles of the type which results when a high energy neutron or proton makes a nuclear encounter. These events then served as a measure of the intensity of the high energy nucleonic component. In both experiments, the apparatus was carried in a B-29 airplane to various altitudes at the latitudes of Rome, N.Y. and of the Canal Zone. In both instances, the radiation recorded by the apparatus was absorbed exponentially in the atmosphere at a rate indicating that the incoming nucleons are being stopped by collisions with particles of the dimensions of air nuclei. The latitude effect indicated that the detected events were produced by primary rays of average energy in the range of 20-30 Bev.

Making use of similar detecting apparatus at the BNL mountain station in Berthoud Pass, Colorado, the interaction of these very high energy nucleons are being studied in greater detail. One experiment measures the variation with altitude of primary rays which produce showers of different penetrating power. Energetic particles which may be presumed to produce the more penetrating showers might include a large fraction of π-mesons and have a longer free path, if previous indications are reliable. On the other hand, one might find a reduction in free path with increasing proton energy because of a dependence of cross section on energy. This experiment has not yet shown a statistically significant correlation between the free path of the incoming particle and penetration of the shower particles.

In another experiment, the free path for absorption of π-mesons produced in penetrating showers is being studied. Work reported a year ago indicated that π-mesons have a somewhat weaker interaction with nuclei than do protons, and the present work is intended to provide further evidence of the strength of that interaction. The same experiment is also giving information on the composition of the large air showers, usually thought to comprise electron-photon cascades. However, this work has revealed the presence in these showers of a nucleonic component, whose density at distances from the center is nearly proportional to the electron density over the range from 1 to more than 100 particles/m^2. Evidently, nucleonic cascades are produced along with the electron-photon cascades by the very energetic primary protons.

Further data on the cross section for nuclear interaction of π-mesons and μ-mesons are being sought in experiments now going on at the mountain station, using cloud chamber techniques. The purpose of this experiment is to study the scattering of mesons by nuclei and to distinguish between the scattering cross sections for the two kinds of mesons. The rays pass in succession through a cloud chamber, a magnetic field (produced by a permanent magnet), and then a second cloud chamber where change of direction due to magnetic deflection determines sign of charge and energy of the ray. In the second chamber, the angle of scattering in a 5-cm block of lead is also measured. Negative mesons can be distinguished from protons by their deflections in the magnet. The two kinds of mesons can be distinguished from each other by the use of penetrating shower detectors or by placing different amounts of absorbing material above the apparatus. The design and construction of the apparatus for this experiment has taken nearly 2 years, and several developments of general interest have evolved. Among these are a new fast operating release valve for the cloud chambers and the clarification of general principles of the design of permanent magnets.

The large high pressure cloud chamber, referred to in previous reports, will soon be ready to make photographs of cosmic ray induced nuclear disruptions and of mesons in the cosmic radiation. This chamber has already been operated satisfactorily with fillings of A and He at 300 atmospheres pressure. The time between photographs has been substantially reduced, with corresponding increase in yield of data, by overcompressing the chamber after each expansion. The preliminary operation of the chamber has shown the necessity of extreme precautions in keeping a constant temperature throughout the chamber. Consequently, an oil circulation system is being installed; and metallic rings in the chamber, where induced currents produced by the pulsed magnetic field would cause undesirable heating, are being replaced by plastic ones.

The Diesel power plant and coil assembly have already been in operation for calibration tests, and an average pulsed field of 36,000 gauss has been produced over the volume occupied by the cloud chamber (16" in diameter and 6" deep), the peak power being 2200 kw. For counter-controlled operation, a single generator, operating at 250 kw, produces a steady average field of 21,000 gauss. For the latter condition, a set of neutron and G-M counters has been designed which will trigger the chamber when nuclear disruptions occur in the vicinity. According to tests simulating the actual conditions, about one in five of these will occur in the gas of the cloud chamber where it can be seen in all detail. With this arrangement, the number of interesting events occurring in the counter-controlled photographs should be several times those observed in pictures taken at random.

Applications of Nuclear Techniques

These studies have included the use of radioactive tracers. In a study of surface self-diffusion, less than a monatomic layer of silver containing the radioactive isotope Ag^{110} has been evaporated through a mask upon a polycrystalline silver plate. The migration of the active deposit after heat treatment is measured by a scanning device which utilizes a G-M counter for detection. If preliminary indications are correct, the surface diffusion proceeds at a higher rate than volume diffusion. The studies should permit determination of the energy required for dislocation of a surface atom, and of the mobility of such dislocated atoms.

In another use of radioactive tracers, a method is being developed for a study of surface wear. In this case, a layer about .0002" thick on the steel surface is made uniformly radioactive, without altering its metallurgical properties, by impregnation with fission fragments from an overlaid uranium foil irradiated by neutrons. The extent of wear of such a surface can then be determined from the activity measured by a beta-ray counter. Preliminary trials show that the method works as predicted, and satisfactory activation can be made by twelve hour exposures to 1 gm of Ra-Be. Activities induced in the steel itself are not troublesome.

Theoretical Topics

Major interest has been devoted to field theories. At the present time, there exists no comprehensive theory of nuclear forces, and the generally agreed upon requirement that a theory of nuclear forces must satisfy conditions of relativistic invariance has thus far been met only by field theories of nuclear forces. However, field theories are infected with numerous difficulties. These difficulties have taken the form of infinite self energies, vacuum polarization, etc. By means of a new mathematical technique, the earlier infinite results have been replaced by finite but ambiguous results. The extent of this ambiguity is indicated by the fact that the vacuum polarizability can be given arbitrary covariant values.

The use of this mathematical technique clearly requires the introduction of additional principles or conditions to remove the ambiguities. One of the principles which must be introduced is that the results must be consistent with the requirements of relativity. This requirement has been shown not to be sufficient to remove the ambiguities. Additional requirements have been suggested and are being tested to see if they do, in fact, clarify the uncertainties.

In a study of the statistics of the scattering of charged particles in cloud chambers or in emulsions, formulas have been derived for the probability of scattering induced curvatures of various magnitudes.

Another study, in collaboration with the Biology Department, analyzes the dosage of radiation received by a small biological organ from radioactive material uniformly distributed within it. The theory takes account of the escape of radiation from the organ and enables the biologist to compute dosage for all kinds of radiation and for a variety of shapes and sizes of the organ.

In another theoretical study, of interest in connection with radiation from the Cosmotron and the cosmic radiation, the diffusion equations of the cascade shower theory have been solved more rigorously than heretofore; the results are presented in tabular form, and give the intensities of electrons and photons as function of depth in various materials.

B-29 Airplane Flights

The Physics Department has continued to provide liaison between the U.S. Air Force and the scientists of the northeast in conducting high-altitude researches with a B-29 airplane. During this report period, the plane assigned to this duty had completed 22 hours of flying at altitude from the base at Rome, New York. Cosmic-ray experiments were carried for the Laboratory and for Yale University. Beginning with June 30, 1950, flights on similar duty from Inyokern, California, under the auspices of the Office of Naval Research, will be discontinued. Future flights of this character will be made from Rome. Researches on various aspects of cosmic-ray phenomena, now scheduled for flight, will be conducted by scientists from Yale University, Bartol Research Foundation, New York University, and Brookhaven National Laboratory.

Compilations

With the rapid accumulation of nuclear data in the form of isolated reports from many research groups, systematic compilations of results at frequent intervals are useful in defining unexplored areas for future programs, and they sometimes reveal inconsistencies requiring more detailed study. Such compilations also are helpful to the theorist who is attempting to formulate general principles of nuclear structure. During this report period, 3 compilations have been completed by the Physics Department, and are scheduled for publication in Reviews of Modern Physics.

The first of these, done in collaboration with the University of Wisconsin, is a revised summary of neutron cross sections. The compilation gives, in chart form, the neutron cross sections of 60 elements as function of neutron energy, and includes all unclassified data available as of May, 1950. It is scheduled for publication in Reviews of Modern Physics, July 1, 1950.

A second compilation, done in collaboration with California Institute of Technology and Cornell University, summarizes the literature on the excited states of light nuclei. It brings this subject up to date as of June, 1950, and includes all available data for the elements H to Ne. This compilation is in the form of an annotated bibliography, with diagrams showing energy levels and the various reactions involved in their excitation and decay. A table containing best values of the radioactive constants is also included. This compilation is scheduled for publication in the October issue of Reviews of Modern Physics.

A third compilation, also scheduled for publication in the October issue of Reviews of Modern Physics, gives energy levels and processes by which they are excited, for isotopes in the range Na to Ca.

ELECTRONICS AND INSTRUMENTATION

The Electronics and Instrumentation Division had an increase of 3 persons since last year. With the start-up of the reactor impending, and the usual influx of summer visitors, the work load of the Division is growing rapidly. To avoid undue delays, the technician staff will soon have to be increased, since only a small portion of the jobs are suitable for farming out.

An electronics stock catalog, which lists all electronic components with detailed specifications of their properties, has been prepared by members of the Department. This catalog will be of great help to those who use electronics components; it will also make possible a considerable reduction in the number of items which need to be carried in stock.

Development and Construction

The many types of electronic equipment under design and construction by this Division are discussed by function.

Precision Pulse Height Measurements

Precision pulse height measurements are finding wide application in physical research. Under proper conditions, the size of the electrical pulses from a counter, due to radiation, will give an indication of the energy of the radiation. By analysis of the pulse height distribution from a counter, it may be possible to study nuclear energy levels or to analyze the radiating material where the energies are known. Accurate measurements require high stability of power supply, amplifier, and pulse height discriminating circuits. A precision high voltage (5 kv) supply has been developed. A study of voltage regulator tubes showed that the new type, 5651, is considerably better than previous tubes. Using this as a reference voltage, the high voltage supply has a drift of less than 0.01% for periods of time up to a day.

In pulse height measurements, some of the pulses, inevitably, overload the amplifier. Conventional amplifiers are paralyzed by such a pulse, causing distortion or loss of small pulses following a large one. A new type of nonoverload amplifier was developed which is direct-coupled; there are no condensers which can be charged by a large pulse. The gain is stabilized by feedback, and other precautions are taken to improve the stability.

This Division has cooperated with scientists at Oak Ridge in trying to improve pulse height analyzers -- circuits which sort the amplified pulses according to height. Several methods based on deflection of an electron beam have not proved sufficiently stable. Most present circuits depend on the stability of vacuum tube characteristics. These characteristics vary several tenths of a volt from tube to tube and with time. Consequently, the discrimination level is uncertain by that amount and the incremental channel width must be comparatively larger. It is difficult, on the other hand, to design amplifiers which have a very large voltage output, and so the number of channels has been limited. It is possible to follow the main amplifier with a biased, nonoverload amplifier which will amplify a part of the pulse height range. For example, those between 15 and 20 v in height may be amplified to cover the range 0-50 v. The pulse height analyzer channels may, then, be 10 v wide but correspond to a width of only 1 v at the amplifier. One such system appears to be satisfactory but is still under test. It is as difficult to test this equipment as it is to design it. The pulses from a counter vary in shape as well as size, so that it is not easy to simulate the pulses with calibrating circuits; the calibrating circuits must be more stable than the instrument under test. Several new pulse generators have been designed.

Range Measurements

In cooperation with the Physics Department, another type of energy measuring system has been designed. In this case, the particle to be measured enters one end of a counter which has a row of electrodes. The path length of the particle in the gas of the counter is approximately proportional to its energy. Those electrodes which the particle passes collect charge and give pulses. Each electrode connects to an amplifier. Electronic circuits record the last amplifier (along the particle path) to give a pulse, and so indicate the range of the particle in the counter gas.

Coincidence Circuits

Coincidence circuits have been developed and improved for measuring short-time intervals in radioactive decay. Two circuits have been built to cover a range in resolving time (for coincidence) from 10^{-8} to 10^{-6} sec; corresponding delays can be introduced in the range 10^{-7} to 10^{-5} sec. A faster circuit has been built with a coincidence time of about 2×10^{-9} sec. One method of calibrating this circuit was to measure the time for a gamma ray to travel 20 cm (7×10^{-10} sec).

Precision Timer

A precision timer has been designed, and is nearing completion, for the "time-of-flight" mass spectrometer. In this instrument, the ion source is pulsed at a repetition rate of 100 cycles. The relative mass measurement depends only on the time of rotation of the ion pulse. By using a technique similar to Loran, it is anticipated that this measurement can be made to 1 part in 10^5 by timing the ion pulse over a number of revolutions. The time standard is supplied by a 1-Mc crystal. This frequency is divided down by 3 "ring of ten" scalers to the repetition rate. Tap switches make it possible to select any 1-μsec interval in the .01-sec period. Fine time adjustment, to .01 μsec, is obtained from tapped and continuously variable delay lines. This timing circuit will be direct-reading and self-calibrating.

Miscellaneous Electronics Circuits

It is often desirable to integrate the ion beam of an accelerator in order to control the amount of exposure or activation of a target. A circuit has been developed which integrates the ion beam current, while it also presents the instantaneous value of the current. It is provided with relays so that equipment can be shut off after a predetermined charge has been accumulated.

A smoke densitometer has been built for measuring the dilution of the smoke from the meteorology tower. The densitometer may be carried aloft by balloons. The signal is presented on a cathode ray tube on the ground, together with a calibrating signal.

After the reactor is in operation, it will be desirable to record the ionization produced by the stack gases by noting the effect of the effluent on the normal atmospheric potential gradient. An atmospheric potential gradient monitor (Figure 1), which is small in size and capable of recording the potential gradient within a small region (1' high), was developed. The probe carries an ionizing source so that it tends to come to equilibrium with the surrounding air. A feedback circuit makes the probe support follow the probe in voltage so that the support will not materially distort the natural field.

Two calibrating circuits were built for use with the slow neutron velocity spectrometer. One of these was a triple pulser for measuring the resolving time of the spectrometer timer circuits, and the other was a scaler arranged to count the number of 1-Mc pulses passed by the timer gates.

Counter Development and Construction

Vacuum systems and other facilities for making G-M, proportional, and other counters are available. In addition to some 50 conventional counters, the tube shop has made 50 G-M and 25 proportional counters of special design.

Considerable work has been done on the production of scintillation counters. The best commercial materials have been procured: anthracene, stilbene, terphenyl, etc. The anthracene has been further purified by various methods to obtain suitable material for crystals. An oven for growing crystals with temperature regulation and other controls was completed (Figure 2). Sizable anthracene crystals are now being produced; other materials will be tried in the near future. More recently, liquid scintillators have been under investigation. The transmission spectra of crystals and various liquid mixtures have been measured to determine the possible efficiency and proper method of use as scintillation counters.

Health Physics Instrumentation

The development of a simple, reliable radiation monitor for civilian defense is a project of considerable importance. Several different approaches to the problem of a cheap gamma-ray indicator covering a wide intensity range and not requiring expensive batteries are being investigated in various AEC installations. This Division has been asked to work on an instrument based on a photomultiplier tube. The detecting element may be one of several scintillating crystals which are stable and available. Measurements of a large number of 931A photomultiplier tubes show that they are sufficiently similar in operation so that they can be used without selection, for this purpose. The high voltage will, probably, be obtained from a vibrator type of supply which is being developed to operate on flashlight batteries by the New York Office of the AEC. Scintillations from the phosphor produce photoelectrons in the photomultiplier. These are multiplied, giving a small average output current which is proportional to the incident radiation. This small current, in the present design,

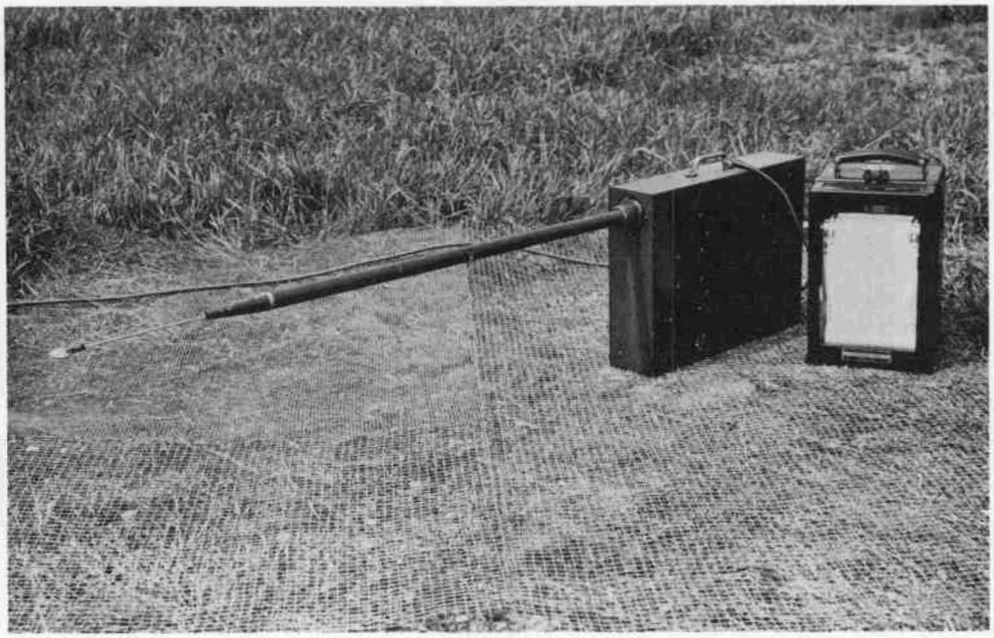


Figure 1. Apparatus for recording the atmospheric potential gradient, using a type of vibrating reed electrometer. The amplifier adjusts the potential of the shield surrounding the probe so as to minimize disturbance of the gradient in the vicinity of the probe.

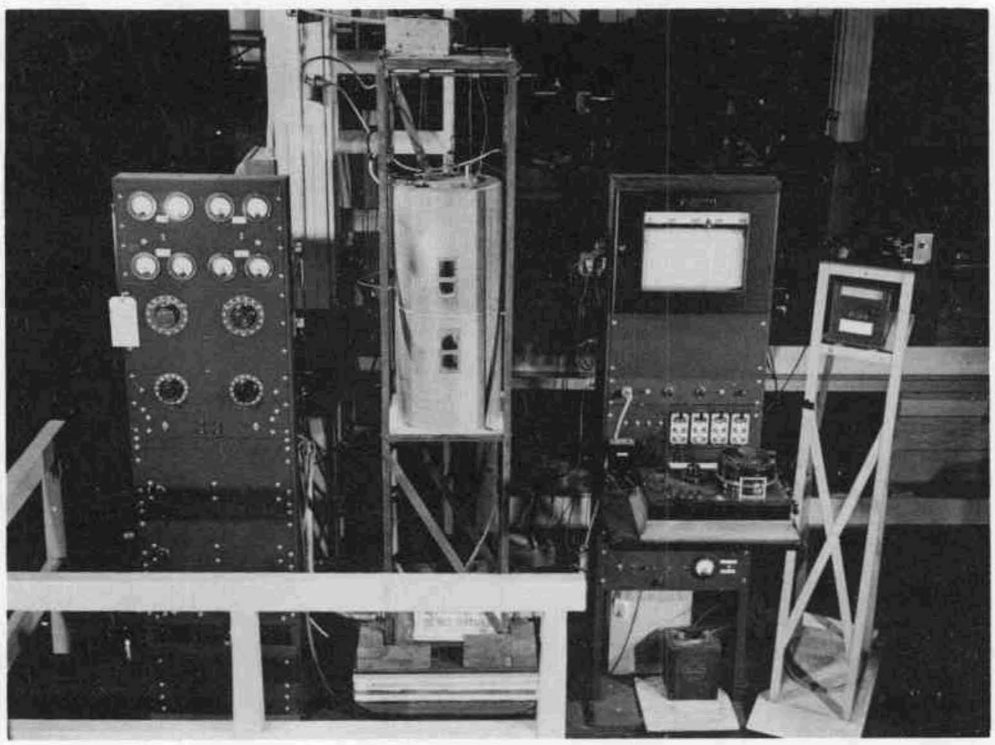


Figure 2. Oven and control equipment for growing anthracene and other crystals. Very good temperature control is required, since crystallization and annealing of a single melt each require about 1 week.

charges a condenser until the condenser voltage is high enough to trigger a cold cathode discharge tube (WL759). The discharge tube pulse rate is an indication of the radiation level; or, the discharge tube current may be used to activate a cheap current meter, so that both visual and aural indication is provided. Both the photomultiplier and the discharge tube give high amplification without needing the filament power of conventional amplifier tubes. Work continues on simplifying the circuit and improving the characteristics of the WL759 (latter through contract with Westinghouse).

An ionization chamber, which is unaffected by the electric and magnetic fields in the neighborhood of the cyclotron, has been developed for use in the cyclotron vault. A highly stabilized d.c. supply, operating on the a.c. mains, supplies the electrometer amplifier and the voltage for the ion chamber.

14 Beckman type MX-3 ionization chamber instruments have been modified for permanent installation about the hot laboratory. They have been modified to operate alarms and to record the radiation intensity at remote points.

Glass Shop

The glass shop for the Laboratory as a whole is under the supervision of the Electronics and Instrumentation Division. In the past 6 months, it has filled 300 requests for glassware, ranging from relatively simple items to the extremely complex. A considerable number of the jobs are, in fact, research jobs, especially in the case of glass and quartz instruments for use in radiochemistry and chemistry at very low temperatures. Together with the research scientist, the glassblower must experiment and develop new designs and new techniques in order to produce apparatus suitable for the particular research project. Although quantity orders are being farmed out wherever possible, the backlog is continuing to grow; it seems inevitable that the shop will have to be expanded and another glassblower hired in the near future.

Repairs

40 to 50 health physics survey instruments are serviced and calibrated each week. 100 electronic instruments were repaired during the report period; about half of these were scaling circuits.

Total personnel in the Accelerator Project now numbers 87, 30 of whom are scientists or engineers. About 80% of the effort of the Accelerator Project is directed toward the design and construction of the Cosmotron (2.5-Bev proton synchrotron), while the remainder is directed toward completion and operation of the General Electric accelerator and the 60-inch cyclotron. Assistance has been obtained from university and college faculty members on leave from their institutions, and from the service departments of the Laboratory. The employment of undergraduate and graduate students in physics and engineering during the summer months was repeated this year, since it proves beneficial both to the students and to the Accelerator Project. Twelve are now employed.

60-Inch Cyclotron

During the report period, the 60-inch cyclotron installation and assembly was completed; all the components, except the oscillator, the deflector, and the dee-stabilizer, were tested individually and are working satisfactorily. Figure 1 shows the cyclotron and its control center.

The oscillator is beginning to perform as expected. With an oscillator input of 15 kw, a dee-to-dee voltage of 120 kv holding steadily for 10 min is being obtained. During the early part of this testing period, numerous component failures, broken glass feed-thru insulators, and punctured water lines were caused by high-frequency parasitics. These have been suppressed so that now the dee voltage output is due to the 11 mc fundamental. Constant repair of vacuum leaks, both air and water vapor, has been required. Pressures of 7×10^{-6} mm of mercury are now obtained, and 4×10^{-6} has been reached from time to time. With further searches for multiple small leaks, plus more tank out-gassing, this pressure can be obtained regularly and reliably.

The initial probe target and controls have been completed and tested. Radiation monitors have been mounted near the machine. Search for a beam resonance has begun and will continue until the beam is located near the center of the magnet and is developed to high intensity, in order to bombard some probe targets for immediate Laboratory needs. Completion of the hot laboratory facilities should be accomplished by the contractors before the specified date of October 15.

Electrostatic Generator

Operation at 2.0 to 2.5 Mev has been possible for the past several months, with resolved and focused proton currents of 2 - 5 μamp. Mechanical and electrical difficulties which cause frequent shutdowns continue to occur, and a program to correct these faults is being worked out with the General Electric Co.

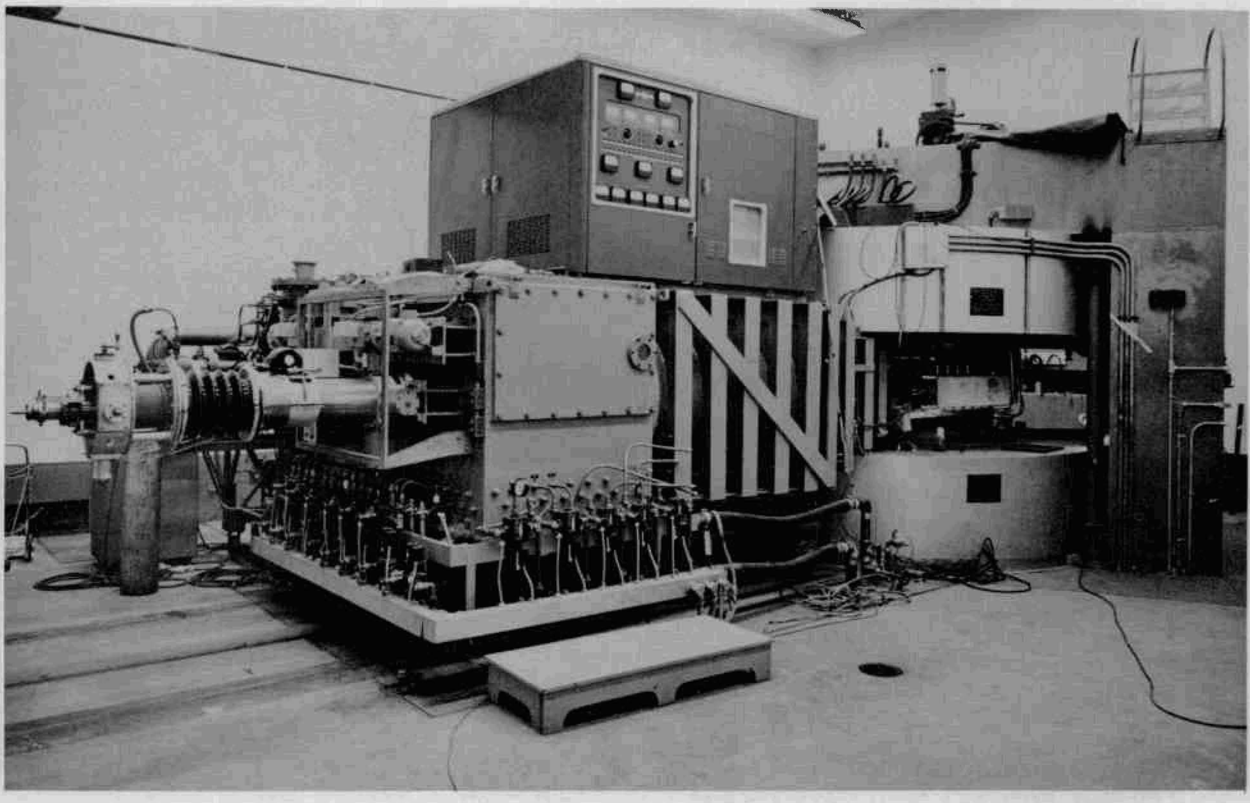


Figure 1. 60-inch cyclotron. Right: magnet and coil structure. Upper center: oscillator.

In the meantime, the generator is being used to study a troublesome phenomenon called "electron loading," and for research purposes. Preliminary tests have started with a cloud chamber to observe proton recoils from neutrons produced in the Li(p,n) reaction. The Li(p,n) threshold lies at 1.88 Mev and, hence, neutrons with a maximum energy of about 500 kev are available from this reaction with the machine operating at 2.2 Mev. Production of neutrons by deuteron bombardment of C^{12}, Li^7, and H^3 is under investigation. Work on the heavy particle spectrometer, mentioned in previous reports, is progressing satisfactorily; installation is under way.

Cosmotron (Proton Synchrotron)

Introduction

The Brookhaven National Laboratory proton synchrotron (Cosmotron) is designed to accelerate protons to energies between 2 and 3 Bev. Details of the design can be found in an article by Livingston, et al., but a few of the important design parameters will be repeated here.# Enough of the principles of operation will be explained to assist in interpreting the more detailed account of the various components, which makes up the bulk of this report.

#Indicates publication. See Appendix for complete reference.

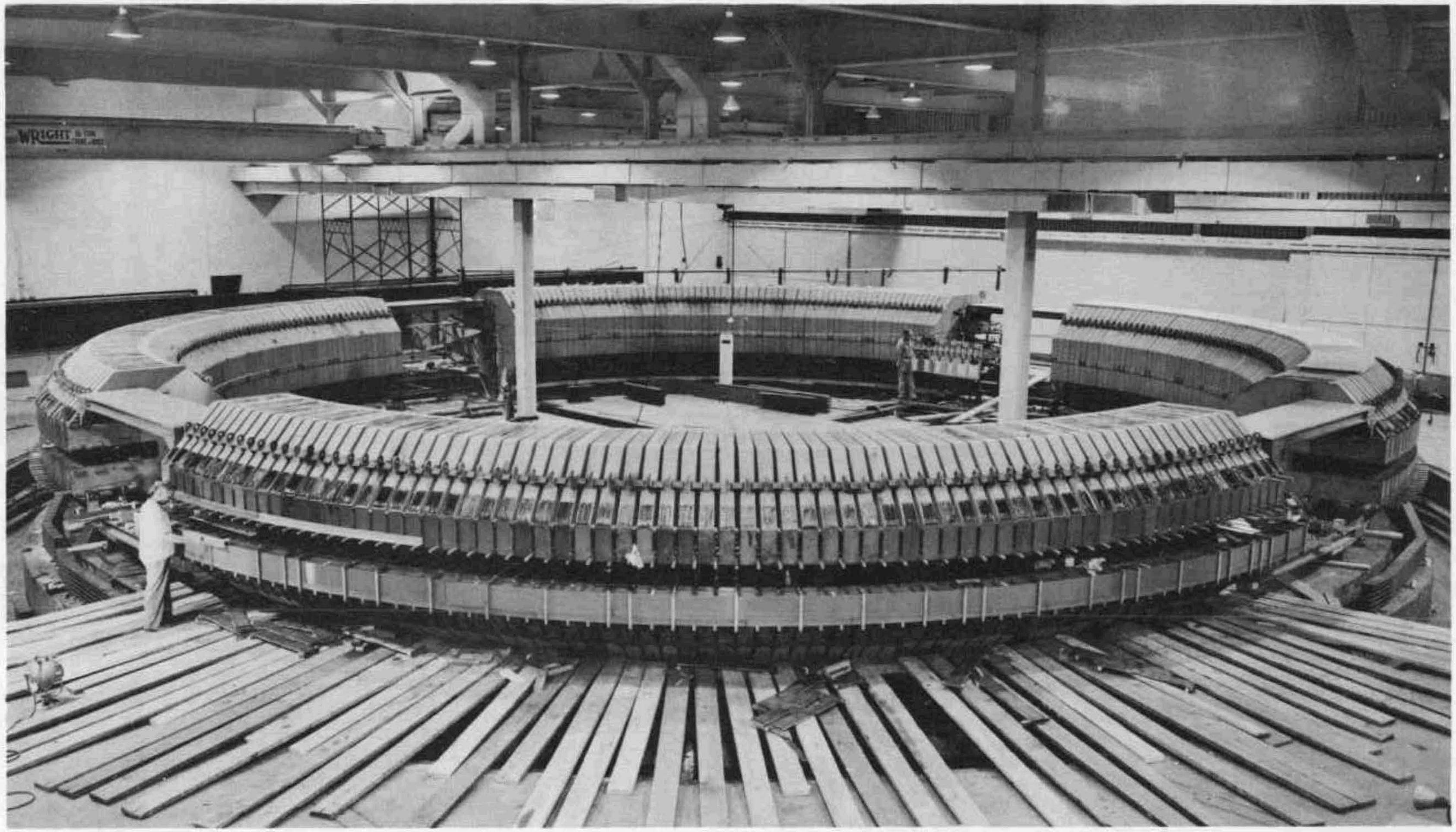


Figure 2. View of the magnet ring while installation of the magnet coils and wireways was in progress.

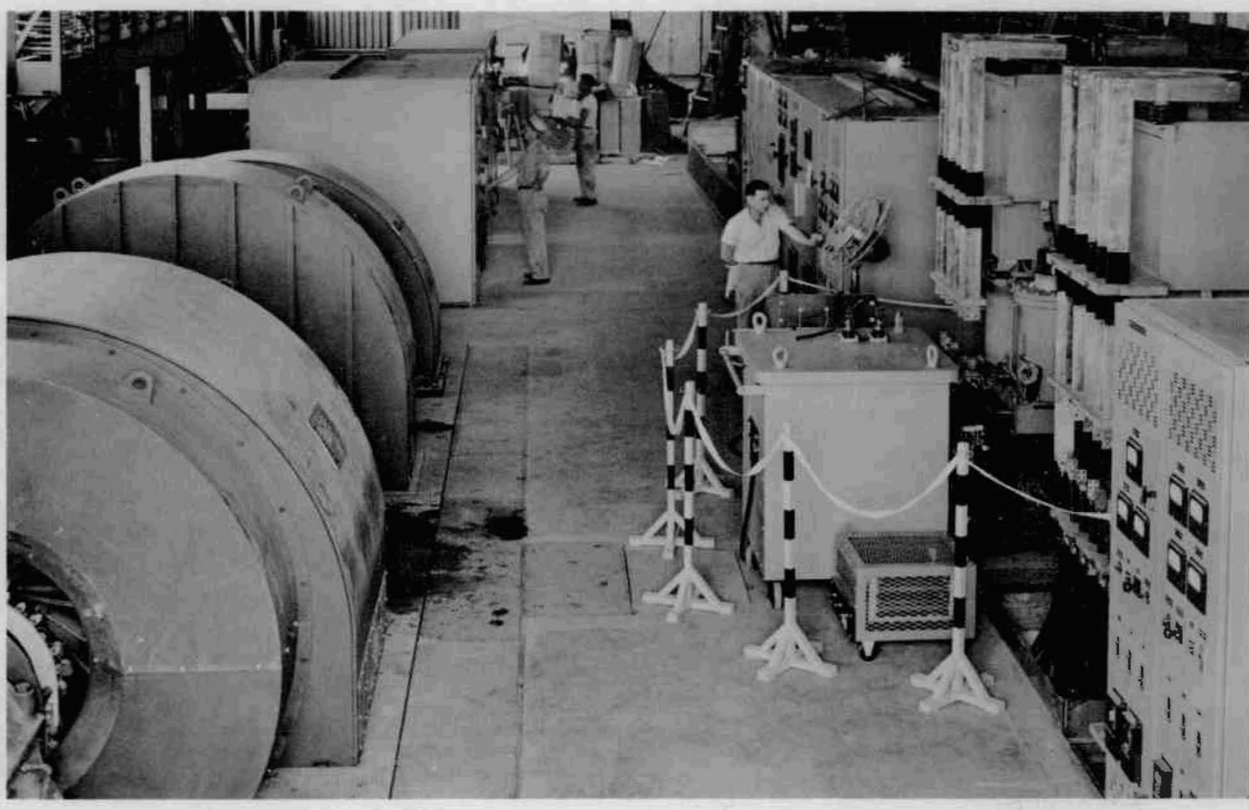


Figure 3. Over-all view of the Cosmotron power room. Left: motor generator set and flywheel. Right: ignitron bank and control panels.

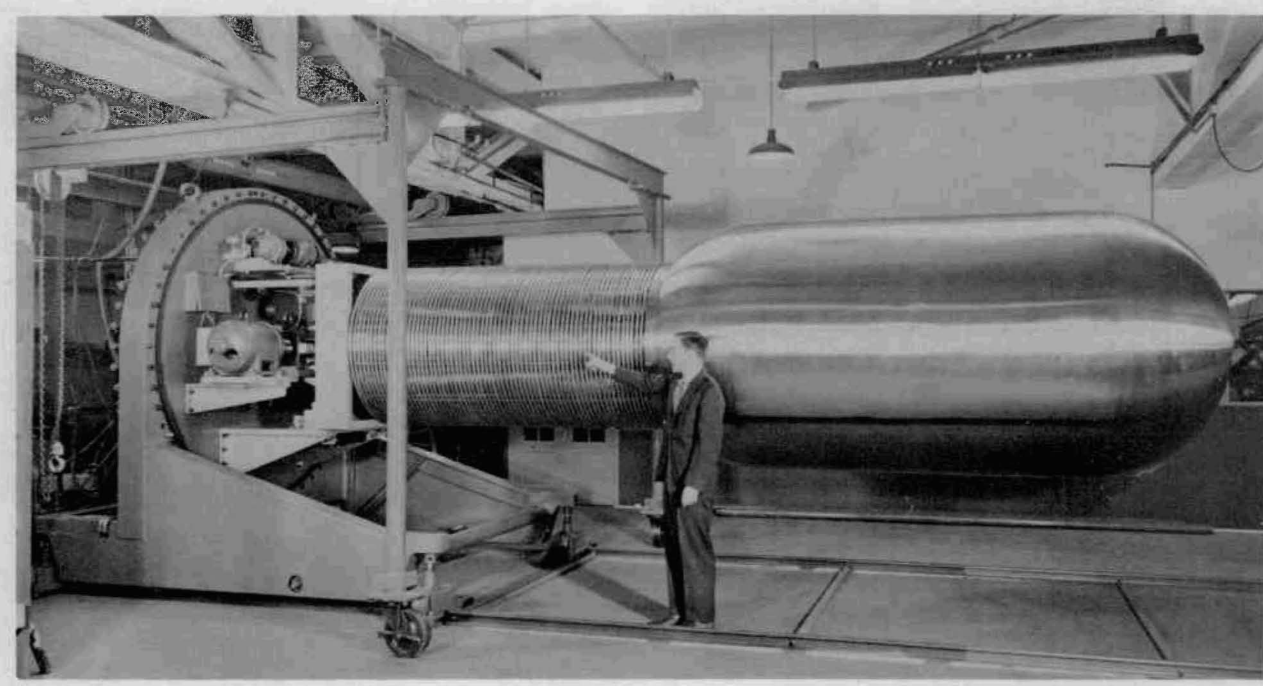
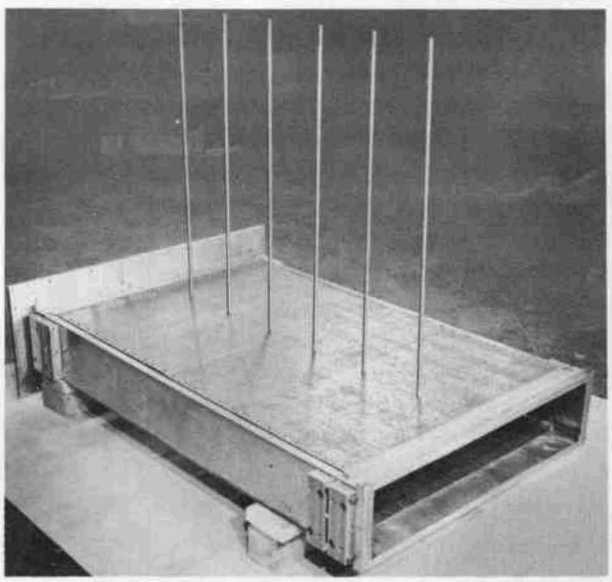


Figure 4. 3.5-Mev electrostatic generator, with pressure tank removed, from which protons will be injected into the Cosmotron.

The proton synchrotron produces pulses of high energy particles; it accepts a bundle of protons at a low energy of about 3.5 Mev, and, during an interval of 1 sec, accelerates some of these protons to full energy -- 2 - 3 Bev. In the Cosmotron, the acceleration cycle is repeated once every 5 sec. The start of the cycle occurs when a set of ignitrons is fired, thus connecting a 21,000-kva generator to the coils of a large magnet (Figure 2). Energy is supplied to the generator by a very large fly-wheel and motor (Figure 3). The magnetic field of the magnet then starts to rise. A pulse of protons from a 3.5-Mev electrostatic generator (Figure 4) is fired into the magnet gap in the proper direction and at the proper time, so that the magnetic field is correct to keep the proton orbits within the confines of the vacuum chamber (Figure 5) placed in the magnet gap. These protons are given an acceleration of about 1000 v per revolution in one of the straight sections of the vacuum chamber by an oscillator amplifier system (Figure 6) at just the proper rate, so that, as the magnetic field rises, the proton orbits continue to have approximately the same radius of curvature.

The central problem in the design of this accelerator is to keep as many of the initial protons as possible revolving in the gap until the magnetic field and energy of the protons have reached full value. It is expected that a large fraction of the protons which start will be lost before full energy is reached. Some protons will be lost as a result of collision with residual gas in the vacuum chamber; others will strike the inside or outside walls if the frequency of the accelerating R-F system is not synchronized with the rising magnetic field. In addition, vertical and horizon-tal oscillations can occur if the magnetic field in the gap is not of the proper shape.



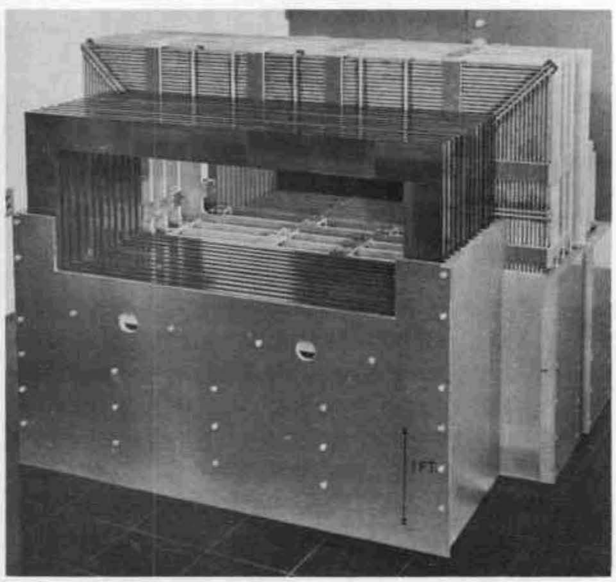


Figure 5 (Left). 4'- prototype of the vacuum chamber, without the plastic sheet which makes the unit gas-tight. Note the saw cuts, in the upper plate, which suppress eddy currents. The rods are "skyhooks" to prevent excessive deformation of the upper plate due to atmospheric pressure.

Figure 6 (Right). Accelerating transformer unit of the Cosmotron. The proton beam gains 1000 v energy as it passes through these ferrite rectangles when they are ex-cited by the power amplifier.

Proton synchrotrons in this energy range have not been constructed before, and, accordingly, considerable reliance must be placed on theoretical calculations predicting the magnitude of effects, such as those mentioned above. The general theories, however, are well supported by experience with electron synchrotrons and a model proton synchrotron built at the Radiation Laboratory, Berkeley, California. In addition, extensive model tests and concurrent analyses have been carried out at the Laboratory in order to establish a broad basis of understanding of the behavior of the individual components of the Cosmotron.

No attempt to estimate the time required to bring the Cosmotron into operation will be given. It is expected that construction will be essentially finished about January, 1951. Estimates of the present stage of completion for major components of the Cosmotron are shown in Figure 7.

Building

The Cosmotron building, a modern factory-type structure covering an area of 200' x 120 , is now practically complete. At the east end of the building, a mezzanine floor is laid out for offices and laboratories; at the west end, the motor-generator room with the main generator, rectifiers, and controls, is located above a machinery room containing the water treatment system, water pumps, and compressors for air supply and water cooling, and the air-conditioning system. The main floor, with the Cosmotron area in the center and the preparation docks under the mezzanine, is reinforced concrete with a section surrounding the magnet ring for a distance of 12' especially reinforced to carry the additional load of concrete radiation shield, if this is necessary. The Cosmotron area is serviced by two 10-ton, 60'-span, track-mounted cranes. The entire floor is interlaced with covered trenches for supplying power, water, gas, and air. A hydraulic, 10-ton capacity elevator transports heavy equipment to the area.

Three separate air-conditioning systems take care of the laboratory wing, the preparation dock, and central Cosmotron area, and provide constant temperature with low relative humidity to protect the magnet and apparatus from moisture. Evaporative coolers on the roof cool the water circulating in the magnet coil. All of this water is reusable.

Power

The Cosmotron magnet power supply receives a.c. power at 13,800 v, and supplies peak d.c. power to the magnet coil at approximately 7,000 amp and 4,250 v. This is accomplished with a 1750-hp, 13,800-v induction motor, driving a 21,000-kva, 12-phase, 8-pole a.c. synchronous generator and a 45-ton flywheel, traveling at approximately 900 rpm. The generator output is rectified through the double grid, 6,000-v, 24-tank ignitron sets, which also act as inverters returning most of the magnetic energy of the coil to the rotating set.

During the past year, the outdoor unit substation was installed and energized. The motor-generator set was operated satisfactorily on August 10 at near-rated speed. As soon as the ignitron tanks are degassed and auxiliary equipment trimmed, the magnet power supply will be ready for load tests. Figure 3 shows the power room with all these parts installed.

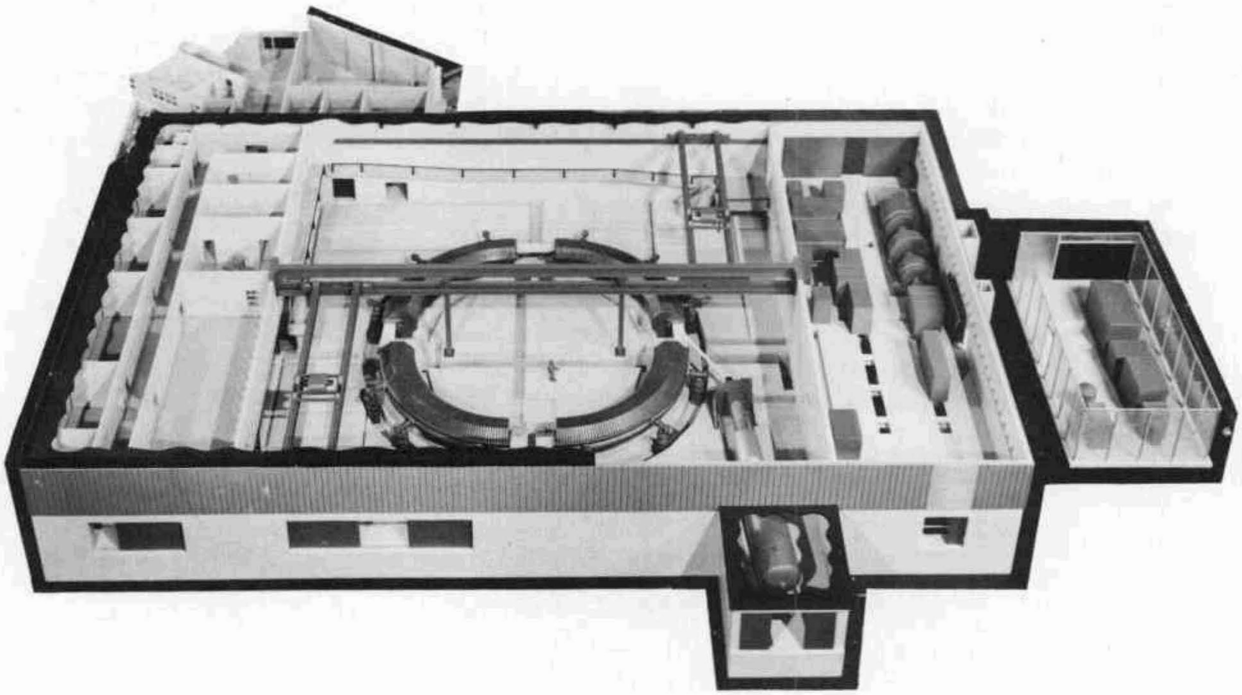


Figure 7a. Scale model of the Cosmotron building interior.

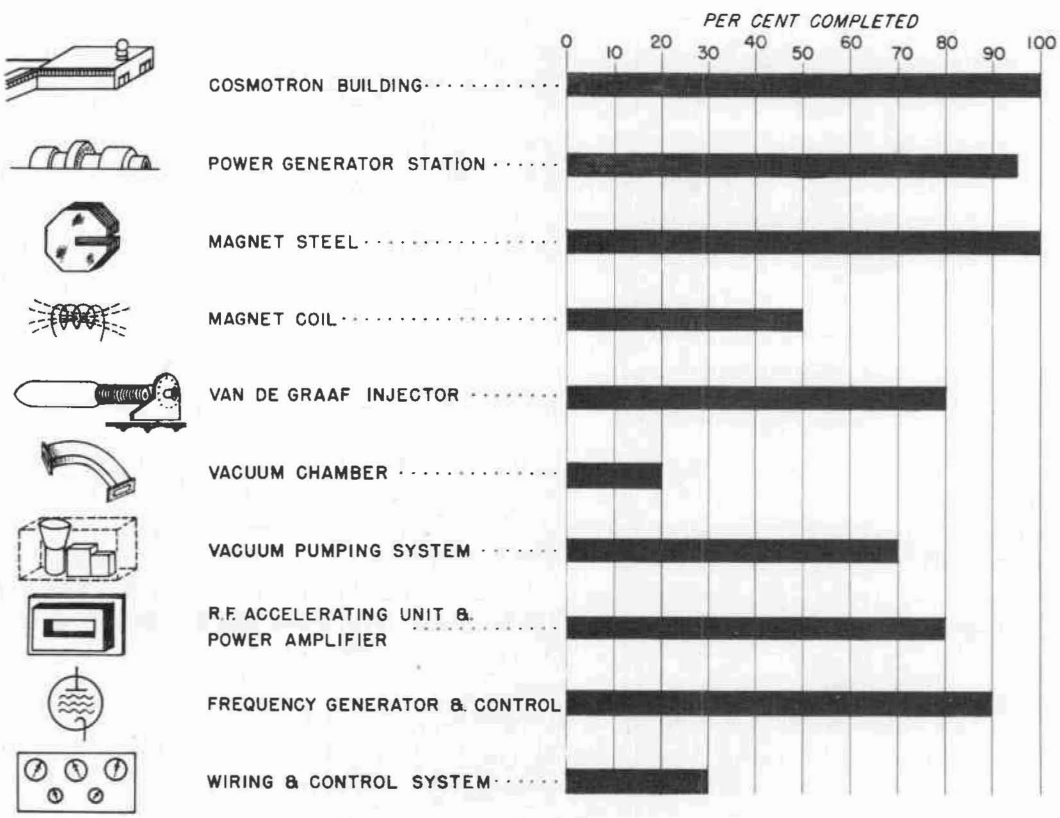


Figure 7b. Present status of the major components of the Cosmotron.

Magnet

The individual magnet blocks of the Cosmotron, 288 in all, and each consisting of 12 half-inch laminations, were subjected to a thorough testing program in order to determine the variations from block to block of the various magnetic properties at different times during the cycle of operation. This study completed, it was possible to assign to each block a location in the magnet ring for optimum magnetic field conditions.

The magnet blocks were then erected upon the base plates; all erection tolerances were maintained well within the required limits. The weight of the magnet structure is supported by a "cured" concrete ring on coarse sand of great depth, and, to date, no measurable alteration of the erected tolerances have been found from settling (4 months).

Bracing has been installed between the magnet blocks and between the quadrant ends (Figure 8) to hold the magnet blocks in alignment and to prevent serious motion of the components resulting from the surge of magnetic forces. Performance tests await the completion of the necessary components to energize the magnet.

The magnetizing coil for each quadrant of the magnet consists of 48 turns of hollow, water-cooled copper bars which will carry a peak current of 7,000 amp. Prior to the erection of the magnet steel, these copper bars were prefabricated as much as was practicable. This consisted of cutting, brazing, wrapping with insulating tape, varnishing, and baking 384 pieces, each about 50' long. Each hollow conductor was tested for leaks at the joints with a helium leak detector, and for its water-carrying capacity.

With the erection of the steel, these conducting bars are being bent and inserted, one by one, into the magnet quadrants. Due to the physical shape of the magnet and its restraining members, a special assembly technique has to be worked out and is now functioning smoothly.

One-quarter of the copper (70 tons, total) is now assembled (Figure 8) in 2 of the 4 quadrants. Fabrication, by an outside contractor, is expected to be complete in about 3 more months.

Vacuum System

The vacuum chamber for the Cosmotron must satisfy several conflicting requirements. The desirable operating pressure is 5×10^{-6} mm Hg or less, yet the structure should enclose as much as possible of the vertical and horizontal magnet aperture. This requires that the walls be thin, but of high mechanical strength. The wall materials must be non-ferromagnetic, and must minimize induced eddy currents, but should prevent accumulation of electrostatic charge.

After more than 2 years of designing and testing, a satisfactory vacuum chamber construction has evolved. The top and bottom of this chamber consist of 3/8" stainless steel plates with saw cuts extending from both sides to within 1/4" of the centerline. These are bolted to 1"-thick solid stainless steel side walls. The steel chosen has minimum ferromagnetism. "Skyhooks," placed at regular azimuthal intervals,

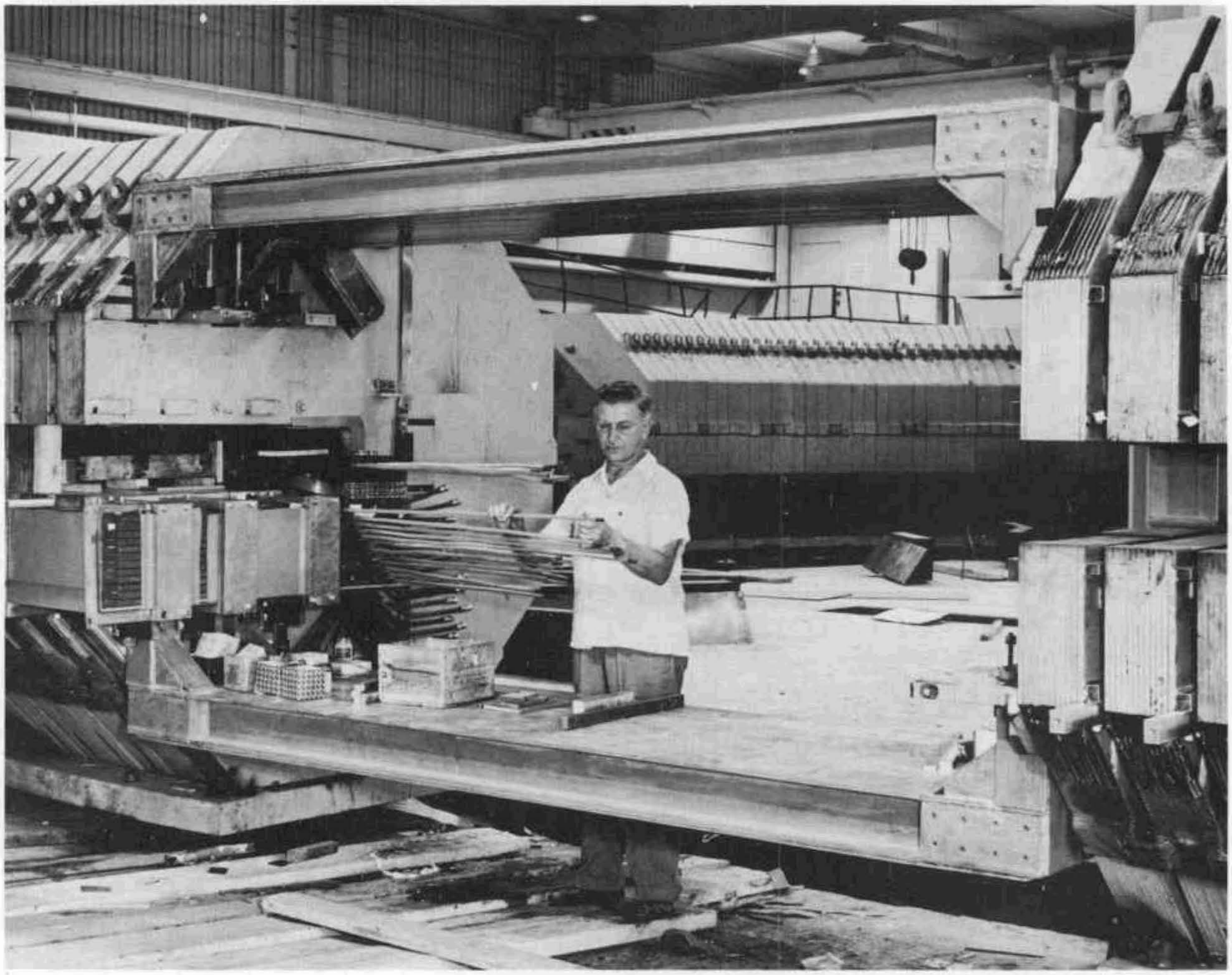


Figure 8. View of one end of a magnet quadrant, showing the lower half of the magnet coil in place. Steel members above and below the gap are spreader bars, used to restrain the forces due to the magnetic fields which tend to push the end blocks outward.

increase the mechanical strength; the saw cuts keep eddy current effects small. The vacuum seal will probably be made with a thermoplastic sheet, top and bottom, of trifluorochlorethylene (Kel-F) which has been found to have exceptionaly good vacuum properties.

A 4'-long prototype of the vacuum chamber with full size ends and straight sides is shown in Figure 5, prior to vacuum testing. Fabrication of the vacuum chamber should be under way shortly.

The vacuum chamber will be evacuated by twelve 20" diffusion pumps located in the trench surrounding the magnet ring. These pumps have been built into individual stands with separate controls so that they may be replaced easily for maintenance or repair. Tests on one of these units have shown satisfactory performance. The remainder of the vacuum system, consisting of valves, chambers connecting the pumps to the vacuum chamber, and fore vacuum pumps, are either on hand or under construction.

Radio-Frequency System

The fields which accelerate the protons in the Cosmotron are supplied by a large radio-frequency transformer. The input of the transformer is supplied by a 100-kw power amplifier. The radio-frequency signal is generated, varied in frequency over a factor of 12, and controlled to better than 0.3% by electronic circuits. The over-all system is about 80% complete.

The variable frequency generator, which is a low-level oscillator tuned by saturation of an inductance, is complete in final form together with its associated power supplies, temperature controls, and control amplifier.

The frequency control system will make an electrical measurement of the magnetic field, and will compute electrically the value of the signal to be fed to the variable frequency generator. The components of the system are almost complete in final form. Tests of the components indicate that each performs its function with errors less than 0.1% -- a more than adequate accuracy. There remains only to run the variable frequency generator from the control system, and to check the over-all system performance.

Peaking strips can be used to derive timing signals for starting the radio-frequency system and signals at discrete values of magnetic field. The former will give starting times to within about 3 μsec, the latter can be used for intermittent checks on the behavior of the frequency control system. The peaking strip technique is now undergoing performance tests.

The signal from the variable frequency generator will be amplified in a broad band power amplifier to a level of about 100 kw. Six of the 7 stages in this amplifier have been built and tested, and the final stage is partly constructed.

The accelerating transformer (Figure 6) involves over a ton of a new ferromagnetic ferrite. The ferrite has been fabricated for the Accelerator Project by two suppliers; it is all on hand. The supporting frame for the ferrite is complete and a shielding structure is under construction. The accelerating transformer will be tested at full voltage as soon as the power amplifier is completed.

Injector System

Design of the Cosmotron has been based on an injection voltage of at least 3 Mev, but it was hoped that even higher voltages would be achieved, since gas scattering losses and effects of imperfect magnetic fields become much less serious at higher injection energies. For this reason, it is most encouraging to report that the electrostatic generator, constructed by High Voltage Engineering Corporation, has produced a beam of protons of 4 Mev, and operation at 3.5 Mev seems assured. Furthermore, the pulsed ion source in this machine is delivering a peak current of one mamp of protons.

The electrostatic generator is of the horizontal type, based on the Wisconsin designs of Professor Herb and his associates (Figure 4). It is enclosed in a steel tank 8' in diameter, and designed to operate at a maximum pressure of 200 p.s.i. The accelerating column is 12' long. An equipotential shell, at intermediate potential, helps to increase the breakdown strength of the radial air gap.

Completion of the machine has been delayed for several months beyond the originally scheduled date, but final testing has now been in progress for several weeks, and shipment to the Laboratory is expected to begin in September. During early test work, unexpected difficulty was encountered with excessive "electron loading" in the large (6" inside diameter) accelerating tube employed to get high pumping speed. The effort to solve this problem has uncovered valuable information concerning processes occuring in accelerating tubes. It is believed that this information will be of benefit to designers of future electrostatic generators.

In order that protons be injected into the Cosmotron with the greatest possible over-all efficiency, a system of ion-optical lenses and accurate viewing mechanisms must be placed along the proton path which connects the electrostatic generator to the Cosmotron. The objective is an emergent beam from this lens system whose angle of divergence is less than 0.05° and 1l" in extent. The principal elements of this lens system are a pair of electrostatic plates, whose purpose is to bend the protons tangent to their equilibrium orbit in the Cosmotron, and a magnetic lens, whose function is to provide proper focussing of the proton beam. The equipment is approaching completion.

Control Console and Wiring

All important controls, adjustments, and meters required for the various components of the Cosmotron are to be centered in the console, located on the mezzanine. The control, metering, and signal wires from the various components and from the console will be collected at the main terminal box, situated immediately below the console, on the main floor. All main cross-connections and interlocks are to be made here. For the wiring, a wireway system was chosen in preference to conduits, because of the greater ease in making changes and additions. The terminal box and the electrical wireway system are now about 70% installed.

During the report period, the staff of the Chemistry Department has grown to 61. This increase includes summer visitors. Of this number, 47 are scientists, 13 of whom are on leave from other institutions, 10 are technicians, and 4 are administrative and clerical personnel.

During the past 6 months, the efforts of the Chemistry Department have been devoted mainly to various investigations of the chemical aspects of atomic energy. This may be taken as evidence that the present staff, although not yet up to its planned size numerically, contains members whose interests correspond to the major outlines of the research program, and that the laboratory facilities, although not yet complete, have been sufficient to support the work of this group. The formulation and choice of problems reflect the scientific interests and training of the individual, his feeling for what is significant and feasible, and his imagination.

Of the 6 wings of the chemistry laboratory, 5 are now essentially completely outfitted and occupied. Building modifications of half of the other wing have been finished. The portion completed during this period contains the principal new item of equipment received -- a 2-Mev electrostatic generator for electrons, manufactured by High Voltage Engineering Corporation, Cambridge, Massachusetts. This machine has been installed, tested, and found to perform satisfactorily. It is currently in use in radiation chemical investigations. A laboratory room for the helium liquefier is nearing completion; when it is finished, the liquefier can be moved and the remainder of the incomplete wing converted into chemical laboratory working space. Design of the radiochemical laboratory associated with the 60-inch cyclotron was completed some time before the period covered by this report; the laboratory rooms have not yet been equipped. The shielded dry boxes in which cyclotron targets will be processed have been designed, and are being constructed in the shops.

Chemistry Research Program

When the scope of a problem makes it desirable, cooperating groups tend to form, but there is no formal group organization with the Chemistry Department. The nature of the research program in chemistry has been outlined in past progress and program reports, most recently in BNL 39 (AS-3), January 1, 1950. The program consists of investigations of chemical problems related to the development and use of atomic energy, and of problems which can be pursued to special advantage with the aid of the nuclear machines which are the major facilities of the Laboratory. Corresponding with the intent of the Laboratory to emphasize fundamental research, the program is set up on a long-range basis, under which general areas of investigation are designated. However, the selection of individual problems is the prime responsibility of individual members of the research staff. The areas of investigation of the Department are described under 4 general headings.

General Chemistry

This broad subject of the general chemistry of substances of particular interest in the field of atomic energy would, in principle, include studies of the chemical properties of the following elements and compounds: a) those which are used directly in devices in which the release of atomic energy is accomplished, especially fuel materials; b) those which are formed in the release of atomic energy, for example, fission products; and c) those which have secondary but important uses, for example, in connection with chemical processing problems. This subject is included in the research program with the view that fundamental research on the materials which are important in the atomic energy program cannot fail to have eventual practical value. Furthermore, some materials of great scientific interest are, for reasons of security or of limited supply, available only at laboratories sponsored by the Atomic Energy Commission. At present, interest in the Department is focussed on the heavy elements protactinium, uranium, and the transuranium elements, with some attention given to certain of the fission product elements. The aim of one line of work is to characterize the electronic configurations, on which chemical properties ultimately depend, of ions of the heavy elements. These studies are being carried out by means of spectroscopic and magnetic measurements. Another line of investigation is the study of protactinium with respect to its solution chemistry, i.e., the species which exist in solution, and their reactions.

Chemical Effects of Radiation and of Nuclear Transformations

The changes in materials caused by exposure to radiations of high energy and intensity are of great practical importance in connection with the release of atomic energy, which inevitably involves such exposures. They are of scientific interest in that they are incompletely known and not well understood. These changes may consist in the alteration of both the physical properties and the chemical nature of a substance of interest. They have a variety of causes, among which the transfer of momentum from the radiation to the atoms of the sample and the production of intense ionization in the sample are undoubtedly of most consequence. Either of these may result in the rupture of chemical bonds, the formation of transient, highly reactive chemical species, and the eventual formation of new substances as a result of the reactions of these species. It is the aim of research in radiation chemistry to identify and understand such radiation-induced chemical reactions.

At present, work in the Department is concerned mainly with the chemical reactions brought about by the exposure of aqueous solutions to ionizing radiations. It is believed that these reactions are initiated by the decomposition of the water molecule into radicals, and that the final effects are determined by reactions of the radicals. By measuring the rates of the reactions under various conditions, it is hoped to characterize quantitatively the primary step of radical formation and to elucidate the mechanisms of the subsequent processes.

The radiation source employed in this work is the 2-Mev electrostatic generator, referred to previously. It supplies alternatively an external beam of electrons of controllable energy and intensity, or X-radiation made by allowing the electrons to fall on a gold target. A great advantage of this kind of machine for studies in radiation chemistry is the readiness and precision with which the energy and intensity of the radiation can be controlled and the accuracy with which the radiation doses can be known.

In addition to the macroscopic chemical changes referred to above, the chemical behavior of an atom which has just experienced a nuclear transformation of some sort (radioactive decay or otherwise) is also of interest. Such an atom usually has an excessive content of kinetic or electronic energy as a result of the nuclear transformation, and is thereby enabled to undergo chemical reactions which do not ordinarily occur at appreciable rates. The study of such reactions is included in the research program, although it is not being stressed at the present time.

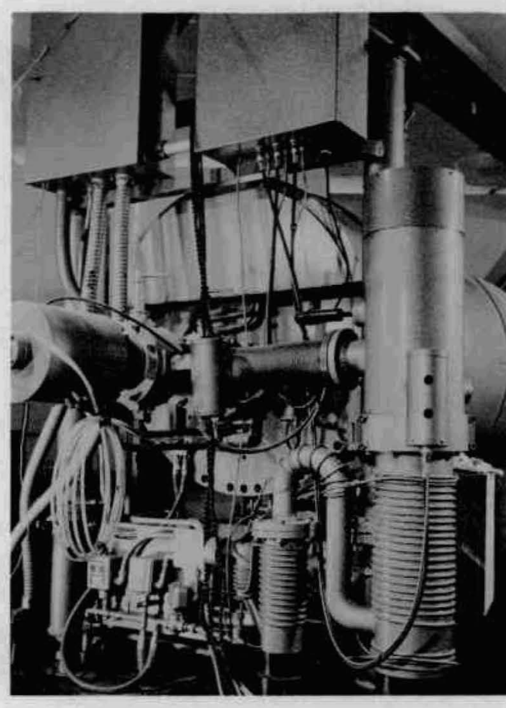


Figure 1. 2-Mev electrostatic generator.

Application of Nuclear Tools to Chemical Problems

Under this heading are included a wide variety of chemical studies with isotopes and also the use of neutron beams to determine molecular and crystal structures by diffraction techniques.

The different isotopes of a given element exhibit nearly identical chemical properties, although they are distinguishable physically, for example, in the case of radioactive isotopes by virtue of the radiations which they emit. This combination of circumstances is the basis for the use of isotopes as tracers, notably in chemistry and biology, for the study of processes which cannot otherwise be investigated readily. A number of investigations in which isotopic tracers are used to study the course of chemical reactions is included in the research program.

Measurable differences do exist, however, in the chemical properties of the isotopes of a given element. These differences are indeed the basis for the separation of isotopes by exchange reactions. It is, therefore, desirable to ascertain and understand these differences, in order to evaluate both the limitations which they place on isotopic tracer applications and their usefulness for the separation of isotopes. These differences affect both the position of chemical equilibria and the rates with which nonequilibrium systems react in approaching equilibrium. Consideration has been given to these questions, with particular attention to the effects of isotopic substitution on reaction rates.

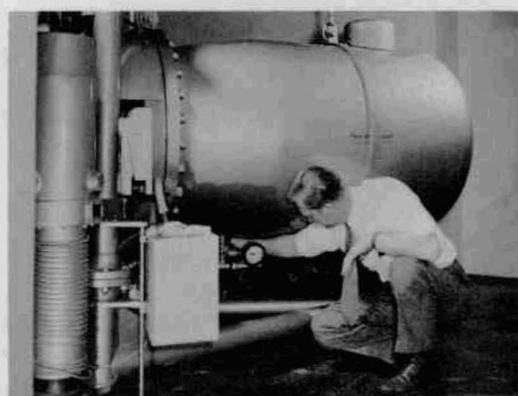


Figure 2. Target end of the 2-Mev electrostatic generator.

The aim of structural chemistry is to determine the characteristic arrangements in space of atoms in molecules and crystals. This has been accomplished for a great number of substances, principally by the techniques of X-ray diffraction and electron diffraction. An important supplement to these methods is found in the diffraction of neutron beams, an approach made possible by the attainment of high fluxes of low energy neutrons in nuclear reactors. Since the effectiveness with which an atom acts as a scattering center for neutrons depends on different factors than does its effectiveness in scattering X-rays or electrons, it is evident that certain limitations in the usefulness of the latter diffraction methods will not necessarily be felt in the case of neutrons. Thus, neutron diffraction promises to be very helpful in cases in which one is interested in the configuration of atoms of very low atomic number, e.g., hydrogen atoms, and in distinguishing the positions of heavy atoms of nearly equal atomic number. Neutron crystal spectrometers for use with the reactor are now under construction.

Nuclear Problems

The study of nuclei *per se* is usually considered to be outside the domain of chemistry, which is concerned with atoms and molecules. Nevertheless, just as techniques from nuclear physics have utility in the study of chemical problems, as remarked above, so also are chemical techniques needed in the study of many nuclear problems. This fact is most marked in work with radioactive substances, in which chemical identifications, separations, and purifications often must go hand in hand with the physical measurements. Such an approach is employed in the study of radioactive substances themselves, in which it is wished to determine the identity of the active material, its half-life, and its decay scheme, i.e., the nature, energies, and relative yields of the emitted radiations. Further, the characterization of new nuclear reactions is facilitated by the identification of their radioactive products; and the cross sections of reactions which form radioactive isotopes may be determined by measurement of the yields of these products. The dependence of cross section on energy (excitation function) is of interest from the standpoint of nuclear dynamics.

Review of Current Investigations

In experiments reported earlier, the paramagnetic susceptibilities of a series of fluoride compounds of tetravalent uranium were measured as functions of temperature. Their temperature dependence was found to follow the Curie-Weiss law, which states the susceptibility to be inversely proportional to the absolute temperature plus a constant (the Weiss temperature). The magnetic moments calculated from the data were close to that of the corresponding rare earth ion, trivalent praeseodymium, and support the concept of a transition series in the heavy elements similar to the rare earth series. More recently, the paramagnetic susceptibilities of some tetravalent plutonium compounds have been measured, in a cooperative venture at Los Alamos, with the finding that the moment of this ion is close to the value expected for its rare earth analog, trivalent promethium.

The observation of unusually large values of the Weiss temperature has made it desirable to reach a better understanding of the significance of this term. Experiments are being carried out to test interpretations which have suggested various types of interactions in the crystal as causes of the Weiss temperature. The general approach is to measure susceptibilities of mixtures of paramagnetic salts with diamagnetic salts, suitably chosen so as to sort out the various effects. Thus, in solid solutions of manganous fluoride with zinc fluoride, the Weiss temperature was found to depend on composition in the way expected if it is due to exchange interactions between neighboring ions. In an attempt to alter the exchange interaction energy by a change in crystal structure, a mixture of manganous chloride with strontium chloride was studied; in this case, no such effect of the structural change was found. Experiments are planned for the study of the crystalline field Stark effect, another possible cause of the Weiss term.

Much of the present knowledge of the electronic states of rare earth ions in solution is derived from their absorption spectra. Techniques have been developed recently for preparing and studying solutions of rare earth and other salts which remain fluid at very low temperatures, at which the spectra are greatly sharpened, and are thus more informative. The absorption spectra of rare earths and heavy elements in such solutions are being studied. In survey experiments, the spectra of solutions at 77° K of gadolinium bromide hexahydrate, neodymium bromide hexahydrate, and anhydrous uranium tetrachloride have been obtained. The spectra are found to be unusually sharp and consisting of separated groups of lines. The uranium spectrum has the characteristics of rare earth spectra, although the line widths are, in general, somewhat greater than those of the rare earths.

The rather unusual properties of these fluid solutions have also prompted a number of experiments on solution reactions at low temperatures. Evidence has been obtained for a reaction between the noble gas argon and boron trichloride to give a solid precipitate. A low temperature reaction between propene and iodine has also been found. It forms a weakly-bonded compound which exhibits an ultraviolet absorption peak very similar to that of the brown solutions of iodine in aromatic solvents such as benzene. The present result seems evidence against an earlier supposition that the ultraviolet absorption peak of the latter solutions is due to a forbidden transition between the energy levels of a conjugated double system, made "allowed" by the presence of the iodine.

In comparison with other heavy elements, surprisingly little is known about the chemistry of element 91, protactinium. This is doubtless due in part to its scarcity in nature, and also in part to the difficulties encountered in working with aqueous solutions of its compounds which have a very pronounced tendency to hydrolyze to insoluble colloidal forms. It has been felt desirable to study the chemistry of this element and its compounds both because of its inherent interest and also because of the possible technical importance of protactinium in the atomic energy program. In order to obtain material for this work, several of the waste residues which result from the processing of pitchblende ores for uranium are being worked up. Isolations have been successfully carried out on a milligram scale, with a combination of precipitation and solvent extraction techniques.

Following the installation of the electrostatic generator, the radiation chemistry program is getting under way. The machine has operated very satisfactorily. The radiation field in the target area is being mapped out with ionization chambers and also by measuring the extent of oxidation of ferrous sulfate solutions placed at various locations. The experiments on aqueous solutions have been started, after development of techniques for thoroughly degassing samples and of analyzing for gaseous and other products formed by irradiation. A large number of X-ray irradiations of potassium bromide solutions have been completed. This system is being studied because of previous reports that bromide ion strongly affects the yields of the main products, H_2, O_2, and H_2O_2, presumably by reacting with the radicals present in the system during irradiation. The results obtained to date are not in complete agreement with the earlier work. Experiments are also being made on the decomposition of solid nitrates under electron bombardment.

The electrostatic generator is also being used to provide service irradiations for other groups in the Laboratory, and a number of X-ray and electron irradiations have been made for the Biology and Physics Departments on problems ranging from the destruction of proteins to the excitation of nuclei.

One subject being studied with the aid of isotopic tracers is the kinetics of exchange reactions between ions in aqueous solution. An interesting class of reactions is that of electron transfer exchanges, the net result of which is the transfer of one or more electrons between two ions of the same element in different oxidation states. This process may be viewed as the simultaneous oxidation of the ion in the lower oxidation state and reduction of the ion in the higher oxidation state, the over-all amounts of the two species remaining constant. Most of the literature on this subject is inconclusive because of experimental difficulties in the measurements which have been appreciated only recently. One such case is that of the ferrous-ferric exchange reaction, which has been variously reported to be immeasurably fast, very slow, or complete within 1-2 hr. Although the causes of these discrepancies are only partially known, a procedure believed to yield dependable data has been devised. The reaction is found to be quite rapid, but measurable; and a quantitative kinetics study is in progress. Concurrently, the cerous-ceric and thallous-thallic exchange reactions are under study. The former of these is of particular interest in that the rate expression contains both a second order and a first order term. The mechanism responsible for the occurrence of the first order term, which gives a rate independent of the ceric concentration, is being investigated. Past work on the thallium exchange has been significantly extended with a series of careful measurements of the effect of chloride on the rate. The data show clearly the participation of the several chlorothallate complexes in the reaction.

Exchange reactions between nickel ion and nickel complexes are also being studied.

The Fischer-Tropsch reaction is a process for the catalytic synthesis of hydrocarbons from carbon monoxide and hydrogen. A wide variety of hydrocarbon species is formed, and the course of the reactions is undoubtedly very complex. Various aspects of these reactions are being studied with deuterium as a tracer. The exchange reaction products which occur when a mixture of deuterium gas and a protium hydrocarbon is passed over the catalyst have been determined for protium methane, ethane, propane, n-butane, and isobutane. Deuterium exchange occurred with all of these compounds, but, in general, the exchanged molecules appear to show a nonstatistical distribution of deuterium, in the sense that a high degree of deuterization is favored. The data are interpreted in terms of radical fragments on the catalyst surface.

The work in organic chemistry is concerned with the tracer study of organic reactions and with the synthesis of isotopically-labeled compounds for use in such studies. In collaboration with the Biology Department, a synthesis of C^{14}-labeled L-ascorbic acid (vitamin C) has been carried out. The procedure involved a sequence of chemical and biological conversions, starting with labeled glucose isolated from bean leaves which had been allowed to photosynthesize in an atmosphere of $C^{14}O_2$. The product will be used by the Biology Department in plant and animal experiments on the metabolism of L-ascorbic acid.

Other work, in collaboration with the Biology Department, has been concerned with the mechanism of the epimerization of glucose and the mechanism of the Willgerodt reaction. Glucose and mannose are two so-called epimeric compounds which differ only in the spatial configuration of the groups attached to the second carbon atom in its skeleton. Either of these is converted to an equilibrium mixture of both on standing in alkaline solution. One possible mechanism would involve a rearrangement of the carbon chain. The lack of occurrence of such a rearrangement was demonstrated with C^{14} tracer, thus excluding this mechanism. As an example of the Willgerodt reaction, acetophenone, when heated with ammonium polysulfide, yields phenylacetic acid and phenylacetamide, the original ketone group having been reduced and the end carbon atom (i.e., of the adjacent methyl group, in this case) oxidized. The mechanism of this reaction is not clear. The question of whether a rearrangement of the carbon skeleton of the molecule is involved has been studied; it has been reported that the phenylacetamide retains the original carbon skeleton, but that the phenylacetic acid has a rearranged skeleton, indicating migration of the phenyl group. Similar data have been obtained at the Laboratory, but it is believed that the evidence for rearrangement in the acidic portion of the reaction is inconclusive. This point is being further studied.

A number of interesting aspects of the thermal decomposition of ammonium nitrate into nitrous oxide and water has been found in experiments with N^{15} and with O^{18}. One feature is that the reaction is catalyzed by water and goes slowly, if at all, in the absence of water. However, using H_2O^{18} it was found that none of the O^{18} appears in the reaction products, and the catalytic mechanism must be formulated in such a way as to be consistent with this lack of exchange. No satisfactory explanation of these facts has yet been reached. With $N^{15}H_4NO_3$, it was shown that the reaction gives exclusively $N^{15}N^{14}O$, i.e., proceeds without rearrangement of the nitrogen atoms. This observation rules out certain otherwise attractive possibilities for the mechanism of the reaction. During the course of the reaction, O^{18} is found to be fractionated by a few percent; the magnitude of this isotope effect is consistent with theoretical expectations. The fact that the N_2O is formed without appreciable mixing of the nitrogen isotopes has been used to prepare samples of the isotopic isomers $N^{15}N^{14}O$ and $N^{14}N^{15}O$. These have, in turn, been used for experiments on the mechanism of the thermal decomposition of nitrous oxide; their infrared spectra have also been studied. Various mechanisms for the decomposition of N_2O into N_2 and O_2 have received consideration; a number of them involves rupture of the N-N bond. The latter have been shown to be untenable by the finding that the N_2 from mixtures of $N^{15}N^{14}O^{16}$ and $N^{14}N^{14}O^{16}$ is formed without mixing of the nitrogen isotopes. The results are consistent with a mechanism involving dissociation into N_2 and O, followed by reactions of the oxygen atoms with N_2O and with each other. In the infrared measurements, the changes in the fundamental vibration frequencies of the molecule caused by substitution of N^{15} in the end position and in the center position were determined. The results permitted some improvements in the values of the force constants of the molecule, and have been used for theoretical calculations of the thermodynamic properties of isotopic N_2O molecules.

A number of mass spectrometric investigations have been made with respect to the effects of isotopic substitution on the mass spectral patterns of molecules. Experimental precautions necessary for insuring that the recorded relative abundances accurately reflect the relative abundance of the ions as they are formed in the ion source have been carefully studied. The relative yields of monatomic and diatomic ions formed by electron impact on the isotopic hydrogen molecules H_2, D_2, and T_2 have been measured, with results which agree much better with theory than do previously published data. In a theoretical investigation, a general approximate method for predicting isotope effects on the mass spectral patterns of simple molecules has been developed. The predictions compared with the limited amount of available experimental data, and satisfactory agreement is obtained.

Work carried out on nuclear problems during the report period has emphasized measurements on cyclotron and reactor-produced radioactive isotopes made outside the Laboratory.

One of the very long-lived isotopes formed in the fission of uranium is I^{129}. Its half-life is being measured by determination of the number of atoms in a given sample and the total disintegration rate. The sample is isolated with normal iodine carrier from a reactor-irradiated uranium slug. Its isotopic composition is determined with a mass spectrometer, the total amount of iodine is measured chemically, and the absolute disintegration rate is measured on a gaseous sample of methyl iodide inside a G-M counter. The preliminary values obtained for the half-life are from 8 to 16 million years, in reasonable agreement with other estimates.

The complex decay scheme of Ni^{57} has been studied and fairly completely characterized. This isotope was found to decay alternatively by the competing processes of positron emission and electron capture; besides positrons, both X-rays and gamma rays are emitted. The characteristic Co X-rays following electron capture were observed and quantitatively measured with an X-ray proportional counter and pulse height analyzer. It was established that the decay is divided equally between positron emission and electron capture, and that both branches lead to excited states of the product nucleus, Co^{57}. In the capture branch there are low energy gamma rays not found in the positron branch. The positron spectrum was measured with a lens type beta ray spectrometer and found to have the shape predicted by the Fermi theory for an allowed transition. This work was done in cooperation with the Physics Department.

It is known that the beta emitter Ag^{110} exists in two isomeric states which decay with half-lives of 270 days and 24 sec. A genetic relationship between the two states, i.e., direct decay of the long-lived excited state to the short-lived daughter state, has been demonstrated by the separation of short-lived Ag from a well-aged sample of the 270-day activity. This was accomplished with the aid of the fact that isomeric transitions often cause the rupture of chemical bonds and thus permit chemical separation of the daughter from the parent. The daughter was collected on copper electrodes immersed in an ether solution of a stable organic complex of the 270-day Ag. The daughter activity from the isomeric transition was collected with an efficiency of about 25%. Its half-life was measured to be 23 sec, in good agreement with the accepted value.

The proportional X-ray counter, referred to above, has also been exploited in the study of phenomena, not previously observed, which occur during alpha and beta decay -- namely, the ejection of extra-nuclear electrons from the decaying atom. It has been thought that this should occur as the result of interactions of the atomic electrons with the decaying nucleus and departing particle. The process has been the subject of theoretical discussions, which predicted a yield of about 1 electron ejected per 1000-10,000 decays. With the proportional X-ray counter, X-radiation due to the process has been detected from the alpha emitter Po^{210}, and the beta emitters, Bi^{210}, S^{35}, and P^{32}. Polonium has been most thoroughly studied; it has been conclusively proved that the X-rays are characteristic of the daughter, Pb. The yield of electrons ejected from the L shell in this case has been measured as one per 1600 alpha particles. The X-rays emitted from S^{35} have been identified, with fair certainty, as characteristic chlorine X-radiation. These experiments are being carried on with the aim of determining the probability of the process as a function of the nature and energy of the radioactive decay particle, and the atomic number of the atom.

Another nuclear problem being worked on concerns the recoil of atoms from neutrino emission. Observations on recoil atoms furnish the most direct known experimental method of studying this essentially undetectable particle. The electron capture isotope, Be^7, presents a favorable case, since the neutrino is the only radiation emitted by the Be nucleus, and since the recoils are reasonably energetic. An attempt is being made to obtain accurate measurements of the energy spectrum of the recoils. Although such measurements have been made in other laboratories, it has been felt worthwhile to attempt further refinements, in order to settle as conclusively as possible the question of whether one or several neutrinos are emitted. The experiments have been directed particularly toward methods of preparation of the surface from which the product lithium ions recoil, as well as toward improved methods of analyzing the recoil spectrum. Some success has been achieved with sources purified by distillations in vacuo, after thorough chemical purification, and with an electrostatic analyzer for the spectrum analysis. The results to date point quite strongly to the emission of only a single neutrino per decay.

The total staff of the Reactor Science and Engineering Department numbers 138, of whom 54 are scientists. Most of the effort of the Department has been expended on the reactor alteration program and the planning for reactor start-up in August. Of a total of 70 scientists and engineers, about 50% have been closely associated with the reactor completion and start-up, and 10% with various phases of the radioactive protection program, including meteorology, geology, and waste handling. All others have been engaged in research and development of applied problems in physics, chemistry, and metallurgy. A few of these latter research problems are discussed in this report. The contributions of the Meteorology and Geology Groups are discussed under the Radiation Protection section.

Detailed discussions of the nuclear reactor design, the recent program of alterations, and the progress reports on the various problems in metallurgy and chemical engineering are to be found in the quarterly classified progress reports of the Reactor Science and Engineering Department. With the approaching operation of the reactor, more time will be spent on chemical problems involving fuels and fission products, the metallurgical problems of an operating reactor, the properties of irradiated materials, the physics and engineering of shielding, and neutron problems.

In addition to the research and development work indicated above, the Department operates and maintains the nuclear reactor. Since the program calls for 24-hour operation 7 days a week, the Reactor Operations Group, to which are assigned 38 persons, has the largest group within the Department.

The Department also operates the hot laboratory and waste handling facilities; 17 persons are assigned to these functions.

Reactor Construction

Revisions in design and subsequent alterations to the reactor have been completed. The Babcock and Wilcox Company has completed all phases of its contract with the H.K. Ferguson Company, and has reported formally that the reactor has been constructed by the H.K. Ferguson Company in accordance with the approved revisions. The H.K. Ferguson Company terminated all manual employees in August and, except for fiscal and property audits, has completed the contract. With the exception of certain mechanical guarantees to be demonstrated under operating flux and temperature, the construction of all the reactor complex has been accepted by the Laboratory. The construction period is thus over and no further construction contracts are anticipated as necessary to augment Laboratory work in order to bring the reactor to design power.

Reactor Criticality

As noted in the general introduction, the completion of the reactor alteration program and the ensuing work and experiments leading to criticality are of special interest and will be noted here, even though they occurred after July 1, 1950.

The construction program was completed on August 11 by the H.K. Ferguson Company, after which Babcock and Wilcox engineers made a final inspection. The personnel of the Reactor Science and Engineering Department immediately started clean-up operations preparatory to the loading operation. Loading of uranium was started on August 13.

During the winter of 1949-50, measurements were made on the subcritical reactor up to a reproduction factor of 0.99. These were made with the purpose of getting parameters of the Brookhaven National Laboratory reactor better to enable the Reactor Theory Group to predict the uranium loading for criticality and the probable characteristics of the operating reactor. Similar experiments were again carried out at various stages of the loading of the subcritical reactor. It is interesting to note that the results of the two series of experiments were in agreement and indicated essentially no change in the reactor characteristics during the past six months.

Criticality was reached on August 22, 1950. Physics experiments on the reactor have been in progress since that time and will be continued through the various stages of operation as the power level is increased. After the current series of tests, the reactor will be turned over to the engineering group to set up the air flow pattern required for high level operation. The next stage of testing, which will occur in October, will be at a level of a few thousand kilowatts. At that time, the research program using the reactor as a neutron source can be started.

Wastes

The problem of radioactive wastes is being attacked by two groups. The first is studying the problem of concentration of the active waste products from large quantities of dilute solutions. The second phase of the problem is that of actual disposal of the active concentrates and other highly active waste products. The difficulty of the latter problem is measured in terms of the degree of permanence desired in the ultimate disposal.

The development of the filtration and the total condensation process for the reduction of large volumes of slightly contaminated wastes is described in other BNL reports. These processes involve evaporative concentration with a high degree of de-entrainment. The results, as recorded in the above reports, indicate that a decontamination factor of 10^6 from feed to product can be achieved with a concentration factor of 100 from feed to concentrate. A further report, summarizing the results of all work in de-entrainment in evaporative equipment, is now in preparation.

Preliminary designs of the full-scale low-level waste concentrating plant were made, based on both the filtration and the total condensation processes. In conjunction with the preliminary design studies, an economic evaluation of the waste concentration project was made and reported. The above studies indicate that a considerable risk was involved in extrapolating from pilot plant data to full plant scale and that a semi-works program was in order. It was also shown that compressive distillation has certain possible economic advantages over standard evaporative methods for conditions at this site. A semi-works program utilizing a compressive still, designed on the filtration process, has been started. It is anticipated that design and construction contracts will be let in the future for the process design of the waste concentration system to be constructed at the Laboratory.

The work on permanent waste disposal has been directed toward the use of certain clays for the purpose of fixing the activity within the clay. The cation exchange capacity of various clays as functions of the concentration and nature of the cation, temperature of the reactants, and the particle size of the clay, has been studied. Most of the work has been done with solutions of radiostrontium 89, although some work has been done with mixed fission products. In the determination of exchange capacities, clay samples which have been dried at 110°C are agitated with radiostrontium. After equilibrium has been established, the clay is centrifuged, washed, and dried at 110°C. The saturated clays are then subjected to a series of heat treatments designed to fix the activity within the clay. Thus far, temperatures in the range from 300° to 900°C have been tried for periods of about 24 hr. The samples are then treated by agitating for several weeks with a large excess of $BaCl_2$ solution. Tests have shown that replacement of radiostrontium by barium is 100% complete in the case of unheated saturated clays and, therefore, this technique serves as a measure of the degree of fixation achieved by heating. The general results for the better clays, such as montmorillonite R2532 (Filtrol Corp.), show that less than 5% of the activity is removed by contact with the barium chloride over periods of 30 days when the clay has been baked at 710°C. Data taken at 875°C showed less than 1% exchange for the same period of time. Tests are continuing on the exchange capacities of the clays and the temperatures required for fixation. The problem of ultimate disposal of the fired clay tile with its locked-in activity is still to be considered.

Radioisotope Production

The Hot Laboratory Operations Group has had under investigation for some time the problem of making a short-lived iodine isotope (I^{132}) available for medical and biological use. The currently used I^{131}, having a half-life of some 8 days, is unsatisfactory for certain medical applications wherein a shorter half-life material is required. I^{132}, which has a half-life of 2.4 hrs, would be well adapted for these applications. However, the separation and shipment of this isotope in form of iodine would be impossible due to decay during the period of shipment. A method has been developed for the separation of the 77-hr parent tellurium, which can be shipped. A simple emanation technique can then be carried out by the user at the time of use. The basic requirements of the program have been, therefore, a safe, easily handled, transportable container for the Te^{132} and the other active and inactive fission-product telluriums, and a molten salt system from which iodine can be recovered from the tellurium or its compounds. The design of the generator is substantially complete. Testing of LiCl and other chloride admixtures has shown these to be satisfactory for iodine recovery, with no observable tellurium carry-over.

During the report period, several unclassified research problems have been in progress. In general, these have been reported in the quarterly scientific progress reports and in the scientific literature. These researches are indicated in brief in the following paragraphs.

Members of the Reactor Theory Group have considered two problems. A study of the systematics of even proton-even neutron alpha emitters has been completed and empirical relationships of the form $\log \lambda = a + \frac{b}{v}$ have been found for Z constant as well as for (A - 2Z) constant. The constants for various values of Z and (A - 2Z) have been found. Values of the nuclear radii and internal potentials calculated from the rigorous form of the Gamow-Condon-Gurney theory resulted in $r_0 = 1.57 A^{1/3} \times 10^{-13}$ cm and $E - U = 0.52$ Mev for "normal" even-even alpha emitters. E is the alpha energy.

Calculations have also been made on a Yukawa potential wave function. A fairly accurate approximation of the wave function of a deuteron in the ground state has been used to calculate V_0 in the nucleon interaction potential $V(r) = -V_0 \frac{e^{-\mu r}}{\mu r}$. V_0 can be represented in various parameters, including μ, the reciprocal Compton wave length of the nuclear force meson, the deuteron binding energy, the deuteron radius, and a variational parameter. Plots of V_0 as a function of the variational parameter are available for several values of μ.

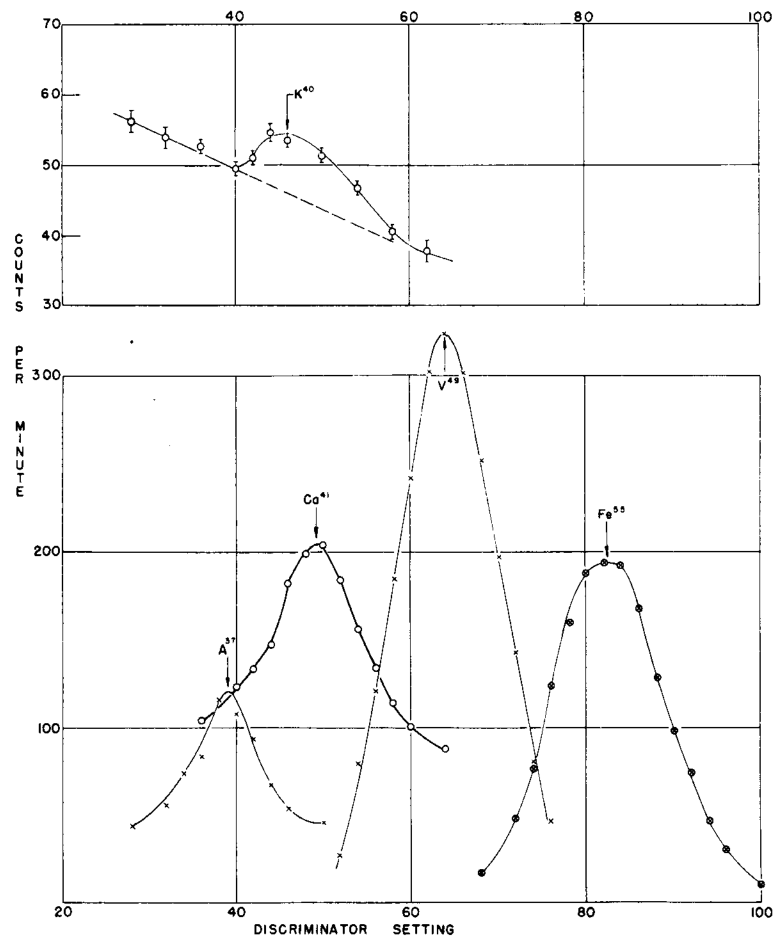
An investigation has been made of the effect of cadmium trays used in obtaining neutron-activated indium resonance activities. Since the lower end of the indium resonance at 1.44 ev extends into the region where cadmium becomes a good neutron absorber, a correction depending on the cadmium and indium thickness must be aplied to the activities of cadmium-covered indium foils. Indium foils of 94.5 mg/cm^2 thickness were covered with cadmium varying from 0.009" to 0.058" in thickness. The activities obtained with thicknesses above 0.020" where cadmium is black to thermal neutrons, were fitted to an equation of the form

$$C' = Ce^{3.507t},$$

where C is the observed activity, C′ is the true activity, and t is the cadmium thickness in inches. This equation is valid for 94.5 mg/cm^2 indium foils, and for cadmium thicknesses between 0.020" and about 0.060".

An X-ray spectrometer has been used to detect the soft X-rays resulting from the electron capture process in K^{40}. The problem of reducing the background due to the presence of the beta particles from K^{40} (60 times as many betas as X-rays) has disclosed some interesting characteristics of this type of spectrometer. Since the betas lose only part of their energy in the counter, and the specific ionization for high energy electrons varies only slowly with energy, the betas give a broad peak on a pulse height vs. energy curve at some pulse height region determined by the type of gas and the pressure in the counter. By a suitable choice of the gas and the pressure, the background peak of the betas can be shifted out of the region of interest of the X-ray peak. The optimum filling for the K^{40} case (argon X-rays) from the preliminary experiments is krypton with 10% methane at slightly less than atmospheric pressure. The resolution of the instrument under these conditions is 20-25%. The data show consistently the presence of argon X-rays from the K^{40} sample, as two previous investigations seem to indicate.

If Ca^{41} can be produced it should decay by electron capture to K^{41} according to the threshold observed for the $K^{41}(p,n)Ca^{41}$ reaction. Several investigators have attempted to observe this decay and have reported a half-life of about 10 days. Other observers have been unable to detect this decay and have found that the cross section for $Ca^{40}(n,\gamma)Ca^{41}$ is less than 0.001 barns if a 10 day half-life is assumed. The presence of Ca^{41} has been observed in a standard "irradiated unit" of calcium which was irradiated in the Oak Ridge reactor more than a year ago. This experiment consisted of searching for the K_α X-ray of potassium which is emitted in the electron capture process of a calcium isotope. Ca^{41} is the only isotope of calcium that could



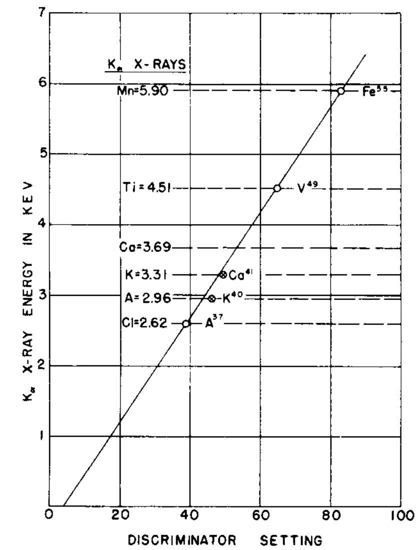


Figure 2 (Above). Calibration of discriminator.

Figure 1 (Left). Upper: X-rays from K^{40}. Lower: X-rays from electron capture.

be present in such a sample and decay by electron capture. A proportional counter and a pulse height discriminator were used as an X-ray spectrometer. The instrument was calibrated by using the K-capture isotopes Fe^{55}, V^{49}, and A^{37} (Figure 1). A background of beta particles from Ca^{45} was present but the peak due to the Ca^{41} X-rays appeared at the proper location with an intensity of about 3 times the background. The strength of the X-rays and the age of the sample indicate that the half-life of Ca^{41} is of the order of a year or longer. If this is true, then the cross section for $Ca^{40}(n,\gamma)Ca^{41}$ must be considerably greater than previous calculations indicate. A program to measure the Ca^{41} half-life and the $Ca^{40}(n,\gamma)Ca^{41}$ cross section is planned.

A theory has been proposed to account for a variety of star known as a supernova of type I. Such stars are characterized by: a) a high intensity maximum of 20-30 days duration; b) an exponential tail to the light curve of half-life 55 days (Δm = 0.0137 $\pm$ .0012 magnitudes per day); c) an integrated visual light emission of nearly 10^{49} ergs; and d) a residual gaseous shell of low hydrogen content expanding at a velocity of 1300 km/sec and radiating 10^{36} ergs/sec visible light about 900 years after the outburst. These characteristics may be accounted for by assuming a massive original star which undergoes gravitational collapse after hydrogen depletion. At a central temperature of 2 - 3×10^9 °C a second order (endothermic) reaction will occur between alpha particles to form beryllium (Be^7) with neutron emission. The reaction is highly endothermic (A = - 18.6 mv), permitting rapid gravitational collapse. Neutrons generated will be absorbed by the heavy elements present in the star. Nitrogen in particular has a (n,p) resonance of 0.1×10^{-24} cm^2 cross section at 550 kev. Since the most probable energy at 3×10^9 °C is 260 kev, and N may be expected to be present to an extent of 0.1 to 1%, it will be an important absorber. After collapse, the star becomes unstable and explodes, driving off a considerable fraction of its mass as an expanding gas cloud, probably leaving a core in a highly degenerate state. The exact mechanism of this explosion is not understood. Several possible mechanisms are: a) the formation of a highly degenerate core, driving the outer layers away by radiation pressure; b) accelerated decay of Be^7 at increased electron density and the regeneration of He from Li^7 and H; and c) rotational instability of the star. The expanding gas envelope carries with it the Be^7 and C^{14} produced by the reaction. As the density drops, the thermal energy is radiated away as the initial maximum of the light curve. Thereafter the energy source is Be^7 ($T_{\frac{1}{2}}$ = 52.9 days). The energy source will follow an exponential curve unless: a) the diffusion of light to the surface of the gas envelope takes a long time compared to the radioactive life, or b) the gas envelope becomes so tenuous as to permit appreciable loss of the 480-kev gamma rays. In the case of two well-known supernovae, observed in 1054 A.D. and in 1937 in extragalactic nebula IC 4182, these restrictions were not found to be limiting from 40 days to 600 days past maximum. The quantity of Be^7 required for these stars was 3×10^{32} g. After the decay of Be^7, the energy source may progress through intermediate periods, representing fortuitous neutron-induced activities, but will rapidly approach the period of C^{14} ($T_{\frac{1}{2}}$ = 4700 years). In the case of the supernova of 1054 A.D., the gaseous envelope, the Crab nebula, is readily observed. Its energy source corresponds to 10^{32} g C^{14}. Assuming an initial mass of 4×10^{34} g, the nebula should contain about 0.2% C^{14} and about 0.7% Li^7. Spectroscopic data show an unusually low abundance of H (< 5%), but show He, N, and O. The abundances of these elements have not been derived from the spectrum.

LIFE SCIENCES

The main functions of the Biology Department are the use of radioactive material to study the distribution, physical transfers, and chemical reactions of elements and compounds in the normal metabolism of plants, animals, and microorganisms, and to ascertain the effects of internal and external radiation on function, growth, and genetics.

Since the Biology Department was organized in June, 1947, Dr. Leslie F. Nims has served as its Acting Chairman, and has gathered a staff which has been yielding dividends at an accelerating rate in the above fields. In order to return to full-time research, Dr. Nims requested, last December, that he be relieved of the chairmanship as soon as a permanent chairman could be appointed. Dr. Howard J. Curtis, Professor of Physiology at Vanderbilt Medical School, has accepted the position, and will assume his duties as Chairman on October 1.

In June, the Biology Department sponsored a two-day conference devoted to carbon dioxide assimilation reactions in biological systems. The first day was concerned with studies on microorganisms and isolated enzyme systems derived from microorganisms and animal tissue. The second day was concerned with photosynthesis and carbon dioxide assimilation reactions in plant enzyme systems. The conference was attended by over a hundred investigators and was very well received. To our knowledge, it was the first such conference devoted exclusively to this important field and it is hoped it will be followed by others at various laboratories around the country.

In addition to the regular staff, the Department has had 14 visiting scientists during the report period. The length of the visits have ranged from a few days up to a full year, with the average stay being 8-10 weeks. One A.E.C. Fellow is presently at work in the Department, and arrangements have been completed for two others to begin their research during the next two months.

The Medical Department covers two fields: medical service to the personnel of Brookhaven National Laboratory, and scientific research. Separate staffs are engaged in the two fields.

Medical service includes physical examination of all employees, dispensary and hospital care, and cooperation with the Health Physics Division.

Scientific research includes studies of the physiology, pathology, and therapy of man, and studies of organisms that affect man, or that may yield information clarifying the human processes. The general factors studied include those mentioned in connection with the Biology Department, but the problems are oriented more directly toward man. The observations on man include studies of selected patients with thyroid cancer, hyperthyroidism, nephrosis, or leukemia. The scientific staff was organized in 1949. Experimental work has advanced as rapidly as could be expected. Laboratories are now active in the fields of pathology, bacteriology, and chemistry. The hospital usually has 12 to 15 research patients.

In the study of the effects of radiation on animal physiology, the fields of medicine and biology overlap. Cooperation between the two departments is essential, and has already begun on several problems. Such cooperation will be facilitated by the ultimate transfer of the Medical Department to a site adjacent to that of the Biology Department.

BIOLOGY

The staff of the Biology Department now numbers 45, of which 21 are scientists, 20 are technicians, and 4 are administrative and clerical personnel. This is compared with the staff on July 1, 1949, which then totalled 38, of which 18 were scientists, 16 were technicians, and 4 were administrative and clerical.

In December, the first phase of new laboratory construction was completed and the building at 46 Bell Avenue was occupied by 31 members of the staff. One of the barracks buildings previously occupied was completely vacated, but has been maintained in stand-by condition for use by short-term visitors or for special experiments requiring some degree of isolation. Another is still being used as regular laboratory space; the third is being used as both stockroom and laboratory space. Plans for the second phase of construction are well under way and it is hoped that work on the building will begin within the next six to eight months. In addition to the building mentioned above, the Biology Department also took over the old dispensary building at 10 Center Street for use as an animal farm. A pronounced increase in the number and variety of animals being used, plus the beginning of a rat breeding program, had made the previously occupied space completely inadequate. Although the dispensary building made more space available, it is far from satisfactory due to the complete lack of temperature and humidity control, inefficient arrangement of rooms, etc. Properly designed animal quarters will be included as part of the building now being planned.

The various research programs of the Biology Department have been greatly facilitated by the additional laboratory space afforded by the new building. Increasing emphasis will be placed on studies in radiobiology as the various nuclear machines become available for experimentation. The installation of a new 250-kev 30-ma tube-current X-ray machine in the biology laboratories will be completed in the near future. Exploratory studies, in collaboration with the Chemistry Department, have demonstrated that their new 2-Mev electrostatic generator will be a most excellent device with which to study the irradiation effects of electrons and X-rays on solutions of materials of biological interest. It should also prove useful in the studies of the effects of radiation on individual organs of small animals, since the output can be nicely beamed.

The activities of the Biology Department are centered around two fields of interest. The first is radiobiology; varieties of plants, animals, and microorganisms are being used to study the physiological, genetic, cytological, and biochemical effects resulting from the irradiation of selected organisms. The mechanism by which the damaging effects of radiation are mediated is also under investigation. Another field

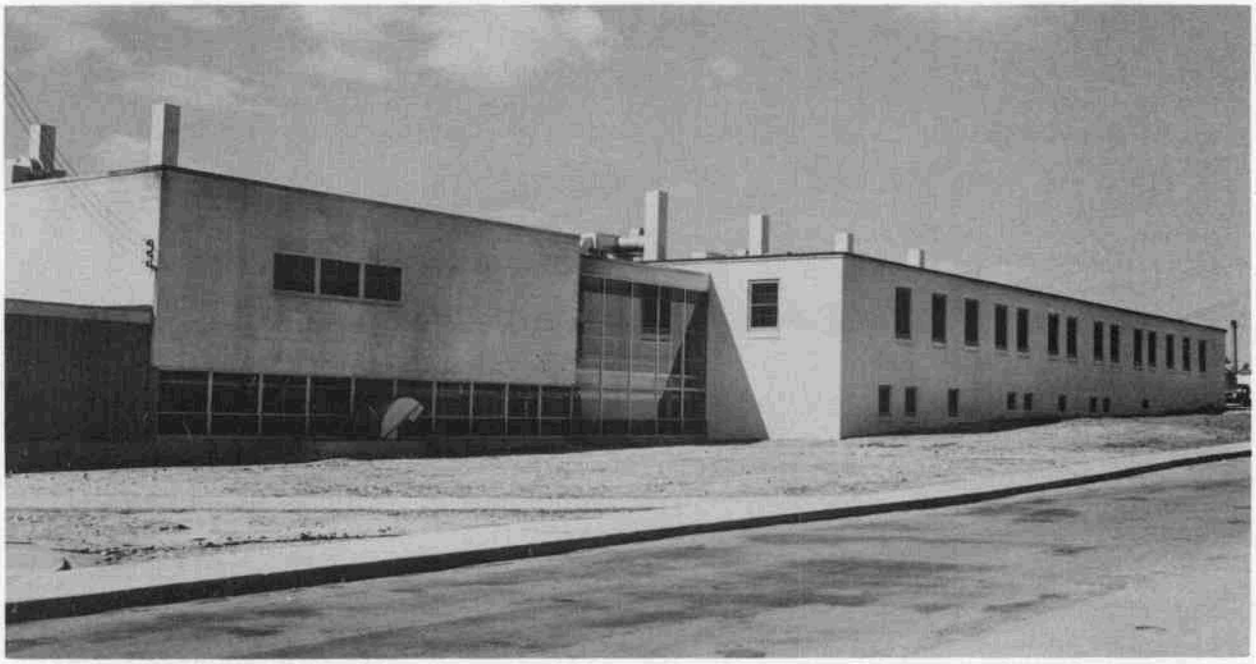


Figure 1. View of new Biology building.

of interest is the application of the tracer technique to fundamental biological problems. In this program, isotopes of carbon, iron, phosphorus, barium, and the rare earths are being used to study problems as varied as photosynthesis and the mineral metabolism of insects. A fuller description of these efforts follows.

Biological Effects of Radiation

Animals

The prevention and treatment of radiation damage in the mammal is difficult. Recent work from several laboratories indicate that there are agents such as cysteine, methionine, cyanide, and even anoxia, which, if present during the irradiation, make the animals more resistant to the radiation. The agents so far discovered do not, however, seem to be practical for mass protection. It seems probable that proper treatment of exposed individuals offers the better means of taking care of radiation casualties. Such treatment should be based on sound physiological principles. The animal work in the Biology Department is directed toward a better understanding of the altered physiology in the irradiated mammal.

Following exposure to X-rays, rats rapidly develop a greatly increased water turnover. The effect is very pronounced. If several exposed rats are caged together, the animals struggle for the water supply. With whole body irradiation, and often at the higher doses, they will drink and excrete an amount of water equal to or greater than their body weight on the first day after exposure. It has been known for some time that animals exposed to whole body ionizing irradiation suffer from bacterial infection, the causative organisms apparently escaping from the gastrointestinal tract. In fact, life in the irradiated animal can be prolonged by treatment with suitable antibiotics. However, control experiments have shown that the disturbed water metabolism is not due to the infection, for treatment of the irradiated rat with aureomycin does not alter the course of the disturbance in water metabolism.

Associated with the disturbance in water metabolism is disturbance in salt metabolism. There is a period of negative potassium balance in the irradiated rat during the first 24 hours after exposure; in the fasted animal, this is associated with a nitrogen loss in the urine that is greater than in fasted control animals. The animals regain normal balance in 4 to 5 days.

Some of the effects of whole body irradiation appear to be mediated through the pituitary - adrenal system. These glands comprise a normal line of defense of the integrity of the mammal to stresses such as high and low temperatures, anoxia, infection, etc. Removal of the adrenal gland makes a rat more susceptible to all types of stress, including whole body X irradiation. Treatment of the adrenalectomized animal with either extracts of the adrenal gland or desoxycorticosterone acetate will restore the deficient animal's ability to withstand stress to normal. In fact, internal shielding of the adrenal gland in the normal animal greatly increases his resistance to irradiation. The mechanisms underlying these effects are not understood and will be the objects of future intensive study, but they do indicate the importance of the pituitary - adrenal system to the phenomena of irradiation sickness.

Some experiments along this line are already under way. For example, it has been found that the blood of the irradiated rat has lost some of its antidiuretic factor; that is, if serum from an irradiated animal is injected into a control animal which has been well hydrated, the control animal excretes water faster than controls which receive serum from unirradiated animals. Also, the irradiated animal excretes excess administered water at a faster rate than do controls. The presumed source of this activity is in the postpituitary gland, and the experiment demonstrates that whole body irradiation by some mechanism is inhibiting the secretion of normal control hormones by the pituitary gland. This explanation is only tentative and further experiments are under way to test this hypothesis. If true, it would indicate that part of the syndrome of radiation sickness is the partial loss of important elements in the circulation and if these factors can be determined they may offer methods of replacement therapy for the syndrome of irradiation sickness.

Plants

Intensive study is continuing of the physiological and cytological consequences of irradiation of plants and plant materials. Many of these studies are being carried on in collaboration with investigators at other laboratories. For example, the Botany Department of the University of Pennsylvania is investigating the tyrosinase activity in potato tubers, and in preparations of the enzyme made from tubers. It has been found that 20,000 r of X-rays increases the enzyme activity in both the tubers and in the isolated extracts. This phenomena is being further investigated. In collaboration with Rutgers University, a study is being made of the histological changes occurring in Tradescantia plants after various exposures to continuous gamma irradiation. Preliminary results indicate that the meristematic zones are almost completely destroyed at doses of 60 r a day or above. At lower doses (10 - 15 r per day), abnormalities and hypertrophy of the floral parts occur.

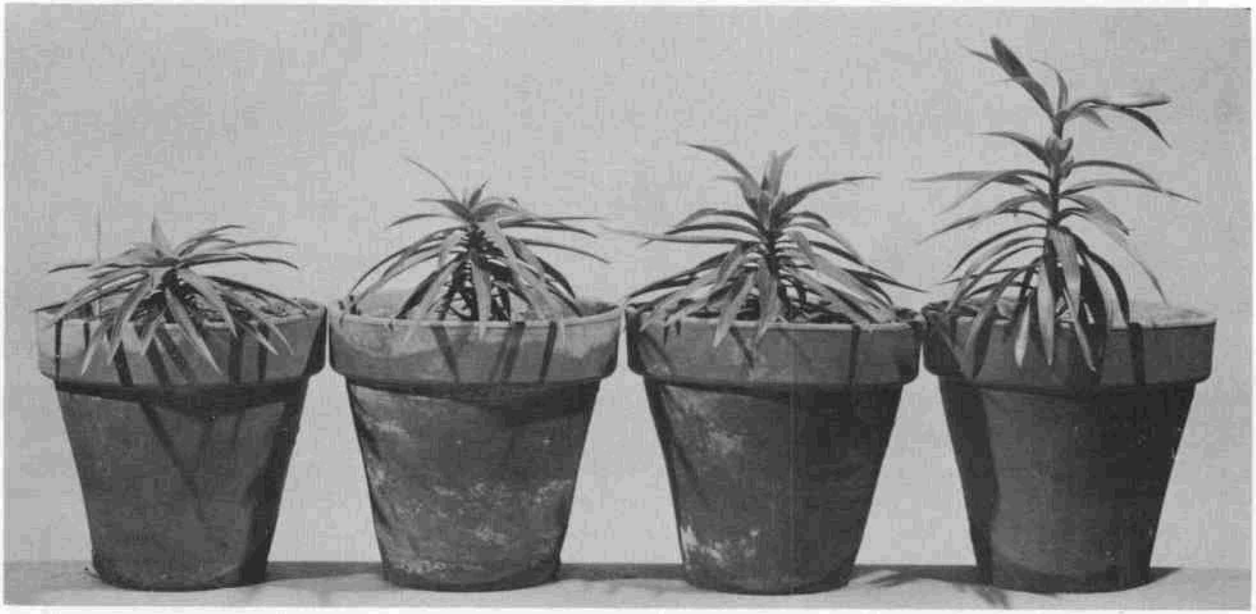


Figure 2. Effects of gamma radiation on the growth of lily. From left to right, these plants have had dosages of approximately 4500 r, 2400 r, and 2000 r. The largest plant is the unirradiated control. The dose rates were respectively about 150, 82, and 66 r per day. Flower bud development in all irradiated plants was incomplete.

The regeneration of vegetative and floral parts of Tradescantia plants is strongly inhibited by high levels of chronic gamma irradiation. It appears that growth is fairly normal for levels of dosage that produce less than 20% aberrations in the chromosomes. When chromosome breakage is greater, so that the aberration frequency approaches 30%, the severe inhibition occurs. This occurs at exposures of 66 r or greater in Tradescantia. The plant species Lilium and Vicia are also inhibited at about the same levels. Other plants tested (maize, tomato, snapdragon, marigolds, potatoes, and various varieties of weeds present in the gamma field) appear to be little affected at this dose rate. These results make it appear that those plants with the larger chromosomes are the more sensitive to ionizing radiation.

The effects of fast neutron, X, and gamma irradiation on the growth of potatoes are continuing to be studied. When tubers are irradiated with X-rays, the time of emergence is lengthened and the yield appears to be decreased at a total single dose of 1200 r. At 4800 r, little, if any, growth takes place. In the gamma field, potatoes were grown at various dose rates; it appears that continuous gamma irradiation (for the whole growing season) is only about 14% as effective as the same amount of acute X irradiation. Preliminary observations on the fast neutron irradiated potatoes (irradiation carried out at Oak Ridge) indicate that acute neutron irradiation is some four times or more as effective as X-rays in inhibiting the growth of potato tubers.

In the cytological studies being carried out on the meiotic cycle of Trillium pollen mother cells, it has been found that differential rejoining is a factor of some importance in accounting for the marked alterations of the sensitivity of the chromosomes (present data indicate well over a hundred-fold variation) to X-rays at various stages in the cycle. The number of rejoins (dicentrics and rings) is significantly greater following irradiation at early interphase than at first meiotic metaphase.

An attempt is being made to assay the effect of a short exposure of Trillium to high temperatures just before irradiation to see how the sensitivity changes. Also, other experiments are under way to compare the effects of beta irradiation upon Trillium chromosomes with those of X-rays. The experiments are still in an early stage and the results are not yet at hand. An attempt is also being made to separate the direct physiological effects of irradiation from the indirect effects resulting from chromosome fragmentation. Experiments have been designed to reduce or eliminate the usual delay of the onset of meiosis following irradiation at meiotic prophase and to eliminate the secondary inhibition due to loss of fragments. Treatment of the irradiated Trillium flower buds with colchicine and indol acetic acid has given promising results. Further work is under way.

Two important questions are raised by the X-ray sensitivity experiments. One is, what is the mechanism by which chromosomes are broken by radiations? The other asks, what is different with cells at one stage of division that they are more sensitive to damage than at another?

The answer to the first question may well lie in the explanation to the second. To attack this problem, one must know what the chemical and physical changes are that go on during normal cell division. The obvious visible changes that occur during mitosis and meiosis are well known. The cell nucleus is the center of activity and the most marked events take place here. The formation of chromosome threads from a more or less homogeneous resting nucleus, and the final transition of these threads into double the normal number of rod-like chromosomes which separate equally to each of two newly-formed cells, are phenomena which have been known for almost a century. But the chemistry of this process is only just beginning to be understood. The key to the sensitivity problem undoubtedly lies in the chemical changes which occur during division.

Nuclei and chromosomes are comprised almost entirely of two classes of chemical substance: protein and nucleic acid. Of the latter, there are universally two kinds: desoxypentose nucleic acid (DNA) and pentose nucleic acid (PNA). DNA is only associated with chromosomes and is believed to be closely related to the gene substance itself. PNA is found predominantly in the cytoplasm but it has also been found in the nucleus; it is generally associated with protein synthesis.

Analyses have been carried out to determine the amount of the two nucleic acids per cell in succeeding stages of dividing Trillium pollen mother cells. During the meiotic division in this plant, each pollen mother cell divides twice and gives rise to four pollen grains. Each pollen grain contains just half the number of chromosomes contained by the original mother cell. Thus, one division reduces the number of chromosomes by half while the other division is an equational one, where the number of chromosomes is not changed. As has been shown above, chromosome fragmentation by X-rays is low at the beginning of the first division process, rises to a high as the first division is actually about to take place, and slowly falls off as divisions progress, until a low is reached after the end of the second division and at the beginning of a long interphase (early pollen grain stage) prior to the start of a third new mitotic division.

The changes in amounts of the nucleic acids per cell (described, for convenience, as amount per mother cell rather than daughter cells) did not correspond with changes in sensitivity. There was a slight increase in DNA at the beginning of the first division process, but there was little or no change throughout the two actual divisions. At the conclusion of meiosis, at the point of lowest sensitivity, the amount of DNA increases again. This is interpreted to mean that before actual division begins, DNA is manufactured by the cell for the two divisions to come. DNA synthesis then stops while the divisions are taking place and begins again at the close of meiosis in preparation for the future (third) mitotic division. PNA, on the other hand, was not observed to increase at the beginning of meiosis; it remained constant throughout, but increased, like DNA, at the end of meiosis.

There is no correlation between the amount of nucleic acid per cell and sensitivity. This is important, because it means that the mechanism of fragmentation must depend on a more subtle factor than just the amount of target substance present. What is significant, however, is the fact that the periods of increasing sensitivity appear to be those where synthesis of DNA (gene substance?) is taking place.

Another approach to the problem of how chromosomes are broken by X-rays is being attempted by studying the behavior of DNA in living and fixed cells and in solution, when irradiated by X-rays. This is being done cytochemically, where the quantitative analysis and even the molecular structure of nucleic acid in single selected cells can be studied. Apparatus and methods have been devised whereby amounts of substance in the order of 10^{-12} gm can be studied. It is too early to discuss the results of these experiments, but it is expected that they will reveal important information about the chemical and molecular construction of chromosomes and the way in which radiations bring about changes in them.

Since the explosion of the atomic bomb at Hiroshima, the public has become increasingly aware that radiation is harmful to living organisms, including humans. Radiation has two definite effects: to damage the organism itself or to produce mutations, many of them harmful to the germ plasm of the exposed individual. For the past year, an attempt to measure just how much radiation is required to produce harmful effects, either to the individual or the germ plasm, has been under way.

One of the materials being studied intensively is corn, because more is known about the genetics and cytology of corn than for any other crop plant. The radiation used was continuous gamma radiation from a Co^{60} source placed in the center of a three-acre field. Plants were grown in concentric circles around the source at intervals of 1 m. The nearest row of plants was 2 m from the source and the farthest one was 38 m. The dosage ranged from 5 r/hr near the center to approximately 1 r for a period of 3 days at the 38 m row, the last one planted.

The results showed no apparent damage to the growing plants in any of the rows, whether near the source or not. The row nearest the source (2 m) which received more than 4000 r during the growing period showed no visible damage. The lethal dose for most animals is considered to be less than 1000 r.

The germ cells, however, apparently can be changed with much less radiation. Mutations were secured from all of the different circles, the farthest one from the source having received only about 14 r for the whole season. Most of the mutations were for kernel characters in corn, starchy to sugary, colored to colorless, plump to shrunken, and purple to red color. In some cases, the mutation rate was more than 100 times the spontaneous rate. Work is in progress to determine these rates more exactly, using a larger number of seeds. Last year, counts were based on

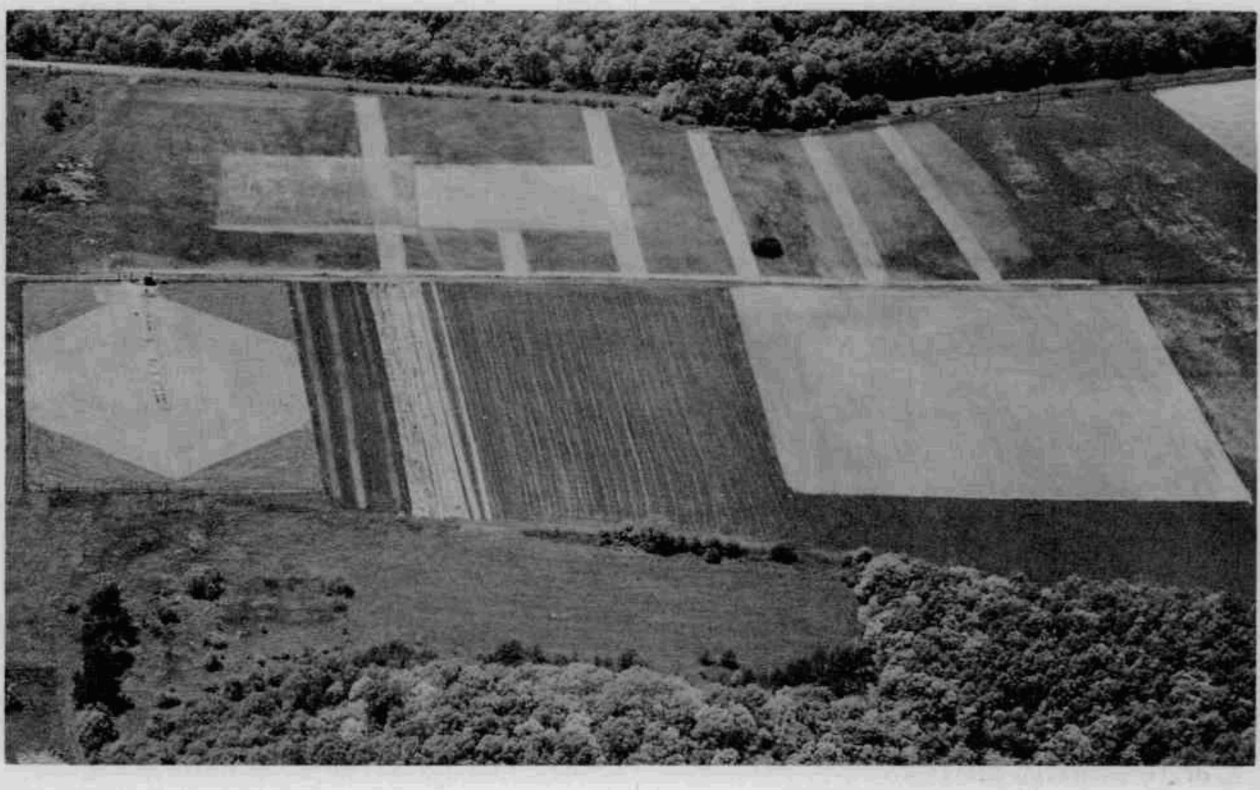
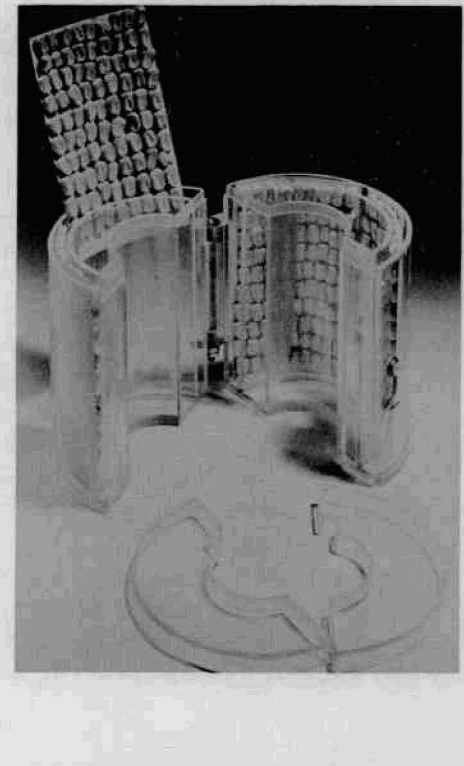


Figure 3. Aerial view of the radiation field and other experimental plots. The radiation field is at the left. Barley growing in the corners of the field gives it an hexagonal appearance. Corn will occupy the largest area, but near the center, where radiation is highest, many other plants will be grown, e.g., potatoes, tomatoes, lilies, Tradescantia, tobacco, Lespedeza, snapdragons, etc.

Figure 4 (Right). This seed chamber is constructed to fit around the pipe in the "gamma" field which contains the radioactive cobalt source. The embryo portions of the seeds receive about 6100 r/hr.



50,000 seeds, whereas this year we expect to have several million.

In addition to seed characters studied last year, mutations to such plant characters as the reduced stalk gene -- one which shortens the corn stalk, thus producing a more efficient grain-producing plant -- are being looked for. If such a gene can be produced by exposing the different inbred lines to gamma radiation, the breeding program of short corn would be speeded up materially.

As a supplement to our own work, plants are being grown in the radiation field for several investigators who are interested in certain specific mutations. In addition to growing crops for these investigators, space is being provided in our radiation area for the Plant Pathology Department, Connecticut Agricultural Experiment Station, New Haven. They are studying parasite-host relationships under radiation and have just found that crown gall in tomatoes can be retarded and perhaps destroyed without killing the host plant.

The chemical test for viability, devised by Lakon in Germany many years ago, has been used sucessfully to detect the effect of extremely high and low temperatures on seeds of various types. In these experiments, the harshly treated seeds lose the ability to stain in a solution of triphenyltetrazolium chloride. In view of these results, it was of interest to determine whether radiation damage to seeds could be detected also by means of this dye test. Accordingly, corn seeds were exposed to various doses of gamma radiation up to approximately 130,000 r. Even with these relatively large doses, the seeds still gave a positive test for viability using the triphenyltetrazolium method. It is of interest to note, however, that even at much lower doses of radiation, the growth of seeds in markedly reduced. Thus, seeds having a moisture content of about 35% when given 15,000 r are unable to grow as well as unirradiated seeds and in many cases die in the seedling stage. It appears that the dye method is not a satisfactory method for detecting radiation damage to seeds.

The chemical analyses of the sucrose in the stalks of the various lines of corn under investigation are proceeding. In some lines, the sucrose content reaches a maximum and then falls off as the ear is formed. In others, the sucrose continues to increase. The factors controlling these differences are under investigation and an attempt is being made to stabilize the high sucrose content genetically.

The genetic changes in bacterial cultures grown in radioactive phosphorus have been shown to arise in part from radioactivity, and, more importantly, from the reaction of the decaying atom. Both the geometry and metabolic versatility of bacteria have been utilized to create a condition in which these effects were clearly separable. The total ionization received by the cells in different media can be shown to be almost identical experimentally, as well as by calculation, while the mutation rate varies with the disintegrations of P^{32} located in the nucleoproteins. A mechanism is thus presented both for explaining the magnitude effect of internally absorbed unstable isotopes, and also to indicate a chemical mechanism by which certain mutations are made manifest. The pattern of genetic changes -- qualitative as well as quantitative -- is distinguishably different from that produced by external radiation.

The design of these experiments requires the growth of bacteria in a field of constant radiation. It was shown that this growth could be quite normal in a field causing a great increase in mutation frequency. More recently, bacteria have also been cultured in a field of an X-ray machine, where they grew well receiving 5000 r/hr for 10 hr.

From these and similar experiments it appears that while resting bacteria are relatively sensitive to radiation, growing ones not only are more resistant, but reproduce in a manner indistinguishable from unirradiated controls.

In the external (X-ray) experiments, it was shown also that total P does not influence the production of mutation by radiation. In the internal (P^{32}-radiation) experiments, it was only the change of total P which produced different mutation rates. The experimental method of incorporating P^{32} in different amounts was thus found valid.

The genetic change measured was the appearance of streptomycin resistance in E. coli. Although there is evidence that this change always occurs at the same locus, many physiologically different streptomycin resistance types were found. The differences among the mutant types were related to growth and survival rate, and to the requirement for a sensitivity to various levels of streptomycin. Under the influence of different mutagenic conditions, the proportionate type changes in a manner to suggest either the selective productions of certain mutants or the interaction of types with a culture. By being able to sort out the mutant types, it has been possible to accurately describe the mutation rate (under background conditions) in the face of the multiplicative origin of a large proportion of the mutants. On the basis of the knowledge of this rate, it has been possible to devise rapid and accurate methods for determining mutation rates and types.

In studying the interaction of mutant types, interest was focused on the phenomenon of streptomycin dependents. A certain proportion of mutants, which are to some extent resistant to streptomycin, also require it for growth and survival. Since it is the appearance of these types which varies with different radiation effects, it was important to understand the metabolic nature of streptomycin dependents. It was soon shown that even when a large concentration of the drug was required, no detectable amount was actually utilized. In fact, none of the mutants destroyed or removed any of the streptomycin from solution, whether or not they required it. The streptomycin could then be recovered (after the growth of the mutants) and measured and finally reintroduced to stimulate the growth of new streptomycin requiring cultures. No trace substance -- organic or inorganic -- was found capable of replacing the streptomycin in the requirement phenomenon. It was possible, however, to completely destroy the antibiotic quality of the drug while still completely maintaining its growth-stimulating effect.

In this way, a better understanding of the genetic effect of radioactive isotopes is being obtained. The studies will be extended in order to explore the genetic effects of atomic recoil by means of slow neutron (nuclear reactor) irradiations. The period between a genetic change and its actual manifestation can be carefully studied by these methods because of the rapid succession of bacterial generations and the immense populations which may be tested. The variation in mutant types provides a tool for the qualitative analysis of different mutagenic effects associated with radioactivity. It will, however, be necessary to explore further the nature of bacterial genetics to provide a basis for the understanding of these variations and interactions. Previously obscure phenomena of bacterial genetics can now help to elucidate basic genetic mechanisms.

Tracer Studies of Biochemical Problems

During the past year, effort has been devoted to an attempt to clarify, by means of radioactive phosphorus, the part played by certain phosphorus compounds in the normal functioning of the liver. These compounds are part of what is called the phosphorylation cycle, and are known to be important in the metabolism of sugars by the body cells. One of these compounds, adenosine triphosphate, usually referred to as ATP, is known to be concerned with the metabolism of fats as well as sugars. There is some evidence that it also plays a part in the metabolism of proteins, the other of the three great classes of foodstuffs.

The experiments were carried out on rats of two genetically different strains. It was found that the rate at which this substance ATP is formed in the liver is very rapid, as would be expected of a compound that is so important in the metabolic activities of this organ. An entirely unexpected finding was that the rate at which this substance is formed is about twice as great in one strain of animals as in the other. Another of these phosphorus compounds is glucose-1-phosphate, which is considered to be the first phosphorus compound formed from glucose. The sugar of this compound, which is the most important one found in the free state in the animal body, is also formed at twice the rate in the one strain as in the other. It is not known yet just what the significance of this difference in the rate of formation of these two compounds in the livers of the two strains of animals may be.

The use of tracer isotopes offers the only way of finding out the rates at which processes such as these take place in the living animal. The amounts of each substance present do not undergo any detectable change during the period of the experiment; the animal is in what is called the "steady state" with respect to them.

The observations made are consistent with the hypothesis that these two compounds, ATP and glucose-1-phosphate, are formed on the surface of the cell, utilizing the inorganic phosphate that is present in the blood plasma.

Experiments are under way to study the effect of diabetes on the rates at which these various phosphorus compounds are formed and break down. Diabetes is a condition in which the ability of the body to use sugars for food is very greatly impaired, and it might, therefore, be expected that there would be some disturbance in the relations between these phosphorus compounds in this condition. The diabetes is produced by injecting the drug alloxan, which specifically destroys the cells in the pancreas, which secretes insulin, the hormone which is most important in enabling the body to use sugars. It is also planned to study the way in which insulin affects the rate of formation of these phosphorus compounds and the relations between them in the liver of the diabetic animal.

There is evidence from various lines of experiment which indicates that radiation acts to interfere with certain of the reactions of the phosphorylation cycle. It is planned to study the effects of radiation on the rates of formation and the interrelations between these phosphorus compounds in the liver of the animal subjected to whole body radiation.

Another experiment carried out during the past year was a study of the fate of tracer phosphate injected directly into the cerebrospinal fluid, the watery liquid which bathes the brain and the spinal cord. This fluid is secreted by the cells of the choroid plexus, structures lying within the ventricles, cavities within the brain substance. The fluid of the ventricles passes into the space surrounding the brain and cord, and is absorbed into the blood vessels of the pia and arachnoid, the delicate membranes which cover the brain surface. It has long been known that the blood capillaries within the brain substance itself, unlike those elsewhere in the body, do not permit the free passage of negatively charged ions such as phosphate. Consequently, the only way in which phosphate from the blood stream can get to the brain substance is by way of secretion by the choroid plexus into the cerebrospinal fluid. Early experiments have shown that when the tracer is injected directly into the blood stream, only a very minute amount finds its way into the ATP and other phosphorus compounds of the brain. From this result the conclusion was drawn that these phosphorus compounds in brain turned over at a very low rate. In the present experiments, when the tracer was injected directly into the cerebrospinal fluid, bypassing the capillaries in the brain substance, there was a very rapid exchange between the phosphate in the fluid and the ATP and phosphocreatine, another phosphorus compound, in the brain substance. Also, more than half of the injected tracer was absorbed into the blood stream from the cerebrospinal fluid within a few hours after the injection.

Two methods were used to determine how much of the tracer was absorbed into the blood stream. One was to compare the amounts of P^{32} in the blood plasma at different times after the tracer was injected into the cerebrospinal fluid with the amounts present there at the same time intervals after the tracer was injected directly into the blood stream. The other was to compare the rates at which the tracer moved into the ATP and phosphocreatine of the muscles from the two methods of injection. This second comparison showed that the rate at which the ATP and phosphocreatine of the brain exchange with the phosphate of the fluids surrounding the cells is higher in brain than in muscle, even though the phosphate has to follow a roundabout pathway from the blood stream to reach the fluids surrounding the brain cells, while in the case of the muscles the pathway for exchange is a direct one.

On the basis of some _in vitro_ incubation experiments, it was reported a few years ago that when iron is added to mammalian blood it is not able to penetrate the red cell. On the basis of these and similar experiments, it has been postulated that the iron in hemoglobin is added to the erythrocyte at a very early state in its development. The mature red cells in the blood of birds are nucleated and correspond to immature erythrocytes in humans. It was suggested that if no iron transfer takes place during _in vitro_ incubation of duck blood, that this would be additional evidence for the theory of hemoglobin synthesis at the time of erythrocyte formation. On the contrary, it has been found that as much as 20% of the iron (either radioactive Fe^{59} or Fe^{55}), added as ferric ammonium citrate, is transferred into the duck erythrocyte in 6 hr and cannot be removed by repeated washings. For comparative purposes, similar studies were completed using pigeon, rat, dog, and human blood. The amount of iron transferred decreased in the order named, the pigeon data showing about equal transfer with that of the duck while human transfer was of the order of 1 - 3%. Very recently it has been reported that immature human red cells (reticulocytes) do accumulate iron on incubation.

In order to prove: (a) that the process involved depends upon a biological system and is not simple diffusion; and (b) whether or not the newly accumulated iron is in the form of hemoglobin, a number of experiments employing duck blood either have been or are in process of completion. Relative to (a) it has been found that addition of sodium cyanide in concentration as low as .005 molar inhibits the iron transfer completely; lowering the temperature of incubation from 37° C to about 5° C partially inhibits it. Simple diffusion probably would not have been affected by cyanide or temperature change. Also in a preliminary double tracer experiment, the hemoglobin in the red cells was tagged with Fe^{59} following its injection into the duck, while Fe^{55} was added to the blood taken from the duck after it was placed in a flask. It was found that the Fe^{55} entered the red cells on incubation but practically none of the Fe^{59} came out. Thus, the process does not appear to involve exchange. It was also found that 95% of the total blood is removed from the rat carcass by perfusion, but, as is obvious from the above fractions, the remaining 5% is unevenly distributed.

It has recently been reported that erythropoiesis (red cell formation) is measurably affected by as little as 5 r of whole body X-radiation. In a preliminary experiment employing 150 r, we have confirmed this finding. The technique consists of irradiation followed by injection of radioiron 24 hr later. The rate and level of the appearance of radioiron in the red cells is then followed as a function of time. Radiation depresses both rate and level. It is planned to utilize the tool of iron incorporation to measure the change in erythropoiesis as a function of radiation from internal sources such as Na^{24}, P^{32}, and Co^{60}.

Radioiron can be most useful in clinical research but there is hesitation to permit its use because it is a bone seeker, has a long half-life, and is not excreted. There are two radioactive iron isotopes: Fe^{59}, whose half-life is 44 days, and Fe^{55}, whose half-life is 4 yr. A method has been developed for measuring the radiations from either isotope in a mixture of the two. By using the one isotope as a radiation source and the other as a tracer, it is planned to measure the effect of radiation from iron upon erythropoiesis as a function of dose and time.

On the basis of studies carried out principally in dogs and humans there is general agreement that iron in the body -- in contradistinction to iron in the gastrointestinal tract -- is very efficiently conserved. In addition, it appears that all the various iron compounds in the body are not in equilibrium with each other. This conclusion is based on the following experiment: a number of rats were injected intraperitoneally with radioactive iron in the form of ferric ammonium citrate. These animals were sacrificed periodically and the ratio of radioactivity to iron isolated from a variety of tissues determined. After 165 days, uniform ratios had not yet been attained.

It has been suggested that under normal conditions the iron in the body is restricted to several "compartments." Thus, iron from one compartment exchanges very slowly with that from another compartment. To test this hypothesis we injected a rat with radioiron (Fe^{55}) and waited until he had used it to build new tagged erythrocytes. Blood from this rat, containing a known amount of radioactivity, principally in the red cells, was transfused into a number of other rats. The radioactivity is now restricted to the red cell compartment. The recipients are being sacrificed periodically, perfused to remove residual blood, and the radioactivity of the various tissues measured. This problem is continuing. It is too early to say whether or not significant amounts of iron can be found outside the erythrocyte cycle.

Creation of oxidizing substances is one considerable effect of radiation on aqueous solutions. One of the most easily oxidizable groups in various biological compounds is the sulfhydryl, i.e., sulfur attached to one hydrogen. The effect of radiation on certain biological material, e.g., many enzymes, is explained by oxidation of sulfhydryl groups. However, shortly after irradiation, no appreciable change in total sulfhydryl groups in blood occurs, although there is some inactivation of enzymes dependent on sulfhydryl groups for activity. This raises the question as to whether the decrease in enzyme activity that follows irradiation of the whole animal is referable to the oxidizing effect of the radiation.

Two methods exist for the synthesis of C^{14}-labeled compounds: (1) classical chemical methods, and (2) biosynthesis or the use of living organisms as the synthesizer. In general, our object has been to make C^{14}-labeled compounds biosynthetically.

This has been carried out by taking advantage of the process of photosynthesis, which is a reaction occurring in green plants whereby carbon dioxide is converted to sugars and subsequently to all other compounds in the presence of sunlight. If one substitutes radioactive C^{14} carbon dioxide for normal carbon dioxide, sugars containing the radioactive isotope are synthesized. Using such a procedure, we have synthesized fructose, glucose, sucrose, and starch containing C^{14}. These compounds have proved useful both in the investigation of carbohydrate metabolism in animals and also in chemical reaction mechanism problems. C^{14}-glucose was used to synthesize radioactive vitamin C. This radioactive vitamin will be used to investigate the use of this essential compound in plant and animal metabolism. From this work, enough of the purified sugars have been accumulated to supply some 25 groups with materials for other programs in a wide variety of fields.

The studies being carried on at the Laboratory are directed primarily towards the elucidation of the CO_2 fixation reactions in higher plants and in microorganisms. The studies are being carried on both *in vivo* and *in vitro*, with more or less purification of the enzyme systems responsible for the intraconversions of the various carbon compounds. Great effort is being expended in the development and refinement of various possible degradation reactions by which tagged compounds produced by the plants are recognized. To state with certainty the course of chemical reactions, the specific activities of all the carbon atoms in the components of the reaction mixture must be determined with great precision. Many of the possible degradation reactions are still imperfectly understood and these must be investigated before some of the major problems can be solved. Technical details of these investigations have been and will continue to be reported in the appropriate scientific journals.

The processes by which radioactive carbon atoms are detected in body tissues and in excretions are still relatively new and subject to much improvement. Each improvement in these processes makes new experiments possible, especially when the improvement means that a smaller amount of radioactivity can be measured. There are two reasons for this. First, some interesting radioactive compounds are so hard to obtain that only extremely small amounts are available for administration to animals. Second, the use of radioactive carbon in tests with human patients may become an allowable procedure if small enough amounts of radioactivity can be administered and later detected. Using a new counting method devised earlier at the Laboratory, a method of detecting radioactive carbon atoms in body tissues and excretions has been worked out, which is fifty times as sensitive as the methods previously in use.

Now that this method is available, it is possible to use radioactive vitamin C, prepared in cooperation with the Chemistry Department, in feeding experiments with small animals. The purpose of these experiments is to find out more about what happens to vitamin C in the body, and what its function is in the body machinery. The first few of these experiments have been done, but it is too early to draw any conclusions from the results obtained. Meanwhile, work has continued on an earlier problem -- namely, what happens to the carbon atoms of sugar when fed to animals. The sugar used was also prepared by the Biology Department by photosynthesizing plant leaves exposed to radioactive carbon dioxide.

It has been found that the sugar carbon atoms are selectively burned and excreted as carbon dioxide much more rapidly after feeding than was formerly presumed to be the case. With some truth it might be said that sugar is fattening, more because it substitutes for body carbon atoms that would otherwise be burned than because its atoms become converted to body carbon. Some of its atoms do become so converted, of course, and the location of these in the body is being studied over several weeks following the feeding.

There are several reasons why the location of these carbon atoms is important to know. First, one wishes to know what parts of the body are very slow in turning over their stocks of carbon atoms. This has to do with the effects of radiation to be expected in the various tissues and is connected with the possible use of radiocarbon in human patients which was mentioned earlier. Second, there are things such as the vitamins and the so-called essential amino acids which cannot be constructed by the body, at least not completely, so that they have to be included in the diet if one is to stay healthy. Now it may be that there are only a few steps in the construction of these compounds which the body fails to carry out. If so, this will be revealed when radiocarbon appears in such compounds as they are isolated from the bodies of experimental animals after feeding radioactive sucrose. If we find out what steps in construction are the ones the animal fails to carry out, this may point the way to understanding certain diseases in which normally present steps of construction may fail to be carried out in addition. It would also be interesting, and, likely, of importance, to know why plants and lower forms of animal life are able to complete these structures, whereas humans and other higher animals cannot do so.

In the past year work has continued on several phases of the general problem of mineral uptake and accumulation by organisms. For comparison with hornets, whose barium and manganese metabolism has been studied in considerable detail, the uptake and distribution of barium by ants was investigated. As expected, very substantial similarities were found between the two closely related groups. As manganese studies in hornets had shown, barium studies in ants revealed a difference in food regimen among the various castes. In ants, the larvae differ from all the other castes examined. It is becoming increasingly evident that radioactive tracers are indispensible tools in studying the relationships within insect societies, whose make-up differs most instructively from ours.

Since, in connections described below, the iron metabolism of _Drosophila_, the fruit fly, was being examined, these creatures were selected to provide a second, less closely related organism, to compare with hornets in respect to barium metabolism. Accumulation of the element was found to be rapid, but the histological and physiological details are strikingly different. The biology of _Drosophila_ is so closely bound up with that of the yeasts on which they feed that it is proving necessary to examine the metabolism by yeast of our strain of both barium and lanthanum. At this preliminary stage it appears that the yeasts selectively reject barium, while accumulating lanthanum. This, should it be confirmed, will be quite surprising, and will also provide us with a new tool for ascertaining the quantitative relative importance, in Drosophila nutrition, of the yeast cells and of the medium on which both grow.

The extended examination of the iron metabolism of larvae of six different species of Drosophila has almost completed its experiment phase. Since this has produced a few thousand slides, both serial autoradiographs and stained preparations, the complete assembly of the data will require considerable additional time. Enough information is now at hand to satisfy the main purpose of the study, and to ascertain whether the histochemical iron stains which have been found by D.F. Poulson, indicating clear differences among the various species, can be used reliably as indicators of fundamental iron physiology. As expected, the staining reactions do not appear to yield reliable information of the metabolism of iron. This is a point of very real importance, since in insect physiology the classical method of finding regions of absorption in the intestine has been feeding iron and then staining. It is evident that most of the descriptions based on this must now be re-evaluated.

In the interstices of the work described above, a program of mineral analysis of marine sponges has been pursued. This study has real practical interest in connection with the cycles of the various trace elements in the sea, now being considered in connection with marine disposal of radioactive waste products. It is also of great fundamental importance in comparative biochemistry, since other workers are studying, on the same material, the various organic fractions so that one may hope to find correlations between organic and inorganic constituents. In the plant kingdom, many of the most bizarre and instructive phenomena of mineral nutrition have turned up in the lower forms, and it is hoped that this will prove equally true of the animals. As data accumulate, it is planned to supplement this program with tracer studies.

Tracer investigations have been made of the uptake and transfer of iodine, phosphorus, and iron by various typical fresh water organisms. The main purpose of this study, still being pursued, is to find short-lived radioisotopes whose movements in nature may be used as indicators of the movements of carbon, for which no suitable isotope is available. Although no success has yet been achieved in this direction, information of real biological value has been obtained. It is reasonable to mention, out of this body of data, that iodine metabolism by Cladocera, minute aquatic relatives of the lobster, appears to differ greatly from that known for insects and some aquatic worms and mollusks. Also, it appears that Cladocera and two species of aquatic insect larvae, contrary to expectation, have no mechanism for the conservation of iron, which has been described as a limiting nutrient for some other plankton species.

Due to a redistribution of Laboratory operating funds, the Department's personnel expansion program was retarded during the past 6 months. However, plans are now under way to acquire the scheduled number of personnel.

As of June 30, 1950, personnel on full or part-time duty in the Medical Department numbered 73, as compared with 63 on December 31, 1949, and 44 on June 30, 1949. At present, the staff includes 9 full-time physicians, 5 of whom are senior members, 2 full-time medical scientists, 1 of whom is a senior staff member, and 3 part-time physicians, of whom 2 are medical examiners and 1 is a roentgenologist. In addition, 1 physician is on leave of absence because of illness. One year ago there were 5 full-time physicians, of whom 4 were in the Division of Industrial Medicine which at present has but 2. On June 30, 1949, of the total 44 employees on duty in the Department, 38 employees were in the Divisions of Industrial Medicine and the Hospital, 4 were in the Division of Pathology, and 2 were in the Division of Biochemistry.

The position of hospital administrator was abolished on March 1. The duties of the administrator were divided among the various supervisory personnel in the Department; thus far, operations have continued at a high level of efficiency. At the same time, many operations were decentralized. Each division maintained its own inventory instead of utilizing the pharmacy as a stock room. This resulted in a saving of 1 full-time person and a definite increase in efficiency, since the user always knows the status of the stock of materials he is using.

This report period has seen the attainment of the objectives of the Department's first stage of operations. These objectives were to complete organizational development, to train a nucleus of personnel in the methods and procedures to be followed, and to lay the groundwork for investigations of long-term character concerning the biological effects of radiation.

Division of the Hospital

On December 27, 1949, the hospital celebrated the first anniversary of operation, and on March 29, 1950, it celebrated the first anniversary of the admission of the first research patient. During the present fiscal year the hospital has shown a steady and gratifying growth. Patients have been admitted from New York, California, Georgia, Illinois, and Virginia, as well as the neighboring states of New Jersey, Pennsylvania, Maryland, and Connecticut. On January 9, 1950, the children's ward was opened, since all present bed space was occupied and sufficient personnel had been trained to permit us to open a ward for children. Within a month, all 8 children's beds were occupied and have remained so. At present, additional beds for children are on order to bring these up to a total of 14 so that the ward may be fully equipped.

During the last quarter of the year, operations were at near capacity and it was obvious that preparations must be made to obtain and train personnel for a third 14-bed ward. When this ward is opened, it will finally bring into use all the hospital facilities with which the Laboratory is presently provided. It remains the policy of the hospital to reserve at all times a few beds for the use of employees, whether or not there are any actual patients. Our experience of the past 2 years suggests that 4 beds for adults will be sufficient for this purpose.

All activities relating to the patients' social welfare, recreation, and education have been centered under the occupational therapist. This section has had a very large growth in responsibilities during the review period. This can best be exemplified by citing the number of patient activities in the occupational therapy shop. From August 1, 1949, when the occupational therapist joined the staff, to December 31, 1949, there were a total of 239 shop activities in which 1 patient working in the shop for any period of time is taken as a unit. The total number of hours work in the shop was 108; the average per patient per day was one hour. From January 1, 1950 to June 30, 1950, there were 916 shop activities. A further increase in hours will be noted from a description of activities given below. In January 1950, an occupational therapy program was started on the children's ward (ages 2 - 5 years). A play therapy group was held every morning from 10:00 to 11:30 a.m. wherein the children carried on various activities such as drawing, modeling clay, cutting out figures and pasting, playing rhythm band instruments, and just playing. This has turned out to be a most successful activity. At the same time, a daily schedule was set up for adult female patients from 1:00 to 3:00 p.m., and for male patients from 3:00 to 5:00 p.m. These were well attended by the patients. Beginning in March, the Sayville Chapter of the American Red Cross completed arrangements for a group of Grey Ladies to come to the hospital two afternoons a week to assist in the patients' recreation and welfare. Games were conducted for adults and children and a weekly class in typing was begun for school-age patients. Recreation was provided by the Young Peoples Fellowship Group from Christ Church, Episcopal, at Bellport. This group came regularly one evening a week beginning December, 1949, to show movies to the patients. When the warm spring weather was expected, a flower and vegetable garden was started by the patients; equipment was obtained for shuffleboard, clock golf, and croquet. These could be played on the grounds adjacent to the hospital. A piano was obtained for a very nominal sum for those patients who can play and for patient entertainment. These ancillary services to patients are exceedingly important as a part of their total care and well-being. In this hospital, the patients remain completely removed from their families and their normal social and entertainment contacts for considerable periods of time. Visitors are few and relatively infrequent because of expense and distance. In order to maintain the psychological well-being of our patients and their ready psychological acceptance of the new treatments, it is absolutely necessary that some substitute be offered for those activities which are cut off. To date our program has been most successful, hampered only by limitations of space and accessibility. This small program, carried out at a very small cost, has added greatly to the patients' contentment and well-being, and has thereby enabled us to carry out numerous observations which otherwise would have been impossible.

Statistics for the patients in the hospital are shown in Table 1. It will be noted that the increase in research patient days for the last six months of this fiscal year is just over 100%, whereas the nonresearch patient days for this period show a decrease of 55%, due largely to the discharge of two chronically ill employee patients.

Research patients during this period comprised those with carcinoma of the thyroid, Graves' disease, leukemia, and the nephrotic syndrome in young children. During the interval, the patients have been increasingly utilized for investigational work bearing on problems associated with radioactive isotopes. In general, this had developed after the organization of the laboratory to dilute and measure isotopes, as noted in the report for the Division of Biochemistry. Treatment of the thyroid patients has been with I^{131} throughout the period. All of the patients with carcinoma were thyroidectomized surgically before treatment with radioactive iodine was begun. In each of these patients, it is necessary to stimulate the tumor with thiouracil or thiouracil and thyrotropic hormone to cause it to take up the iodine satisfactorily. At the present time, in some patients therapeutic doses can be given at long intervals only, and a new approach to treatment in these patients is needed urgently. Work on this aspect is planned for the next interval. In the patients under observation for the past year, there is no evidence to suggest that a near cure has been effected. In some, there is a suggestion of control of the growth of the tumor following the repeated radiation, but this, as noted above, cannot now be given frequently enough to fully control the cancer. The easy optimism which has been broadcast in the popular press in regard to treatment of patients with thyroid carcinoma finds no support in the cold facts obtained by our observation. There can be no question of the value and worthwhileness of this therapy to these individuals, and for some surcease from the disease, radioiodine is irreplaceable. The goals reached by it are, however, limited and these limits must become generally known by the public as well as the profession if the best results are to be obtained.

Table 1

Hospital Statistics

Patient Days	Dec. 1948	Jan. 1-June 30, 1949	Fiscal 1949	July 1-Dec. 31, 1949	Jan. 1-June 30, 1950	Fiscal 1950
Research	0	423**	423	1208	2551	3759
Employees						
occupational	0	81	81	0	0	0
nonoccupational	6*	220	226	180	71	257
dependents	0	46	46	26	61	87
Total	6	770	776	1414	2689	4103

*First patient admitted December 27, 1948.
**First research patient admitted March 29, 1949.

In the patients with Graves' disease, the use of radioiodine has permitted us to achieve a reduction in gland function which could not be sought surgically for these individuals. In each instance the result has been gratifying. The experience in handling isotopes for use in this group of patients has greatly expedited training of the professional staff of the Hospital. While radioiodine is an effective thyroidectomizing agent, it is our belief that it should not be the method of choice in treatment of patients with Graves' disease because of the as yet not evaluated hazards of radioiodine over a long period.

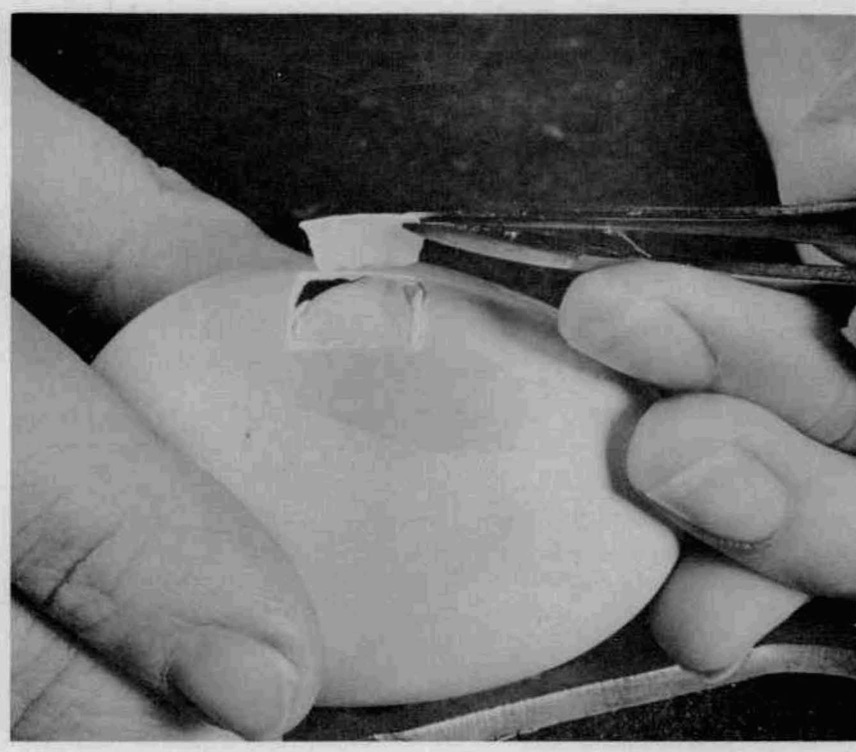


Figure 1. Section of shell being removed from a chicken egg to provide a window for the injection of virus to the embryo.

Figure 2. Radiation count being taken on a thyroid patient in the Laboratory Hospital counting room.

During the latter part of the review period, it was possible to begin studies in the distribution of body sodium and rates of equilibration of Na^{24} in young edematous children with the nephrotic syndrome. During this time, the studies made on these children were preliminary. However, they were extensive enough to yield information of some theoretical interest and to enable us to modify the procedures in such a manner that further studies can be done. In each instance, a very small dose of the 14.8-hour half-life isotope was given on the order of 5 μc per kg of body weight. Calculations indicate that the total radiation from such a dose, which is in fact evenly distributed in the body extracellular fluids, would radiate less than the tolerance dose during its period in the body. In dealing with the children, extraordinary precautions are taken to insure absolute safety at all times. The information to be obtained by this study is of very considerable importance and has an immediate application in the drug dosage and manner of administration to these children when they are stricken with bacteremia and peritonitis, all too often fatal. It will permit certain observations also to be made of the nature of the kidney lesion which so frequently progresses to complete loss of function and death.

A counting room has been set up to do in vivo counting in patients so that both the take-up of various lesions can be determined as well as scanning for new lesions carried out. Some improvements in the equipment and set-up are planned for the near future.

Additional nurses, orderlies, matrons, and kitchen assistants are needed greatly at this time to take care of the increased work load as represented by the increase in hospital days for this period.

Division of Industrial Medicine

As of June 30, 1950, personnel of the Division comprised 2 full-time physicians, 4 part-time physicians, of whom 3 are medical examiners and 1 is a roentgenologist, 9 technical staff members which includes 3 registered nurses, 3 clerical staff members, and 2 service staff members for a total of 20 as compared to 16 one year ago. After the start-up of the reactor, the routine examinations will increase and 2 additional full-time physicians will be required.

Personnel visits to the clinic have remained quite steady during the year and it is believed now that demands for this service can be predicted quite accurately. Special examinations will increase as the reactor becomes operative. These will be conducted as a precautionary measure. Statistics on clinic visits are shown in Table 2.

The clinic laboratory has carried out all the hematology for the hospital during this period. The number of technicians in the clinic laboratory dropped to 3 during one 6-week period due to the absence of one technician who has subsequently returned to her duties. Despite this reduction in personnel the work was satisfactorily performed.

The X-ray statistics are shown in Table 3. The load in this group is now approximately constant except for an increasing amount of work on research patients. It is believed that the present equipment is adequate for present employee health needs.

Table 2

Statistics on Clinic Visits

Visits	July 1-Dec. 31, 1948	Jan. 1-June 30, 1949	Fiscal 1949	July 1-Dec. 31, 1949	Jan. 1-June 30, 1950	Fiscal 1950
Employees						
occupational causes	840	490	1330	538	696	1234
nonoccupational causes	2905	2684	5589	2723	2037	4760
subcontractors	141	133	274	151	230	381
dependents	141	436	577	442	407	849
preemployment examinations	124	156	280	194	97	291
annual examinations	676	622	1298	491	804	1295
Total	4827	4521	9348	4539	4271	8810

Table 3

X-ray Examinations

Examinations	July 1-Dec. 31, 1948*	Jan. 1-June 30, 1949	Fiscal 1949	July 1-Dec. 31, 1949	Jan. 1-June 30, 1950	Fiscal 1950
Employees, nonoccupational	69	116	185	93	100	193
Employees, occupational	0	69	69	52	83	135
Employees, dependents	6	32	38	43	36	79
Annual and Preemployment Examinations						
14 x 17 films	159	265	424	344	454	798
P F X films	178	524	702	294	463	757
Hospital Patients, nonresearch	0	12	12	9	14	23
Hospital Patients, research	0	19	19	78	125	203
Total	412	1037	1449	893	1275	2168

*The X-ray group began operations on October 11, 1948.

During the review period, one employee became contaminated with Sr^{90} and Y^{90}. This person has been repeatedly examined physically and with laboratory aids. Urine analyses have been carried out through the generosity of the Oak Ridge National Laboratory. Most of the contaminating chemical was removed immediately, but a small amount was either inhaled or ingested and became fixed in the body. The latest analyses indicate the patient is now cleared of radioactive contamination. Examinations of additional employees for radiation cataracts were all negative. Those employees who might in the future be exposed to radiation which would cause cataracts have also been examined to be certain of the absence of any defects prior to radiation exposure if it occurs. Examination with a slit lamp is planned for this group as soon as the equipment is received.

Physicians in this Division continued their inspections of the cafeteria and were aware of all health developments effected by changes in sanitary conditions, garbage disposal, and similar public health problems. Members of the Division consulted with other members of the Laboratory staff on these problems as the needs arose.

During the year the general health of Laboratory employees was excellent. Very few employees developed medical illnesses and injuries were few and relatively minor as a whole. Definite plans have been laid for protection of employees' health when the reactor begins operation; it is to be hoped that accident and injury rates can be maintained at their present low levels.

Division of Biochemistry

As noted in BNL 39 (AS-3), this Division took over part of a building which has been improvised into a biochemistry laboratory and is now functioning. During the last six months of the review period, plans were completed for the remodeling of another building in order to provide more suitable quarters for the Division. It is believed that the contract will be let shortly after the beginning of the new fiscal year and that the remodeled laboratory will be ready for occupancy about January 1, 1951.

One year ago personnel in the Division numbered only 2, of whom 1 was a junior scientist and 1 was an administrative assistant. At this date, there are 2 senior scientists, 3 junior scientists, 4 technical assistants, and 1 clerical assistant, for a total of 10 people working in the Division, although technically, at the present time, 1 senior scientist is carried on the administrative officer roster. Further expansion of the Division will take place during the coming year in both personnel and work. Although there has been some research accomplished during the past year, the major effort was the organization and setting up of necessary methods in the laboratory.

On February 2, 1950, Dr. J.S. Robertson joined the Division to head the Department's Biophysics Section. At that time, the counting facilities consisted of an *in vivo* counting arrangement in the hospital, with the counter as yet unstandardized. This made it necessary to send patients to Memorial Hospital in New York City for any *in vivo* counts desired. Several patients were so transported to enable us to make estimations of uptake of radioactive iodine by the thyroid gland and tumor metastases. In the laboratory, a Marinelli cup counter was available for counting liquid samples. At this time all iodine doses were obtained from Memorial Hospital through our consulting staff.

Beginning in February, existing facilities were expanded as follows. There was obtained equipment necessary for remote handling and pipetting of radioactive sources, i.e., a remote-controlled bottle clamp and opener, and a motor-driven pipette manipulator. Lead bricks were obtained for necessary shielding of sources. An electrometer was placed in service. This equipment enabled us to receive the

Figure 3. Three-year old child upon admission to the Brookhaven National Laboratory Hospital, showing typical swelling of the nephrotic syndrome.

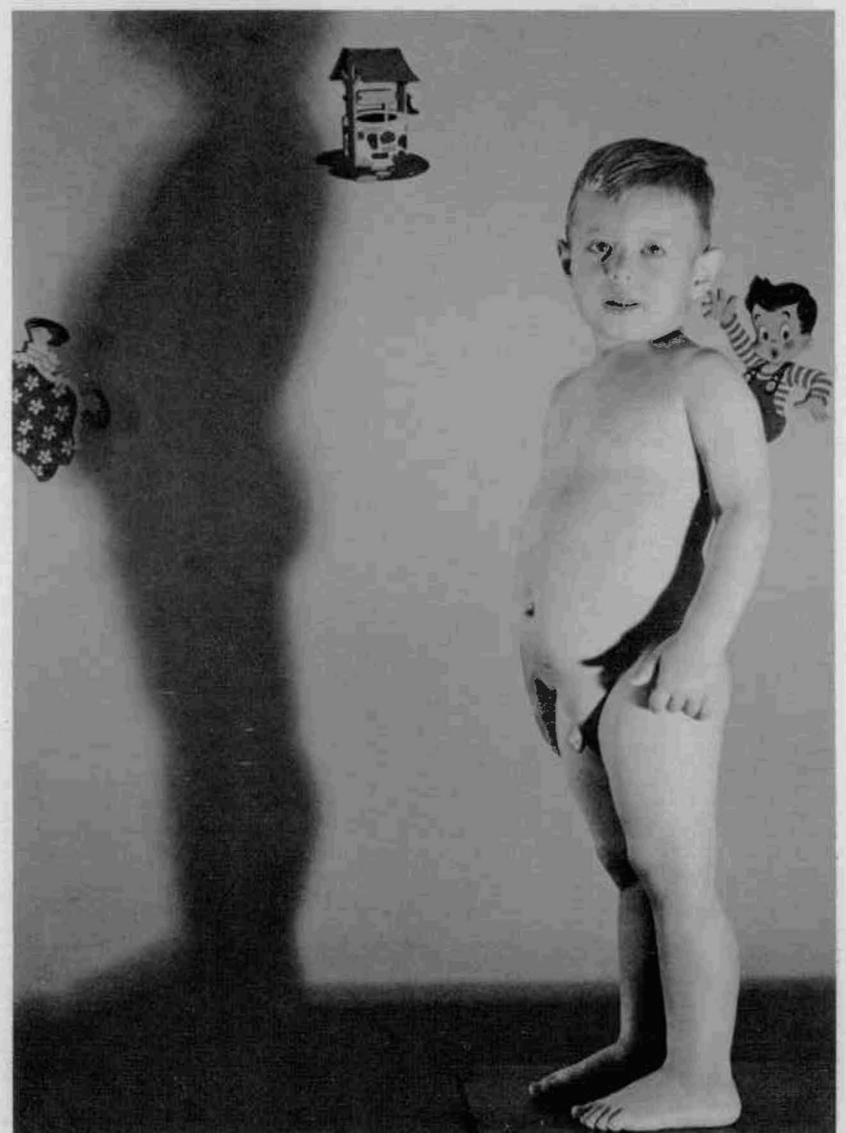


Figure 4. Same child after 9 months in the hospital.

isotopes directly from our source custodian, and to perform the necessary standardizations and dilutions, together with the required preparation for administration. Therefore, it was no longer necessary for us to depend upon an outside institution for assistance.

A second in vivo counting arrangement was installed in the hospital counting room. This consisted of a second shielded gamma-sensitive G-M tube, together with a scaler. This makes it possible to count over a given region and over a control area simultaneously. The scalers for both tubes are mounted in a single rack with a master control panel.

In the laboratory, a shelf counter using an end window G-M tube in a lead housing with a scaler was obtained and put into use for counting solid samples.

All of the counting circuits in use have now been calibrated for absolute counting. Determinations of the corrections for geometry and for coincidence losses have been made for the in vivo and the shelf counters.

Procedures for many of the biochemical analyses to be done on patients are now in operation. Further methods particularly useful for renal function studies will be instituted during the next month.

Using Na^{24}, studies have been started on the rate of turnover of Na^{24} in tissue edema fluid and in ascitic fluid of nephrotic children. The first experiments provided information regarding the most suitable procedures to plan. It was found that the extracellular water compartment of the body, as measured by Na^{24}, comprised a larger percentage of body weight than was anticipated. In five nephrotic children this has ranged from 35 to 47% of observed body weight, as contrasted with a normal figure of about 20%. It has become apparent that the time required for equilibrium to occur is greater than was expected and is a very considerably larger period than is observed in normal adult individuals. A complete study of the children presently in the ward will be done during the next two months for total Na^{24} space and changes in that space as associated disease manifestations become altered.

In collaboration with the Biology Department, the manometric wet carbon combination method of Van Slyke and Folch has been modified so that the total carbon of the sample is first measured as CO_2 and the gas is then quantitatively transferred for measurement of radioactivity. The radioactivity may be measured by quantitatively precipitating the CO_2 as barium carbonate and counting from a disk applied to a methane flow counter, or by transferring the CO_2 to an evacuated gas counter of the type designed by Ballantine and Bernstein. This latter method is particularly advantageous for small amounts of C^{14}. This method enables studies to be done on smaller amounts of biological material than was heretofore possible and with no loss of accuracy.

Division of Bacteriology

This Division has been entirely staffed and organized within the past year. On June 30, 1950, Dr. Horace T. Gardner reported for duty as a senior scientist. At the present time, 2 senior scientists and 2 junior scientists together with 5 technical and

1 clerical assistant comprise the staff. Further personnel plans for the Division call for but 1 additional junior scientist and 1 more technical assistant to come to full strength.

As noted in the last progress report (BNL 39(AS-3)), the Division began work in improvised quarters. In September it moved to better improvised quarters before the present building became available on December 15, 1949. Since that time, it has been possible to extinguish the infected mouse colony and to develop clean "infection free" breeding stock to a point where all present needs for experimental mice can be met from the Division's own stock.

The 2-curie Co^{60} source was soon found to be too small for adequate experimentation, although experiments done with this source were suitable to show the need for a better source for study of the various infectious processes of bacteria and viruses in mice. When the needs were made known, the Reactor Science and Engineering Department designed a 72-curie source which, it is believed, will meet the Division's immediate needs for a radiation source. This is now in the process of construction and the cobalt has been ordered. It is planned to locate the new source in the hot laboratory, since no facilities for a source of that intensity are now available in the Division's laboratories.

Considerable preliminary work has been done on tumor immunity using transplantable and spontaneous tumors in mice. At the present moment attention is being directed primarily toward the relation of homologous tissue immunity to the development of tumor immunity. Preliminary experiments which have been completed have served as pilots for development of procedure and techniques.

Irradiation of chick embryos in the present 2-curie source has indicated that for such experiments the larger source designed for the mice will be desirable. With the present source it is impossible to give the required amount of radiation to significant numbers of chick embryos within the time at one's disposal. This work will be enlarged in scope and intensity when the new source becomes available.

Preliminary data on effects of irradiation on "infection free" mice were given in the quarterly progress report (BNL 51 (S-5)). Further significant data along this line have also awaited completion of the 72-curie Co^{60} source.

Some preliminary work has been done on bacterial nutrition involving, in part, the type transformation of the pneumococcus. This work is being continued at present.

During the year, the Division has made 556 determinations on 155 specimens obtained from patients in the out-patient clinic and the hospital.

Division of Pathology

One year ago, this Division had a total of 4 employees, whereas 6 months ago there were 7. On June 30, 1950, there were a total of 8 employees, 2 of whom are scientists. In addition, 1 senior scientist remains on a leave of absence because of illness. As noted in the last semiannual progress report (BNL 39 (AS-3)), the

Division moved to its present quarters about November 1, 1949. Final work on the facility was completed in December. Since then the laboratory has been available for research. In addition, a histological technician on the Hospital staff has been trained for tissue work. At the present time, the Division is offering pathological laboratory service for other divisions of the Department.

Research work is continuing on the influence of injuries and disease states upon the formation and fate of tissue and blood proteins. It is known that previously normal persons suffering from any one of a variety of acute conditions, such as physical injury with shock, bone fractures, radiation injury, certain inflammatory processes, and similar states will show an increased breakdown of general body protein. These patients will often show clinical evidence of delay in or even resistance to its regeneration during recovery. In most, if not all such conditions, the minimization of these protein losses and the facilitation of their restitution may be regarded as important medical goals.

With the aid of amino acids labeled with the isotopes N^{15} and S^{35}, we are studying the formation, the breakdown, and the reformation of certain of the body proteins of animals in which controlled abnormal states are induced. The influences of certain hormones, antibiotics and metabolites, upon the responses of these animals are an added part of the investigations. We are also interested in further discoveries of the functions of the many specific particles of which cells, as seen under the microscope, are composed. We are at present investigating the origin and fate of certain particles which can be seen in and separated from essential kidney cells after the animal has been injected with blood plasma, amino acids, or foreign proteins. This latter investigation is being conducted in collaboration with the Department of Pathology, Long Island College of Medicine of the State University of New York.

RADIATION PROTECTION

The Brookhaven National Laboratory radiation protection program covers the protection of individuals from harmful radiation, both on and off the site, in several ways. In regard to the handling of radioactive materials, the Health Physics Division provides personnel and equipment for the survey and control of radiation levels in working areas. The day-to-day control of decontamination and the disposal of active products are also controlled by the Division. The special problems introduced by the nuclear reactor are being investigated by groups within the Reactor Science and Engineering Department as well as by the health physicists. The topics under investigation are of meteorological and geological character. Information gained from these studies is used to safeguard personnel in the area of and adjacent to the Laboratory site from possible exposure to radiation due to the exhaust gases from the reactor air-cooling system, and from possible water leaks from the Laboratory waste system into the ground water.

Stringent requirements as to the quantities of radioactive materials which can be released into the air and into the waste system have been set by the AEC. The Health Physics Division, through its continuous monitoring equipment, measures the level of activity at all times at sixteen fixed locations on and off the site, and can make localized spot checks by means of mobile equipment. The Meteorological Control Group has developed techniques for the taking of weather data and for the prediction of ground level activity due to the exhaust gases from reactor operation. Geological information will be required only on a control basis. The normal waste will be controlled so that activity is within prescribed limits. However, should a leak develop in some water system in which considerable activity is contained, it is necessary to know the flow pattern and ultimate path of contamination.

The several activities have been in actual or simulated action over the report period. With the operation of the reactor, meteorological predictions can be checked by actual records of activity. The geological studies will be carried to completion while monitoring of the ground water flow continues.

Health Physics

The staff of the Health Physics Division has remained stationary at 36. Of this number, 16 are engaged in building survey activities, 9 in area monitoring, 6 in personnel monitoring, and 5 in general administration and clerical work. Service activities have continued on about the same level, but a considerable increase is expected this fall as a result of the start-up of the reactor and 60-inch cyclotron. At the request of the AEC, there was a large increase, last spring, in the effort expended on training programs. A second group of AEC Fellows is scheduled to come to the Laboratory next spring or summer for field experience, but there are no definite plans for other training courses during the next year.

Plutonium urinalyses are being obtained for staff members who have previously worked with this substance at other laboratories or whose work at BNL might be concerned with it. Since plutonium is a component of irradiated uranium and fission product mixtures, a large number of individuals are involved. The analytical work is, at present, being done for us on a temporary basis by Oak Ridge National Laboratory. The advisability of setting up a facility for this and similar analytical work at the Laboratory is being considered. A series of strontium-yttrium analyses were also obtained from Oak Ridge National Laboratory for several individuals exposed to inhalation of these substances. In all cases, the amount deposited in the body was found to be negligible compared with a conservative tolerable limit. A report of the findings in one case is being prepared, since the data obtained are of considerable scientific interest.

A revision of Safety Manual material on waste disposal is being prepared and will be issued soon.

A health physics surveyor has been on 24-hour emergency call. An average of 2 calls per month has been received, mostly of a minor nature. Round-the-clock shift coverage is to be provided by the Health Physics Division during the reactor start-up period in August. Some after-hour coverage is anticipated during routine operation of the reactor, but the extent of such services which will be required will only develop with experience.

Training

A 5-day training course in health physics was conducted for 92 representatives of 42 casualty insurance companies. This course was arranged by the AEC at the request of the casualty companies. The field of radiation safety was thoroughly covered by 12 lecturers drawn from Brookhaven National Laboratory, universities, and the AEC technical staff. Publication of the proceedings by the AEC is scheduled for this fall.

The second major project in health physics training was the 5-week course in civilian defense against atomic attack, given for representatives of states in the northeastern part of the country. This was one of several primary courses given in various parts of the country for those who will take responsibility for establishing broader training programs in the states. There were 15 representatives from 10 states, Puerto Rico, and the District of Columbia in attendance.

During the course, 38 lectures were delivered by Laboratory staff members, and 9 by other speakers. Also included in the curriculum were 17 laboratory experiments, 3 field exercises, 10 moving picture films, and 8 seminars. Considerable literature was obtained for distribution to those attending, and a number of lectures were recorded and distributed after suitable editing.

Field experience was provided by staging a simulated disaster. For this purpose, a surplus building (Figure 1) was contaminated with 1.7 c of activated KBr. A general radiation field was produced by the use of 15 c of radiocobalt. The class was organized into teams equipped with transportation, communication equipment, and radiological monitoring instruments. Later in the spring, a similar field exercise was conducted for the New York monitoring team of the AEC. Exceptionally pure KBr was used to avoid long-lived contaminants; the residual activity of the site is now less than 2 μc.

There has been a continuing program of training in health physics for hot laboratory and reactor technicians, including both lectures and operating experience. Five AEC Fellows are now at the Laboratory for a 10-week period of practical experience in health physics operations, after having completed a course at the University of Rochester.

Waste Disposal

The AEC has approved a policy for disposal of radioactive liquid waste at BNL. This policy requires that the effluent from the Laboratory sewage system, averaged over a 3-month period, shall not exceed 3×10^{-12} c/cc. Peak values of 10 times this concentration are permissible, but the total amount released per year is limited to 1-1/2 c.

In order to guarantee compliance with the above limits, extensive monitoring facilities have been provided at the sewage plant. They consist of 2 gaging stations for determining the flow of the stream to which effluent is discharged, and automatic sampling and flow-measuring installations at the input and output of the filter beds. All 4 of these installations have been constructed and will be put into routine operation as soon as minor adjustments are made.

In order to achieve the low limits for liquid waste disposal, it has been necessary to provide monitoring and hold-up facilities at certain laboratories. During the past 6 months, automatic samplers and hold-up tanks have been installed at the new biology laboratory and at the cyclotron chemistry laboratory. There has been considerable difficulty with the proportional sampler in use at the chemistry semi-hot laboratory, because of low flow rates and imperfect neutralization by the neutralizing tanks. A new type of sampler, operating on a simple mechanical principle, has been designed by the Architectural Planning and Plant Maintenance Department and shows great promise.

Figure 1. View of simulated disaster in civilian defense training course in radiological monitoring. The wrecked building was contaminated with 1.7 c activated KBr. About 15 c Co^{60} were used to produce a general radiation field which the trainees mapped.

The activity of the effluent from the waste processing tanks has usually been less than 10^{-14} c/cc. On occasional days, activities in the range of 10^{-13} to 10^{-14} c/cc have been noted as a result of the dumping of the hold-up tank at the chemistry semi-hot laboratory.

A conference was held with New York state public health officials and representatives of the AEC in regard to the Laboratory's waste disposal practices. The state representatives expressed general approval of the BNL procedures, and plans and arrangements were made for a continuing interchange of information.

Detailed plans for the setting-up of a decontamination laundry have been completed by the Architectural Planning and Plant Maintenance Department. A contract for the necessary construction work has been let, and operation of the laundry should commence late this fall. An existing building in the hospital area adjacent to the steam plant is being modified for this purpose.

Building Survey

The usual surveys of laboratories and clean areas for contamination control purposes have been carried out. The few "spills" which occurred were localized so that very clean conditions have been maintained. A set of instructions for safe handling of curie size Ra-Be and Po-Be sources has been prepared, since such sources are being used widely for apparatus testing and neutron irradiations. A summary of hazards and explanation of proper procedure has been prepared for use by those experimenters working with uranium.

Detailed studies have been made of the shielding of a 2-Mev electrostatic generator, recently put into service in the Chemistry Department. Two deficiencies have been noted -- an undesirably large amount of scattered radiation coming through the wooden door giving access to the vault, and scattered radiation in the surrounding area due to lack of overhead shielding. The first difficulty is being solved by improvements to the shielding of the high energy electron beam, and by the addition of a steel door between the outer laboratory and the passageway outside the vault door. The second difficulty is not a health problem, but is receiving consideration since the resultant erratic disturbance to background radiation levels may be a handicap to experimenters in near-by laboratories.

Necessary alarm circuits and monitoring routines have been completed for the Accelerator Project for their 2-Mev General Electric accelerator. Instrumentation and plans are ready for the initial phase of the 60-inch cyclotron operation. Some thought is being given to health physics responsibilities connected with the Cosmotron. The radiations to be produced will be in a very high energy region where little is known about the behavior of instruments or about biological effects.

Neutron-measuring instruments needed for use at the reactor have been procured and their operating characteristics and calibrations determined. Both BF_3-counter and ionization chamber types are being provided. Plans have been completed for very comprehensive radiation protection activities during the period of reactor start-up.

An 8.5 l ionization chamber that can be evacuated and filled with a sample of laboratory air through a drying tube has been constructed and tested. This is particularly useful for detecting contaminants in gaseous form or with low radiation energy which are not detected with the filter paper type of air sampler. Using a standard minometer, a "tolerance" concentration of 10^{-12} c/cc of C^{14} is detectable in a few minutes. For tritium, which has the same concentration limit, a longer observation carefully corrected for background radioactivity is necessary. A similar chamber with an open end has been constructed for direct assay of liquids. It is relatively insensitive compared with the evaporation method but may be useful for checking hold-up tanks or wastes that are thought to be dilute enough to pour into a laboratory sink.

Work has continued on a variety of testing and development projects. Among these are the design of an apparatus for the safe opening of liquid isotope shipments, an arrangement for reducing the operating temperature of air sampling equipment, design of a Co^{60} howitzer for use in irradiation experiments by the Biology Department, manufacture of Co^{60} and plated polonium sources for laboratory use, and determination of counting efficiency and dead time for the beta-gamma counter used with precipitron samples.

Samples of airborne particulates are being collected at selected locations on sedimentation frames and radioautographed so that the possible occurrence of radioactive particulates can be detected as Laboratory operations expand. Health physics headquarters have been set up at the hot laboratory, where extensive tests of the shielding and establishment of procedures for contamination and exposure prevention are being instituted. The operating characteristics of an aspirator type air sampler, designed and constructed by the Survey Group, have been determined. This instrument has been quite useful for continuous monitoring in critical locations. It is shown in Figure 2 with the cover removed. The heart of the apparatus is a glass filter pump (A). The rotameter (C) can be placed between the filter paper holder (H) and the pump to determine the rate of air flow. Cotton, celotex, and an acoustic labyrinth are used to deaden the noise of the escaping air.

Area Monitoring

The 16 area monitoring stations have been fully equipped for some time, but a number of improvements has been made to the continuous dust monitors and the battery operated ratemeters. A great improvement in the photographic record has resulted from the use of properly adjusted side lighting. Operation difficulties, due to wear, have developed after long continued use. Improvements in design and maintenance techniques are being made continually in an attempt to overcome these difficulties. The over-all operating efficiency of the stations (fraction of possible data actually obtained) has been about 83% during the past 6 months.

A very good understanding of natural radiation conditions has been achieved during the period of disturbance-free operation of the area monitoring stations now drawing to a close. During the next year, data from the stations will begin to serve their major purpose of recording the effect of reactor operation. Close cooperation and joint action by the Health Physics, Meteorology, and Reactor Operations Divisions are planned for the start-up period. Procedures for routine operation will be worked out on the basis of experience gained in the first few months of actual operation.

A study is being made of the radiation at the edge of the site produced by the large cobalt-60 source, used by the Biology Department for field irradiations. It appears that the present field will have to be modified or abandoned when the reactor commences operation. However, a second field, using a larger source, which is planned for next year, appears to be more favorably located.

Personnel Monitoring

The use of personnel monitoring equipment has increased only slightly, and now amounts to about 2200 film badges and 2000 pairs of pocket chambers per month. One hundred twenty-five neutron films are being used per month, which is double the number in use 6 months ago.

There have been no serious over-exposures of personnel to radiation during the report period. In only two instances did a film badge record slightly over the 300 mr weekly limit. Some use was made of finger rings and wrist badges to control hand exposure during certain types of experiments.

An analysis of pocket chamber readings showed that readings of over 50 mr, unconfirmed by the second chamber worn by the same individual, were obtained for 1% of the chambers read. Routine cleaning and drying procedures are used to combat the prevalent high humidity.

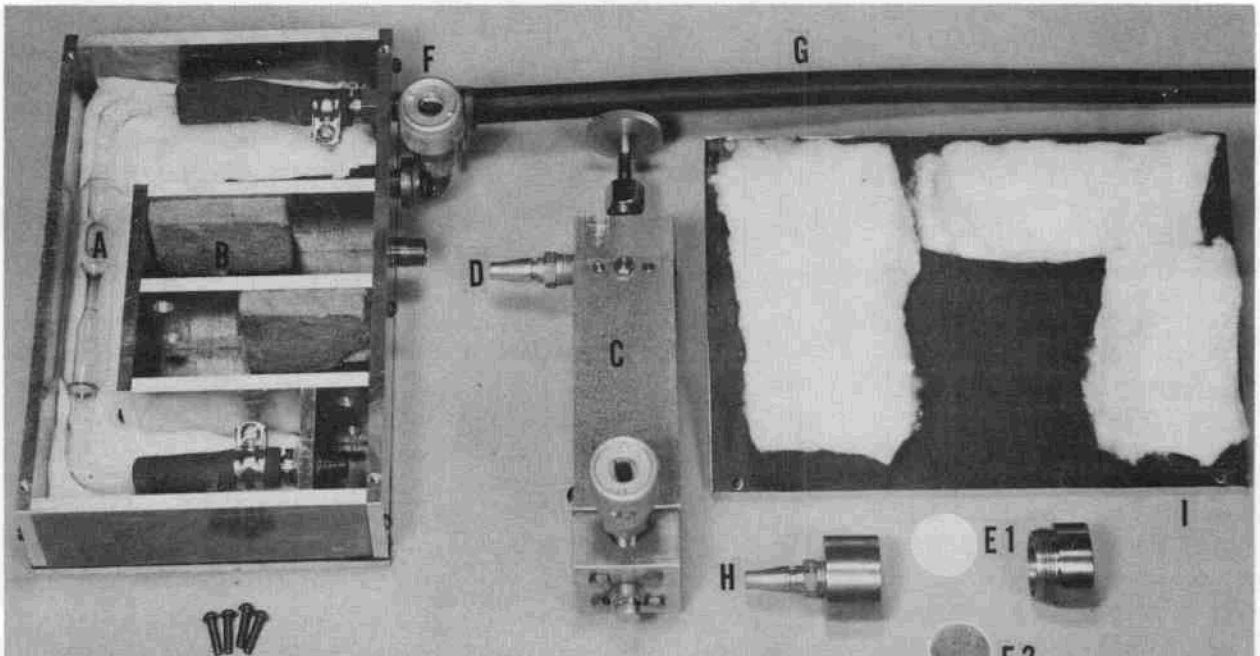


Figure 2. Aspirator air sampler for monitoring active dusts. The glass aspirator pump A, operated from the laboratory-compressed air supply through tube G, draws in a sample of air through inlet F. The filter paper holder H, containing the paper E on which the dust is collected, may be plugged into F, or the rotameter C may be interposed if it is desired to measure the air flow. The exhaust is muffled in the labyrinth B to avoid annoyance to the occupants of the room.

A study was made of the effect of the cap of the finger ring on beta exposure measurements. It was found that the cap excludes all beta rays of less than 300 kv energy, and results in a 25% lower exposure estimate for uranium betas when the film is read using the regular Ur-beta calibration.

Emergency Radiological Monitoring Team

At the request of the AEC, the Laboratory has been organizing a disaster team to provide radiological monitoring in the event of an off-site accident involving radioactivity. Pending the training of a state civilian defense monitoring service, the Laboratory team will be held in readiness to serve in the event of an atomic bomb attack. At present, personnel for the team has been designated and most of the necessary equipment procured. An available Fire Department emergency truck has been adapted for the purpose, communication equipment has been provided, and two jeeps, earmarked to supplement the main truck and necessary instruments and supplies, have been assembled. Several training sessions have been held for the team members, and more are projected. Liaison is being established with county and metropolitan civilian defense authorities.

Meteorology

General

The staff of the Meteorology Group has remained almost completely stable in all respects during the past year. The activities of the 16 persons continue to be divided nearly equally among the three major subdivisions of the organization: instrumentation, statistical analyses, and forecasting.

The focal point of virtually all activities during the past six months has been final preparation for reactor operations. This has involved the revision of both facilities and procedures, in order to make the most effective use of the data available. Of the changes made, the recalculation of the radiation dose-rate templates is probably the most important. These templates, used to convert meteorological data to ground-level radiation dose-rate values, are based necessarily not only on the oil-fog tests, but on a number of assumptions that cannot be verified prior to actual reactor operations. It has been possible, however, to simplify the mathematical treatment and to refine several of the approximations so that the accuracy is believed to be improved significantly.

The Health Physics Division and the Meteorology Group share a joint responsibility in the radiation protection program as far as the reactor is concerned. With the approach of reactor start-up, liaison between the two groups has become increasingly close. Plans are now established to obtain the necessary comparisons between calculated and actual radiation dose-rates, so that appropriate adjustments can be made. Cooperative procedures to be followed during adverse dispersion conditions have been agreed upon.

Several other organizations and individuals have been making use of the Laboratory's meteorological data. Two graduate students, from N.Y.U. and M.I.T., have been with the Group while preparing their doctoral dissertations. In addition, co-operative research programs with the National Advisory Committee for Aeronautics and with New York University have been approved and are now in operation. The NACA project is concerned with the correlation of meteorological measurements of turbulence with those obtained from aircraft in flight, while the New York University program is concerned with the comparison of wind tunnel tests and natural atmospheric dispersion.

Instrumentation

As is to be expected with unusual installations, the first year and a half of operations has revealed a number of defects in equipment and procedures. As a consequence, a considerable portion of the Group activity has been associated with the relocation of instrumentation, and with the revision of maintenance and calibration procedures.

The 410' tower has been equipped with Friez Aerovanes at every level; the 160' tower has been equipped similarly with Gurley wind equipment. This change will insure uniform measurements through the height traversed by each tower. The Leeds and Northrup temperature instrumentation has been found to be adequate for our purposes. However, the double-cylinder aluminum housings for the thermohms were found to be difficult to disassemble following the lightning strike (December 2, 1949) -- so difficult, in fact, that several were damaged beyond repair in the process. A new and simpler design has been prepared, and these housings have now replaced the old units.

Adequate calibration of meteorological instruments has constituted a problem since the inception of the program, primarily because the equipment must be calibrated after installation on the towers. The original method of calibrating thermohms by comparison with mercurial thermometers when air temperature variations were small has been replaced by a water-bath technique. This consists of immersing the resistance thermometer in a container of water which is brought to within 0.1° C of the prevailing air temperature at the level, as indicated by a mercurial thermometer. The water temperature is then sufficiently stable to make the difference in lag between the resistance and the mercurial thermometers of little consequence. A new technique for the calibration of anemometers in situ has also been adopted. A synchronous motor connected to a gear housing provides rotation speeds corresponding to a wind speed range of 2.4 to 39 m sec^{-1}.

Since February, 1950, continuous records of both vertical and horizontal gustiness at the 355' level of the 410' tower have been obtained from a BNL-designed bivane. Prior to installing this bivane (Figure 3) on Ace (410' tower), both the transmitter and the associated recorder were tested in the low speed wind tunnel at the College of Engineering, New York University. The tests were designed to measure response characteristics. It was found that the natural period, both vertical and horizontal, is 40 sec at a wind speed of 1 ft sec^{-1}, and, of course, varies inversely with wind speed.

The cascade impactor, described in BNL 48, has been calibrated for use with oil-fog smoke. Using four jets with areas ranging from 6.444 mm^2 to 0.841 mm^2, sonic velocities are obtained in the fourth stage. A number of samples of test oil-fog smoke have been taken. Methods of analysis and photography have been investigated with the assistance of personnel of the Biology Department and the Photography and Graphic Arts Group.

Figure 3.

Analysis

The mathematical basis of the dose-rate templates, described in BNL 48, has been revised and extended in three important respects: the initial rise of the effluent plume above the stack has been taken into account for both inversion and lapse conditions, a more exact model of turbulent diffusion has been used to calculate dose-rate under lapse conditions when significant vertical diffusion occurs, and the beta contribution is now properly accounted for.

All of the data on the initial rise of the plume above the stack have been obtained in wind tunnels; no full-scale tests have been reported in the available literature. There is general agreement that the principal parameter to be considered is the ratio of stack exit velocity to the horizontal wind speed. The buoyancy of the relatively warm effluent is of less significance except under nearly calm conditions. Considering the relatively small density difference between the ambient air and the reactor cooling air, the effect of buoyancy has been neglected.

If, as most investigations have assumed, there is no scale effect (i.e., the rise is independent of stack size when measured in units of stack diameter), observations on the meteorology test stack may be applied to the reactor chimney. These observations are in rough agreement with most of the wind tunnel studies. Based on an assumed exit speed of 7 m sec^{-1} at the reactor stack, values of the effective reactor stack height for various wind speeds are given in the accompanying table. These values, based on a standard site ground elevation of 80' (msl), have been used in the preparation of the new inversion templates (Figure 2).

Effective Stack Height (m)	Horizontal Wind Speed (m sec^{-1})
150	2.0
120	5.5
108	9.5
108	14.0

The diffusion equation for a continuous point source, developed by O.G. Sutton, has been the chosen model from which the ground level dose-rate under lapse conditions has been calculated. The contributions from gamma and beta radiation have been calculated separately, because the mean path of the gamma rays, neglecting scattered quanta, is of the order of 300 m in air, while the maximum beta range is 5 m. The beta dose-rate may, therefore, be calculated on the basis of an infinite cloud, while the gamma dose-rate depends on the activity of a fairly large volume of the radioactive plume.

The dose-rates obtained by adding the gamma and beta contribution at each (x, y) represent that amount received from the reactor stack, with a nonvarying wind direction. The actual dose-rate for a 1-hr period will be spread over a wider area, according to the hourly frequency distribution of wind direction. The distributions used are the average of a number of observed hours at the stack level for each weather condition. The final templates, as described in BNL 48, give the mean hourly dose-rate in multiples of the off-site operating level.

The meteorological conditions of primary importance in the restriction of reactor operations are wind direction and rate of dispersion, the latter being a combination of both wind speed and turbulence. An average dose-rate in excess of the off-site operating level almost always will be associated with a persistent wind direction over a number of days, coupled with relatively poor dispersion of the effluent.

The original set of dose-rate templates has been used in the preparation of a study giving the azimuthal distribution of ground level dose-rate values exceeding the off-site operating level from January to May, 1950. The assumption of full-power reactor operation provides the basis for the calculation.

The results of this study are compared with the frequency distribution of wind direction (Figure 4). The danger of using the frequency distribution of wind direction alone to find the most probable areas of maximum dose-rate is also shown in Figure 4. The percentage frequency of the direction toward which the wind was blowing for the period January to May, 1950, is shown, together with the frequency of off-site dose-rates in excess of the off-site operating level. West was the most frequent direction of excessive dose-rate, amounting to 29% of the total number of days above design level, while the wind was easterly (blowing toward the west) only 9% of the time. Of equal significance is the complete absence of any dose-rate 3.5 mr/week to the north and east of the reactor, despite the fact that the wind was blowing toward that direction 38% of the time.

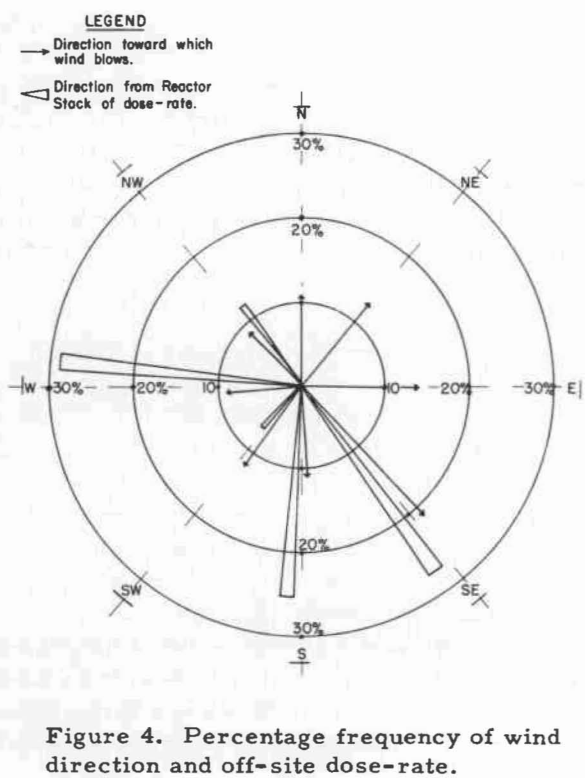


Figure 4. Percentage frequency of wind direction and off-site dose-rate.

Forecasting

The forecast program has also undergone a significant change in the sense that the emphasis has been placed on complete stability of the system, rather than development. This has provided an opportunity for intensive practice in the day-to-day situations that will confront the forecasters when the reactor reaches full power. Both scientists and technicians have participated in the practice sessions routinely, and all are now well versed in the technique.

In previous reports, analyses of general and micrometeorological forecast accuracy have been presented. These were of interest in assessing the progress of the various portions of the program. However, it cannot be said that they provided any direct indication of the effectiveness of forecasting in terms of meteorological control of the Brookhaven National Laboratory reactor. However, the practice forecasts made on the basis of a 5-day week between January and June, 1950, were evaluated directly in this manner.

Of the total number of days during the period when calculated radiation dosage would have exceeded the off-site operating level, 75% were accurately foreseen in the 24-hour operational forecasts. In the unforeseen 25%, a recommendation for restricted operations would have been made between 4 and 12 hours in advance. On three occasions, the operational forecast called for restriction of operation when it would not have been necessary. During actual operations, the recommendation for shutdown or restriction would thus have been cancelled on a few hour's notice.

The achievement of 75% accuracy for the 24-hour operations forecast is encouraging, because the micrometeorological forecasts during the period June to December, 1949, averaged only 60% accurate. The improvement results largely from two factors: continuous practice on an unchanging system, and the fact that the reactor operations situation is often easier to predict than the micrometeorological situation. For example, a number of cases are found in which operational accuracy depends only on correctly forecasting that the wind will not blow in a given direction. In cases of this type, the micrometeorological prediction may be in error without affecting the operational outlook.

Geological Studies

During the past year, the difficulty and the importance of setting up a network of water sampling wells adequate to detect any possible contamination of the ground water have been realized. The previous studies have given a picture of the geology and hydrology which would be sufficient to solve the usual type of water supply problem. However, this information is not complete enough to predict with assurance the path that would be followed by possible contamination. It is necessary to determine local departures from the average water flow and also the details of the direction of the flow. Another important point is to determine the width and thickness of the contaminated body of water that might be expected at any distance from the source of contamination. Only when these are estimated can the proper location, spacing, and depth of the sampling wells be determined.

Because of the complexity of this problem, some of the previous plans had to be modified. The present plans call for two distinct, closely related approaches. The first is a detailed inventory of what happens to rain. Assurance can be gained that there are no important unsuspected movements only if one can account quantitatively for all of the water. The need for the study is emphasized by the discrepancy between calculated and measured rates of flow of ground water in the Laboratory area.

Detailed studies have been started on the relationship between rainfall, evapo-transpiration, soil moisture, and recharge to the water table. In this way, it is hoped to determine more exactly the quantity of recharge, now believed to average 21" a year.

The second approach planned is the use of chemical tracers to determine directly in the field the direction and rate of flow of the ground water.

Final samples for background determination were taken and sent to Washington for analysis, in order to complete plans for a network of water sampling wells.

The studies of the Gardiners clay were completed. They substantiated the suspicion that this important barrier to the downward movement of the ground water is not so widespread and continuous as drilling records would suggest.

DIRECT SERVICES

The direct services of the Laboratory include those groups that provide direct supporting service to the research programs of the various scientific departments. These services are of a technical nature and include such items as drafting, shops, photography, library, and publications. The work load of all groups has remained about constant. The Library staff is decreasing, since the initial phase of setting up a library has been passed. The present staff is adequate to operate the Library and to take care of normal yearly expansion. The Photography and Graphic Arts Group has increased in size by the addition of groups from other departments, consolidating the duplicating services of the Laboratory with a net saving in manpower. The construction load (reactor and accelerators) of the Laboratory has not decreased sufficiently to show any decrease in the required direct services. In fact, the steady demand of these projects plus the increasing demand of the research projects has established sizable shop backlogs which must be completed.

Information and Publications

During the review period, the Information and Publications Division* has become increasingly active in its functions for assembling and disseminating technical information, both within the Laboratory and to other atomic energy installations. This growth in the work load reflects the steady progress of the Laboratory's research program. In the meantime, the Division's staff is being reduced from 36 to 20, a reduction made possible in part by the postponement of several of its less critical technical information services, and in part by the transfer of the report reproduction facilities to the Photography and Graphic Arts Group.

While the basic program of the Research Library remains unchanged, demands for library service are continuing to increase. There has been an important shift in the work load emphasis from the Acquisitions and Cataloging Sections to the Circulation and Reference Sections. Now that the basic collection is virtually completed, the volume of new acquisitions has been reduced to those current items, mainly periodicals and textbooks, most urgently needed by the scientific staff. Very few back sets of periodicals have been procured during the past year. In many instances where back items have been needed, they have been obtained through the interlibrary loan system.

The reference staff has been called upon to give increasing service in bibliographic research and translations, particularly to the Biology and Physics Departments. Some assistance was also given to the United Nations staff in checking over 2,000 references for their international bibliography on atomic energy. A microcard reader was recently installed in the Library; this machine enlarges to readable size pages of books and periodicals which have been printed in greatly reduced size on 3" x 5" cards. A number of the back issues of the rarer periodicals is now being reproduced and made available by this means.

*Renamed Technical Information Division, effective August 31, 1950.

The demands being made on the Classified Library are also on the increase. The holdings of the Classified Library at this time average four copies each of over 8700 classified reports, 4000 memoranda and letters, 1500 drawings, 1000 photographs, and 120 laboratory notebooks. All these classified documents, over which the Laboratory has accountability control, are being inventoried by the Group on a continuous basis, with the objective of approaching completion at the end of each calendar year. In addition, the classified files of duly authorized staff members within the exclusion area are being inventoried at 7 to 9-week intervals, depending upon the existing work load of the Group.

During the past six months, the Publications Group has edited and processed for publication over 30 major documents. This figure does not include the Weekly Bulletin or the Weekly Selected Reading List, which continue to be issued on a routine basis. There has been a marked increase in the number of classified reports, emanating from the Reactor Science and Engineering Department, which have been processed by the Division during the review period. As compared with a figure of 2 for the last six months of 1949, 11 reports have been handled so far during 1950. The Guide to Russian Scientific Periodical Literature, now in its third yearly volume, is still issued on a monthly basis. Increasing stress is being given to translated abstracts and even full-length articles in the fields of nuclear physics and nuclear chemistry instead of restricting the scope of this publication to titles only, as was done at the inception of the Guide.

In addition to the publication of reports under Brookhaven National Laboratory auspices, the Division is also responsible for the processing of technical manuscripts written by Laboratory scientists for publication in the professional journals. The number of these papers, which must be reviewed for security and patent significance before they can be submitted for publication, has increased steadily from 70 to 90 to 102 during the past three successive six-month periods. It is anticipated that the volume of such material will increase further as the Laboratory's research facilities continue to develop.

The Division's functions in distributing the Laboratory's unclassified reports within the atomic energy project have continued. Much effort has been given to insure that the information in such documents is made available to those most likely to benefit. Accordingly, every report is given an individual distribution based on its subject content, in addition to receiving the established standard distribution.

Photography and Graphic Arts

During fiscal year 1950, the personnel of the Photography and Graphic Arts Group* decreased from 19 to 18. However, as of July 1, 1950, 7 persons were absorbed from the Information and Publications Division and the Office Services Group, in order to have all of the Laboratory's report reproduction facilities consolidated into one unit. The acquisition of 1,650 sq ft of space permitted the consolidation of all photo-offset operations, which has materially increased the efficiency of the Group. A technician has been permanently assigned to a classified darkroom in the same area. This enables the Group to do classified work without additional guard services. The consolidation of the photo-offset operations has relieved considerably the pressure for photographic space, and has permitted the construction of two additional darkrooms.

*Renamed Photography and Duplicating Division, effective August 31, 1950.

Services rendered to the Laboratory have proved to be of a greater variety and have continued at an increasing rate. A collection of photographs depicting the activities of the Laboratory, to be used by lecturers and for public relations and public education activities, has been started and is progressing satisfactorily.

During the report period, production figures for the Group were as follows:

photographic negatives	2,553
photomicrographs	746
photographic prints	29,002
lantern slides	1,554
photostat prints	22,164

In addition, 8.75 miles of 16 mm film were processed.

The offset unit handled 260 jobs, 30 of which were BNL reports.

total impressions	1,527,616
offset plates	1,671
negatives	2,789
pages collated and bound	1,092,820

Drafting

The Drafting Group staff comprised a total of 29 persons, of whom 19 were designers. Assignments to the Accelerator Project for design and development work on the Cosmotron varied between 6 and 7 men. An additional 3 men, on assignment to the Cyclotron and Van de Graaff Groups, are doing similar work. Project development and construction work in connection with the reactor and associated facilities included studies of the alteration program, review of laboratory furnishings and equipment requirements, and collaboration in designing a closed dissolver unit for the hot laboratory. Some personnel were also assigned to drafting work for field changes necessary during the course of the reactor alteration program.

Work done on design, development, and construction, in connection with completion of the major research facilities as outlined above, represented approximately 25% of the available design time of the Drafting Group. It is expected that the coming year will see a marked shift in emphasis from engineering design work to design of experimental apparatus for use with these facilities. A total of 153 special projects for laboratory apparatus and equipment for direct research use were completed and released to the shops during the year. Several were of such major proportions as to require up to 1,000 hours of drafting time. Among these special projects might be noted:

1. A remotely-controlled, power-driven, neutron spectrometer for the Chemistry Department, for use at the reactor.
2. A beta-ray spectrograph.
3. A lead dry box for handling cyclotron-produced isotopes, for use in the target room at the cyclotron.
4. A proton spectrometer, for use with the electrostatic generator.

The following breakdown of the 153 design projects, referred to above, indicates the spread among major subdivisions of requirements for the services of the Drafting Group.

Requested By	No. of Designs
Biology	11
Shops	24, including 16 shop equipment items
Chemistry	7
Electronics	4
Health Physics	8
Medical	1
Physics	25
Cyclotron and Van de Graaff	19
Reactor and Hot Laboratory	54
Total	153

In addition, the Group was called upon to handle from 400-450 other jobs involving the preparation of sketches, graphs, diagrammatic illustrations, and other drawings not requiring extensive design work.

An over-all increase in demand for experimental design work for the various research departments, and a continuing requirement, though on a lesser scale, for the Drafting Group to function in the field of engineering are anticipated for the coming year.

Shops

The total personnel of the Shops Group numbered 86 on June 30, 1950, as compared with 88 at the beginning of the six-month period.

The work load of the Shops Group has increased steadily as the Laboratory's staff and research facilities have increased. During the past six months, all shops worked overtime in order to absorb the backlog. Part of this backlog had resulted from work done for the reactor and for the Cosmotron. These jobs were not in the nature of experimental shop work and will not be a continuing factor in the shop load. The rest of the backlog was caused by other noncontinuing requirements of the research staff for "tooling up" in anticipation of reactor start-up, and by the cyclotron becoming available for research use. Although the work load is expected to ease off when the preparation phase is over and research using the major facilities gets under way, it is anticipated that the continuing normal level will be such as to require an increase in shops personnel during the coming year.

Department	Total Man-Hours	%
Physics	18,274	16.3
Accelerator	15,713	14.
Reactor	50,216	44.8
Chemistry	6,250	5.6
Electronics	4,829	4.3
Biology	5,621	5.
Medical	2,455	2.2
Geology	510	.5
Maintenance	704	.6
General Shops	7,511	6.7

ADMINISTRATION AND MAINTENANCE

Significant changes and transfers in personnel and responsibilities have taken place in the over-all administration of the Laboratory during the report period. The effort has been directed toward reducing the ratio of nontechnical to technical personnel in keeping with the desired trend of the Laboratory since its early days of operation. The ratio on July 1, 1950 is 4.8 to 1. This has been accomplished both by consolidating several administrative and maintenance activities, as described in the following sections, and by reducing personnel in many groups and sections. While the scientific staff has not increased significantly in number, the staff of technical helpers has been augmented appreciably and the general administrative and maintenance groups have been reduced.

In the general consolidation of functions, several areas of responsibilities have been changed. The Security Group became the Security and Plant Protection Division, and reports directly to the Business Manager. The Fire Department, which formerly was a part of the Architectural Planning and Plant Maintenance Department, has also been incorporated into this Division. This made possible the reduction in the number of full-time firefighters. The consolidation provides a more flexible organization with better over-all service to the Laboratory. Reductions in receiving, warehousing, and distribution are significant, as well as the transfer of the Stock Records Section to the Fiscal Division.

Architectural Planning and Plant Maintenance

During the fiscal year of 1950, the Architectural Planning and Plant Maintenance Department reduced its personnel considerably. This process is still continuing. It is expected that by September 1, personnel of the Department will number 275, which is a decrease of 140 persons since January 1, 1950. This reduction is accounted for in two ways:

1. 52 by transfer and reclassification due to organizational changes within the Laboratory. Included in this group are:

   14 firefighters reclassified to policemen, and transferred to the Security and Plant Protection Division for police duty;

   27 remaining Fire Department staff members, transferred to the newly formed Security and Plant Protection Division, which assumes responsibility for fire protection;

   2 radio and alarms maintenance technicians, also transferred to the Security and Plant Protection Division; and

   9 janitors and matrons, transferred to the newly organized Laboratory Residents Services Section, which is now responsible for service in the dormitories, apartments, and guest houses.

2. 88 by reduction in the strength of almost every section of the Department.

During the past six months there has been a net gain of over 80,000 sq ft of building facilities in active use, made up as follows:

Facility	Area (sq ft)		
	New Construction	Modified	Not Modified
Cosmotron building (partial only)	32,000	-	-
Hot laboratory building	34,700	-	-
2-Mev electrostatic generator (Chemistry)*	-	1,100	-
Physics laboratory*	-	2,000	-
Temporary animal quarters (Medical)	-	-	3,800
Air test room (Meteorology)	-	-	1,500
Temporary animal quarters (Biology)	-	-	2,100
Conference building (summer only)	-	-	3,300
Dormitory (taken over from HKF)	-	-	4,700

*Work was accomplished by outside contractors under the supervision of, and from plans and specifications prepared by, this Department.
In addition, sixteen buildings with a total area of 49,700 sq ft have been removed from the site during the past six months.

On June 30, there was a total of 1,096,600 sq ft of floor space in active use by the Laboratory, of which 259,900 sq ft is new construction built by the Laboratory since the take-over from the AEC, 469,500 sq ft is space which existed here, but which has since been modified for Laboratory use, and, finally, 367,200 sq ft which is in use as it existed.

The Department is currently working on basic studies, plans, and specifications for major modifications or new construction involving 13 buildings. These include such facilities, for example, as the engineering laboratory, biology laboratory, animal house, and 6 utility installations, such as emergency power and water supply for the apartment and warehouse areas. In addition, the Department has large areas of responsibility toward the design and supervision of the construction of the Cosmotron building and its utility services.

There are also in progress by numerous outside contractors 16 projects of a varied nature, for which the Architectural Planning and Plant Maintenance Department is supplying plans, specifications, and general supervision.

Approximately 1,000 jobs of a more or less routine nature have been completed by the Building and Grounds Division during the past fiscal year. In addition, the Cabinet and Carpenter Shops have had several large projects, including the installation of a sample chemistry laboratory in one wing of the nuclear reactor building, and the design and fabrication of special stainless steel-covered laboratory furniture for the hot laboratory building. The two major projects of the Roads and Grounds

Group were the grading and seeding of the nuclear reactor building hill and the rebuilding of 300 feet of railroad track.

The entire Building and Grounds Division was alerted to assist in the cleaning and maintenance of the reactor building at the time of take-over from H.K. Ferguson Company.

The Transportation Group reports an average decrease of over 10,000 miles in the total monthly vehicle mileage; the principal reduction has been in the use of trucks. The daily courier service to New York City was discontinued in June. During the report period, the number of stationary gasoline engines which the Group maintains has grown to twenty-three.

The Department will take over and operate the Maintenance Stock Room after July 1. It is planned to study closely the number and variety of items which are called for with the hope of being able to reduce the inventory. Effort will be made to speed the service, in order to reduce delay to the mechanics drawing stock; steps will be taken to develop a stock catalog.

Business Management

The area of responsibility of the Business Department, which formerly included budget and fiscal functions, purchasing, property control, and technical services, was extended in January to include the Security Office and Police Group. These latter units were subsequently incorporated, together with the Fire Department, into the Security and Plant Protection Division, which is under the Business Manager. During the report period, the Business Manager also assumed responsibility for coordinating the reactor alteration program. In this capacity, the Project Engineer's Office also came within his cognizance for the duration of the construction work.

Budget

During the fiscal year 1950, a number of adjustments were necessary in the approved budgets of Associated Universities, Inc. and of Brookhaven National Laboratory. In November, 1949, at the request of the Atomic Energy Commission, these budgets were changed to reflect a cost and accrual type of operation as opposed to the previous expenditure and commitment method of doing business.

When it became apparent that there would be delays in the completion of the reactor, it was necessary to make an adjustment in the budget to meet the resultant increased costs. This was taken care of largely by applying to reactor construction funds the savings in operating costs for which budgetary provisions had been made in anticipation of earlier completion of the reactor and its availability for research during the fiscal year. Such savings occurred in salaries and wages, insurance, and other personnel costs effected by the necessary delay and smaller scope of the increase in scientific personnel, and from nonexpended funds for reactor operation.

Budgets for the fiscal years 1951 and 1952 were prepared in such a manner as to conform to changed requirements of the Commission with respect to a sharper definition of program, with more detailed presentation of activities, particularly in the applied research areas, than had previously been necessary.

Fiscal

The change-over, in November, 1949, from an obligation to a cost-type budget, made it necessary to convert accounting procedures and fiscal reporting methods from an authorization and obligation basis to an expense and accrual basis.

As of July 1, 1950, in accordance with the request of the AEC, the fixed assets of the Laboratory were capitalized on the books. This step made it necessary to set up detailed property records controlled by appropriate accounts in the general ledger. The basis of valuations for fixed assets agreed on with the Commission for this purpose has been set down in the notes to the balance sheet of the monthly financial statement.

In January, 1950, the Stores Records Section was transferred from the Materials Control Group to the Fiscal Division. This transfer brought about an increase from 49 to 59 for the Division. As a result of an agreement between the Laboratory and the Commission to expand the accounting program and to introduce job costing, it will be necessary to increase the personnel level by several positions during fiscal 1951.

During the fiscal year, periodic audits were conducted by representatives of the AEC and the General Accounting Office. A review of fixed asset accounting and property valuations was made for the Commission by the firms of Day and Zimmerman, and Ross Bros., Lybrand and Montgomery. Haskins and Sells also made an examination of the accounts of the Corporation for the period ending June 30, 1949.

The Laboratory has prepared itself to undertake, effective July 1, 1950, the "industrial-type" cost accounting and fiscal reporting procedure requested by the AEC. Although introduction of this system has involved some extension of record-keeping and requires additional, more detailed reporting, in many areas of operation it has meant mostly the formalizing of records previously kept on an informal basis for use by the Laboratory management in its planning and control activities.

The Laboratory, further, has defined more specifically certain areas of its organizational structure, in order to meet the Commission's planning, costing, and reporting requirements of basic and/or applied research.

Purchasing

As Laboratory activities have shifted from construction and organization to research work, purchasing activities have tended to become more stable. Partly because of this, and partly because of the development by the Purchasing Group of more efficient internal procedures and complete buyer's reference files, based on three years experience of the Laboratory's requirements, it has been possible to decrease the working staff of the Group without impairing or reducing efficiency. The Purchasing Group now numbers 15 persons, as compared with 22 on January 1, 1950.

As indication of the volume of work this Group was called upon to handle during fiscal year 1950 may be found in the following figures:

number of purchase orders issued	-	11,548
value of purchase orders issued	-	$2,334,491.42
change of purchase orders issued	-	1,499

About two-thirds of this volume was handled during the last half of fiscal year 1950. During the first six months of the fiscal year, purchasing was restricted to a lower rate as the budgets of the research departments were adjusted to permit transfers of funds to the reactor alteration program.

Receiving, Warehousing, and Distribution

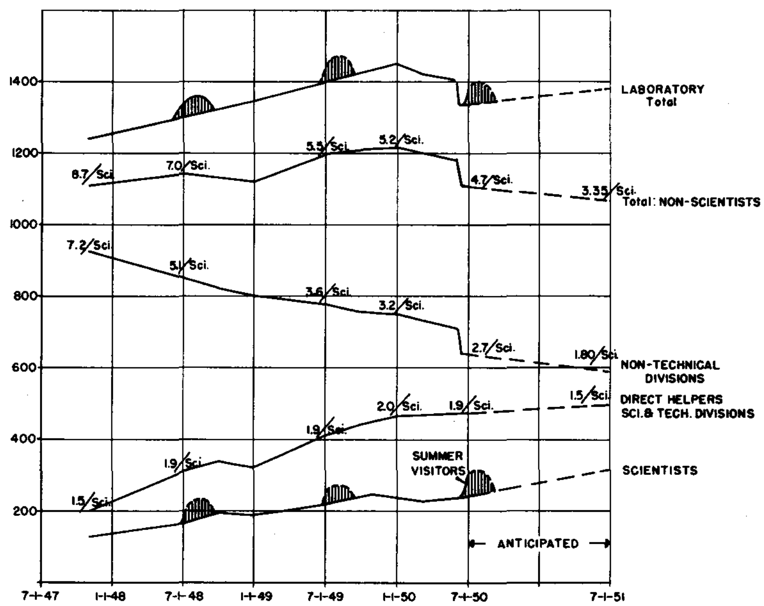
A total reduction of 15 in the personnel of materials handling activities has been accomplished since January, 1950. The decrease has taken place mostly among warehouse and stockroom men. In addition, the Stock Records Section, comprising a staff of 10 clerks and 1 supervisor, was transferred to the Fiscal Division. The Receiving, Warehousing, and Distribution Group's present personnel totals 43, as compared with 69 on January 1. During the report period, the Group experienced a continuing increase in total receipts, issues, and outgoing shipments. It is anticipated that an increase in the work load will continue to be the case during the next year.

During the past year, the task of preparing a series of useful catalogs covering all supply items was begun. The first completed catalog, listing and identifying electronics supplies, has been issued to the staff. Currently in preparation are catalogs covering glassware and laboratory supplies, and general supplies. As the various stock lists are completed, the system of identifying items by specific catalog numbers will be used in all transactions involving inventory items. The catalog identification system has already been proven advantageous in the electronics stockroom in terms of ready identification of items from receipt to issue. Savings in time and better service to the research staff have resulted. The cataloging program will assist in cleaning out slow moving or "dead" stock and in the development of a more active inventory.

Branch stockrooms have been opened in the reactor building and in the hot laboratories to service more efficiently the needs of the research staffs using these facilities. Activities of the Salvage and Disposal Section also were at a higher level during the past six months as contractor and Laboratory surpluses were transferred or sold. A persistent effort is being continued to reduce further excess inventory items.

Office Services

The personnel of the Office Services Group was reduced by termination and transfers from 30 to 22 during the report period. As of June 30, the Stenographic Pool had been reduced to 1 employee. The entire Duplicating Section, except for the supervisor, was transferred to the Photography and Graphic Arts Group in a move to consolidate all multiple reproduction and printing facilities within one organizational unit. The supervisor of the former Duplicating Section of the Office Services



PERSONNEL TRENDS, BROOKHAVEN NATIONAL LABORATORY
(Ratios do not include summer visitors.)

Figure 1.

Group has been on a special assignment in connection with the reactor alteration program.

Mail and messenger service requirements continued to constitute a consistent work load. The following indicates the volume of correspondence handled by this unit, which comprises 6 employees including a chauffeur.

The mail and messenger section has proven to be particularly valuable in training employees. A relatively high record of promotions of female employees of the Section to positions of greater responsibility in other departments results from both excellent basic training in the standards of Laboratory operations, and from familiarity gained with rules, regulations, and the general Laboratory organization.

The Telephone Section has experienced an increased work load; this has been handled with no increase in personnel. A new switchboard installed in the Medical Department has been covered by the regular staff. In addition to its normal duties, the staff handles all telephone service requests, acts as coordinator with the N.Y. Telephone Company, and prepares invoices for personal billings.

The Archives program is well under way. Procedures and forms have been established, and already well over one hundred "transfiles" of records have been processed. At present, the archivist is taking over about 200 cases of records from the H.K. Ferguson Company.

The Office Machine Repairs Section, staffed by 3 employees, has handled an average monthly volume of 135 jobs. The Section is responsible for repair and maintenance of over 1,000 office machines.

Personnel

The total number of employees on July 1, 1950 was 1325, representing a net reduction of 86 staff members during the fiscal year 1950. The ratio of 1 scientist to 4.8 nonscientists on the staff on June 30, 1950, corresponds to an 11.1% reduction from the comparable ratio at the close of the previous fiscal year. The net turnover rate for fiscal 1950 was reduced by 45% from the rate for fiscal 1949. Pertinent personnel statistics are set forth in the following tabulation:

Staff Data	Fiscal Year Ending June 30, 1950	Fiscal Year Ending June 30, 1949
Total number of employees	1325*	1411**
Scientific staff	229	220
Ratio: scientists to nonscientists	1 to 4.8	1 to 5.4

Turnover Data	June 30, 1950 Total Numbers	June 30, 1950 Annual Rate	June 30, 1950 Average Monthly Rate	June 30, 1949 Total Numbers	June 30, 1949 Annual Rate	June 30, 1949 Average Monthly Rate
Accessions	205	14.46%	1.21%	382	28.19%	2.35%
Separations (turnover)	291	20.63%	1.72%	288	21.30%	1.78%
Net accessions	-86***	-6.28%	-0.52%	94	6.88%	0.57%
Replacements (net turnover)	146	10.23%	0.85%	252	18.60%	1.55%

*Not including 43 temporary appointees and 4 employees of the Public Education Office.

**Not including 27 temporary appointees and 4 employees of the Public Education Office.

***A reduction of 97 nonscientific personnel in June contributed significantly to the negative rate of net accessions during fiscal 1950; the average monthly net accession rate for the eleven-month period ending May 31, 1950 was 0.01%.

The evolution of the current ratio of scientists to nonscientists, excluding temporary appointees, may be appreciated from the following data:

Employees	Fiscal Year Ending June 30, 1950	June 30, 1949	June 30, 1948	June 30, 1947
Total No. of Employees	1325	1411	1322	915
scientific staff	229	220	184	64
nonscientific staff	1096	1191	1138	851
Ratio: scientists to nonscientists	1 to 4.8	1 to 5.4	1 to 6.2	1 to 13.3

The growth of the scientific staff from January 1, 1947 is shown in Figure 2 of the section, "Report of Brookhaven National Laboratory." The "continuing staff" includes all regular appointees to the Laboratory's scientific staff. "Salaried visitors" include scientists and engineers on leave from their institutions, graduate students doing doctoral investigations on leave from their graduate schools, and temporary appointments of duration up to three months. "Guests" include scientists and engineers who receive no remuneration or reimbursement of expenses from the Laboratory.

This graph, however, does not include the man-months of service rendered by scientists and engineers who hold consultant contracts. During fiscal 1950, there were approximately 35 man-months of service rendered by these consultants. While, as seen from the graph, there is an increasing stabilization in the size of the continuing staff, there has been considerable change in individual personnel. This is in keeping with the policy of providing a stream of younger scientists and engineers who remain at the Laboratory for two to four years before taking their gained experience to other organizations. Specifically, in this category, the change from 196 to 210 staff members during the year results from an influx of 48 new members, a departure of 33 members, and a net category change of 1.

Scientific Staff Changes During Fiscal 1950

Scientific Staff	June 30, 1949	Reported	Departed	Transfers	June 30, 1950
Continuing Staff					
tenure	23	4	0	+2	29
term	106	41	22	-4	121
indefinite	67	3	11	+1	60
Total	196	48	33	-1	210
On-leave scientists	25	14	19	-1	19
Temporary	26	60	43	0	43
Guests	7	29	23	0	13
Salaried Visitors and Guests	58	103	85	-1	75
Total Scientific Staff	254	151	118	-2	285

Of the 210 continuing staff members on June 30, 1950, 112, or 53.3%, possessed doctoral degrees. This compares with 44.9% as of June 30, 1949.

The peaks on the graph (Figure 1) show the natural influx of salaried visitors and guests to the Laboratory during the summer months. There is an increasing interest on the part of these summer visitors, and it appears that the number of such appointments will be limited only by the housing accommodations that are available. In several cases, scientists from different institutions -- experts in different techniques -- have collaborated to carry out investigations that have resulted in scientific reports of unusual interest.

Referring to the above table, it will be noted that the number of salaried visitors and guests increased from 58 on June 30, 1949, to 75 on June 30, 1950. This net increase does not, however, indicate the actual flow of this type of scientific personnel into and out of the Laboratory. During the year, 103 reported for work and 85 departed. Most of this flux, of course, occurs in the temporary and guest appointments during the summer months.

There has been continuous interchange of services between universities and the Laboratory during the past fiscal year. The major type of affiliation has involved the appointment to the Laboratory staff of faculty members and graduate students. In these two categories, 244 individuals from 51 different educational institutions have been affiliated with the Laboratory. These appointments resulted in services rendered amounting to a total of 38.5 man-years.

The affiliations are given in more detail by the following statistics:

Appointments of faculty members to the Laboratory staff:

1. On-leave - 22 from 10 institutions for 134 man-months
2. Temporary - 46 from 22 institutions for 46.2 man-months
3. Guests - 10 from 10 institutions for 14.5 man-months
4. Consultants - 124 from 28 institutions for 22.4 man-months

These appointments represent an affiliation with the Laboratory of 165 staff members from 39 different educational institutions for a total of 18.1 man-years on a twelve months per year basis.

Appointments of students to the Laboratory staff:

1. Research fellows - 19 from 9 institutions for 143.5 man-months
2. Guest fellows - 20 from 7 institutions for 35.8 man-months
3. Temporary - 44 from 21 institutions for 65.3 man-months

The above appointments involve 78 students from 26 different institutions for a total of 20.4 man-years.

Research fellows include those graduate students who receive appointments to the Laboratory staff directly from the Laboratory and who come here to carry out research projects as doctoral investigations. Guest fellows include 3 graduate students who hold predoctoral AEC Fellowships at universities, 1 AEC postdoctoral Fellow, 3 graduate students from universities, and 13 AEC Fellows in radiological physics, who have been sent to the Laboratory for training in the Health Physics Division.

For the summer of 1950, arrangements have been made for 37 staff members from 28 different universities to work at the Laboratory; 5 others are guests. In addition, 35 graduate students from 16 different universities have been given temporary appointments, of which 8 are in the guest category.

Twenty-three faculty members from 13 universities have given invited papers at Laboratory scientific conferences. The Laboratory staff has given invited papers at university seminars, and, in a few cases, given lectures in regularly scheduled graduate courses. Forty-two seminar papers were given on invitation at 22 universities.

On July 21, 1950, negotiations with Federal Labor Union No. 24426 of the American Federation of Labor were concluded; an agreement with the Laboratory extending until June 30, 1955 without interim reopening provisions was executed. To prepare for the increased demands upon experienced service personnel anticipated with the completion of major research facilities, a vacation privilege of one working day per month for hourly and weekly personnel was substituted for the two days per month privilege previously in effect. Adjustment of basic wage rates included provisions for monetary remuneration approximately equivalent to the additional time which would be worked as a result of the modified vacation policy, and provided for an annual improvement factor in recognition of increased efficiency. In view of the extended contract period, provision was made for a cost of living allowance to be adjusted up or down each six months in accordance with the Consumers Price Index of the Bureau of Labor Statistics. The first such adjustment, if necessary, is to be made in July, 1951. On the basis of experience, under the initial collective bargaining agreement, minor changes and formalization of certain procedures relating essentially to such matters as seniority, union security, and grievance procedure were incorporated into the new document. Relations between the Union and the Laboratory under the initial agreement and during the recent bargaining period are indicative of the continuing mutual desire to work harmoniously in the interests of both the Laboratory and its employees.

The National Safety Council's Distinguished Service to Safety Award was conferred upon the Laboratory on the basis of a 66% reduction in frequency rate during the calendar year 1949, as compared with the calendar year 1948. Significant disabling injury data are recorded in the following table:

Rate	Fiscal Year Ending		Reduction in Rate (improvement)
	June 30, 1950	June 30, 1949	
Frequency	2.63	4.84	46%
Severity	.03	.07	57%

During the week of May 8, 1950, the Laboratory served as host for the annual AEC Safety Engineers Conference. Considerable effort was expended by the Safety Group during the past four months in assuring the provision of maximum safety for the extra-hazardous operations associated with the repairs to the reactor. A special committee was appointed by the Director to consider the complex electrical safety problems of the Laboratory. Material improvements in fire protection were effected with the installation of automatic fire alarm systems in many of the temporary structures housing valuable equipment, and through the approval of the installation of fire walls and doors in the inter-connecting hospital area.

During the fiscal year 1950, as in fiscal 1949, the activities and arrangements sponsored by the Brookhaven Employees Recreation Association were accomplished without direct subsidy from the Laboratory. Participation in one or more of the activities of the Association by approximately 60% of the staff members continued.

The extent of employee participation in the hospitalization, group insurance, and retirement plans is summarized in the following table:

Plan	Fiscal Year Ending	
	June 30, 1950	June 30, 1949
Hospitalization (Blue Cross)	90%	75%
Retirement	53%	45%
Group Insurance	89%	89%

The activities of the Housing Office in assisting employees to arrange for the purchase or lease of houses, and the extent of lease authorizations for properties controlled by the Laboratory are reflected in the following data:

Housing	Fiscal Year Ending	
	June 30, 1950	June 30, 1949
Assistance in:		
purchases	29	34
leases	93	109
Lease authorizations (Laboratory properties)	$92,363.65	$81,532.27

Security and Plant Protection

In January, 1950, the Security Office and Police Group, formerly reporting to the Executive Assistant to the Director, came within the cognizance of the Business Manager. In May, the Security Officer and his staff moved into offices in the Police Headquarters Building, an arrangement designed to provide more efficiency in the working relationship with the Police Group. Subsequently, in June, 1950, a Security and Plant Protection Division was set up to combine within one organizational unit the security and police functions formerly within the jurisdiction of the Security Office, and the Fire Department which formerly reported to the Architectural Planning and Plant Maintenance Department. In effecting the change-over, the Fire Department staff will be reduced by September, 1950, from 53 to 29. The Police Group will be increased by the re-employment of 14 former firemen as patrolmen, resulting in a net reduction of 12 in the total number of personnel in these activities. In addition, two employees constituting a Radio and Alarms Maintenance Section are being transferred to the new Division.

The cut in personnel accomplished by this reorganization, although substantial, increases effectively the security force, in anticipation of greater requirements in this area; at the same time, it provides a fire protection force no less efficient than before. The Fire Department staff of 29 is scheduled on a round-the-clock, seven-day week basis, to provide a nucleus of men who will keep the equipment in shape and get it into action in case of an alarm. This group will be able to cope with the average emergency. When required, the force will be supplemented by an auxiliary force from the Police Group, which has received intensive training in fire prevention and protection methods, and fire-fighting techniques. About half of the total police force has received such training. These members, including the foremen employed as police, are so scheduled that each police shift can provide a Fire Department auxiliary in the event it is required. In addition, volunteer fire-fighter brigades have been organized from among the general staff of the Laboratory. These groups are being given training in fire-fighting techniques and will be available as an auxiliary force in the event of a major emergency. Although this reorganization is admittedly an experiment, there continues to be available on each shift the same number of men trained in fire fighting as formerly. Effective normal security protection has been increased. The working arrangement is apparently a satisfactory one, although it has not yet received a major test.

In June, one ambulance was transferred to the control of the Medical Department. A second ambulance has been retained by the Security and Plant Protection Division as emergency apparatus.

The Police Group, as such, has remained highly stable in terms of personnel turnover. Training and freshener courses in police activities have continued. The unit has experienced a normal work load in terms of numbers of cars passed in and out of the site, investigations (nonsecurity), guarding security areas, and responding to emergency calls.

Fire Department activities involved few calls of minor significance.

The work load and scope of responsibility of the Security Office continued unchanged.

APPENDIX

A. UNCLASSIFIED PUBLICATIONS, JULY 1, 1949 - JUNE 30, 1950

This list includes official Laboratory publications, abstracts of papers which were or will be presented at scientific meetings, and publications by staff members and consultants. All these listings result from work done at the Laboratory; they were submitted during the review period. Abstracts are indicated by (A); letters to the editor, (L); and notes, (N). Acceptance for future publication is designated by (In press.).

GENERAL PUBLICATIONS

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

Progress Report, July-December, 1949 (BNL 39 (AS-3))

Quarterly Progress Report, January-March, 1950 (BNL 51 (S-5))

Quarterly Progress Report, April-June, 1950 (BNL 64 (S-6))

Chemistry Conference #3, July 14-15, 1949 (BNL-C-9)

Chemistry Conference #4, January 19-20, 1950 (BNL 44 (C-10))

Guide to Russian Scientific Periodical Literature 2, #4-12 (BNL-L-61 to 69)
3, #1-6 (BNL-L-70 to 75)

Weekly Bulletin 2, #49-52; 3, #1-48

Weekly Selected Reading List 2, #17-52; 3, #1-16

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)

Blachman, N.M.
Synchrotron-oscillation resonance
Rev. Sci. Instruments (In press.)

Blewett, J.P.
Radio-frequency problems associated with particle accelerators (A)
Presented at I.R.E. convention, 1949

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

Blewett, J.P. (See Pressman, A.I.)

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 21, 7-22 (1950)

Pressman, A.I. and Blewett, J.P.
A 300 to 4000 kc electrically-tuned oscillator
Proc. I.R.E. (In press.)

Yuan, L.C.L.
Design of a wide-band radio-frequency power amplifier for a 2.5-Bev proton accelerator
Cathode Ray Press (Machlett Laboratories) 7, 16-8 (1950)

Architectural Planning and Plant Maintenance Department

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

Biology Department

Acher, F. (See Gibbs, M.)

Bennett, F.A. (See Gibbs, M.)

Bowen, V.T.
Manganese metabolism of social *Vespidae*
J. Exp. Zoology 115 (October, 1950)

Bubeck, M.R. (See Gibbs, M.)

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

Culbreth, G.G. (See Sharpe, L.M.)

Damast, B. (See Sacks, J.)

Dumrose, R. (See Gibbs, M.)

Edelmann, A.
The adrenal cortex and survival of rats after X irradiation (A)
Federation Proceedings 9, Part I, 36 (1950)

Fleming, T.C. (See Nickerson, J.L.)

Gastel, R. and Gibbs, M.
On the mechanism of lactic acid synthesis by the fungus *Rhizopus oryzae* studied with C^{14} (A)
Amer. J. Botany (In press.)

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

Gibbs, M., Dumrose, R., and Acher, F.
C^{14} uniformly labeled sucrose
Book - "Biochemical Preparations" (In press.)

Gibbs, M., Dumrose, R., and Acher, F.
C^{14} uniformly labeled starch and glucose
Book - "Biochemical Preparations" (In press.)

Gibbs, M.
Distribution of labeled carbon in the sugars and alanine of sunflower leaves after exposure to $C^{14}O_2$ in the light and dark (A)
To be presented to 18th International Physiological Congress
(Travel Award)

Gibbs, M.
Distribution of labeled carbon in various metabolites of sunflower leaves after exposure to $C^{14}O_2$ (A)
Am. Soc. Plant Physiologists, Columbus Meeting, September 11-13, 1950

Gibbs, M., Dumrose, R., Bennett, F.A., and Bubeck, M.R.
On the mechanism of bacterial fermentation of glucose to lactic acid studied with C^{14}-glucose
J. Biol. Chem. 184, 545-9 (1950)

Gibbs, M.
On the mechanism of the chemical formation of lactic acid from glucose studied with C^{14}-labeled glucose
J. Amer. Chem. Soc. 72, 39-64 (1950)

Gibbs, M. and Udenfriend, S.
The preparation of C^{14} uniformly labeled fructose by means of photosynthesis and paper chromatography
Science 110, 708-9 (1949)

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

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

Gibbs, M. (See Bothner-By, A.A., Chemistry)

Gibbs, M. (See Gastel, R.)

Gregersen, M.I. (See Nickerson, J.L.)

Holt, M.W.
A semi-automatic injection apparatus for use with radioactive solutions
Science 112, 142 (1950)

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

Koester, M.L.
A chemical test for seed viability
Maize Genetics Cooperation News Letter, #24, March, 1950

Matthews, S.A.
The effect of thiouracil on the uptake of radioactive iodine by the thyroid gland of summer frogs (*Rana pipiens*)
Am. J. of Physiology (In press.)

Moses, M.J.
Nucleoproteins and the cytological chemistry of *Paramecium* nuclei
Proc. Soc. Exptl. Biol. and Med. 71, 537-9 (1949)

Moses, M.J., Steele, R., and Sparrow, A.H.
Quantitative determination of nucleic acids during meiosis in *Trillium* (A)
Histochemical Society Meeting, Philadelphia, March 24-25, 1950

Moses, M.J. (See Sparrow, A.H.)

Nickerson, J.L., Sharpe, L.M., Root, W.S., Fleming, T.C., and Gregersen, M.I.
Simultaneous blood volume determinations in dogs with dye (T-1824) carbon monoxide and radioactive iron Fe^{55} (A)
Federation Proceedings 9, Part II, 94 (1950)

Nims, L.F. and Scheraga, H.A.
The effect of X-rays on fibrinogen (A)
Amer. Chem. Soc. Meeting, Chicago, September, 1950

Nims, L.F.
Nuclear tools in biological research (A)
Bulletin of the Suffolk County Medical Soc., #2, February, 1950

Pond, V. (See Sparrow, A.H.)

Root, W.S. (See Nickerson, J.L.)

Rubin, B.A. and Steinglass, P.
The effect of absorbed radioactive phosphorus (P^{32}) on the genetics of E. coli.
Proc. Soc. Amer. Bacteriologists, page 13, 1949

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. 1, 8 (1950)

Rubin, B.A. and Steinglass, P.
The genetics of streptomycin resistance induced by absorbed radioactive phosphorus (P^{32}) (A)
News Letter of N.Y. Soc. of Amer. Bacteriologists 2, #23, 3 (1950)

Rubin, B.A.
The nature of streptomycin requirement and its effect on the genetics of streptomycin resistance in E. coli. (A)
Amer. Inst. of Biol. Sciences meeting of the Genetics Society of America, to be held at Columbus, Ohio, September, 1950

Rubin, B.A. and Steinglass, P.
The nonutilization of streptomycin by resistant E. coli mutants (N)
Microbial Genetics Bull. 2, 13 (1950)

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The pattern and significance of delayed phenotypic expression of mutations induced in E. coli by absorbed P^{32}
Genetics 35, 133 (1950; Records of Genetics Soc. 18, 113 (1949)

Rubin, B.A.
Radiation microbiology; problems and procedures
Nucleonics 7, #3, 5-20 (1950)

Rubin, B.A.
A rapid method for the determination of mutation rate of E. coli to streptomycin resistance
Microbial Genetics Bull. 1, 9 (1950)

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