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BROOKHAVEN NATIONAL LABORATORY

Annual Report
July 1, 1951

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

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

Brookhaven National Laboratory is operated under a contract between the United States Atomic Energy Commission and Associated Universities, Inc. Part One of this, the second annual report of the Laboratory, describes Associated Universities, Inc., its origin and purposes, its organization and some of its activities. Part Two is an account of the progress of the Laboratory during the interval July 1, 1950 - June 30, 1951, and its plans for the future.

This report is submitted under the terms of Contract #AT-30-2-GEN-16 between Associated Universities, Inc. and the Atomic Energy Commission.

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

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CONTENTS

WEST FACE OF THE
BROOKHAVEN REACTOR

PART ONE

ASSOCIATED UNIVERSITIES, INC.

Associated Universities, Inc. is a non-profit educational corporation operating under a charter granted by the Board of Regents of the State of New York in July 1946. It was formed to enable the sponsoring universities and other research organizations in the northeastern region to cooperate with one another and with the Government of the United States in building and operating laboratories, conducting research programs and training scientific personnel for fundamental study and development in the nuclear sciences at Brookhaven National Laboratory. Although the need for a laboratory devoted to nuclear research provided the impetus for the founding of AUI, its charter is a broad one and reflects the belief of its founders that in time it would be a very useful instrument for cooperation among universities and between universities, the government and business institutions for many kinds of scientific research and for both scientific and educational development.

As provided by its charter, the purposes of the corporation are:

1. To acquire, plan, construct and operate laboratories and other facilities, either under contract with the Government of the United States or its agencies or otherwise, for research, development and education in the physical and biological sciences, including all aspects of the field of nuclear energy and its engineering and other applications, and to educate and train technical, research and student personnel;

2. To constitute an agency through which universities and other research organizations will be enabled to cooperate with one another, with the Government of the United States and with other organizations toward the support and use of laboratories and other research facilities and toward the development of scientific knowledge in the fields hereinabove set forth;

3. To accept and collect pledges, donations and contributions from participating universities and others toward the construction, maintenance, and operation of the foregoing laboratories and facilities and of all services incident thereto.

Nine eastern universities sponsor AUI through the presence on its Board of Trustees (see page 2) of two representatives from each, one of whom is a principal administrative or corporate officer of the University, and the other usually a senior scientist from its faculty. The sponsoring universities are: Columbia, Cornell, Harvard, Johns Hopkins, Massachusetts Institute of Technology, University of Pennsylvania, Princeton, University of Rochester and Yale. Although these nine universities are thus intimately associated with the management of AUI, all other institutions, public and private, with similar

ASSOCIATED UNIVERSITIES, INC.

*Member of the Executive Committee until October 1951.

interests in the fields of research and education development are encouraged to participate in its activities, and to make use of its resources. It is AUI's fixed policy that no institution shall receive preferential treatment.

The Board meets as a whole four times each year. Its Executive Committee meets each month to perform the Board's executive function. In addition to these regular meetings, Trustees are individually consulted as occasion demands about particular problems of administrative, scientific or education planning.

Activities of AUI

The principal activity of Associated Universities, administered through its Board of Trustees and committees, and through its officers, is the management of the Brookhaven National Laboratory under contract with the AEC. In the discharge of this responsibility, Associated Universities, Inc., working with the Laboratory, undertakes a continuous review of the state and progress of science to provide the foundation on which the significance of ultimate scientific performance can be evaluated. Based on its appraisal of the situation, AUI:

1. Establishes sound and general policies for operation of Brookhaven National Laboratory.
2. Maintains a capable staff to evolve and carry out those policies.
3. Appraises the performance of the Laboratory against high standards of achievement.
4. Serves as a channel through which the experience and resources of the universities can be mobilized to aid in the performance of the Laboratory's assigned tasks.

AUI is one of the principal contractors of the AEC in the field of nuclear research and development. Since it also represents a substantial portion of AEC's research activity, AUI inevitably bears a heavy responsibility to the AEC for development and recommendation of plans and policies that can be evolved in light of the special skills and facilities available to it. The close association of AUI with the forefront of scientific progress, both in the universities and at Brookhaven, provides AEC with one important channel of the real access to science and to the meaning of its development which underlies construction of progressive national policies in the field of nuclear energy.

Until 1951, AUI devoted itself to its initial task of establishing Brookhaven National Laboratory and managing its activities. Believing that task has now been well begun, the Board of Trustees have approved plans for expanding the corporation's activities in other fields of scientific research or scientific and educational development which are of particular interest to the universities, the United States Government or private business institutions. It is expected that in due course AUI will become a strong link between such institutions in the task of solving problems which may be beyond the abilites of any one of them to solve alone.

This phase of AUI's activites is now under development. As a first step, AUI has undertaken a special short-term study for certain agencies of the United States Government. This study involves integration of special skills from the academic, business and professional life of the nation to solve a great national problem. In the conduct of this

Visiting Committees

For the Biology Department:		Terms Expire in November
Chairman,	J. Walter Wilson, Brown University	1952
	Richard Bradfield, Cornell University	1951
	H. Bentley Glass, Johns Hopkins University	1953
	Arthur K. Parpart, Princeton University	1953
	Harland G. Wood, Western Reserve University	1952

For the Chemistry Department:

Chairman,	Louis P. Hammett, Columbia University	1951
	Ralph Connor, Rohm and Haas Company	1953
	David Harker, Polytechnic Institute of Brooklyn	1953
	Joseph W. Kennedy, Washington University, St. Louis	1952
	George B. Kistiakowsky, Harvard University	1952

For the Medical Department:

Chairman,	James H. Austin, College of Physicians of Philadelphia	1951
	Herrman L. Blumgart, Harvard University	1952
	G. Failla, Columbia University	1952
	W.O. Fenn, University of Rochester	1953
	Colin MacLeod, New York University	1953

For the Physics Department:

Chairman,	Jerrold R. Zacharias, Massachusetts Institute of Technology	1953
	Hans A. Bethe, Cornell University	1952
	J. Curry Street, Harvard University	1951
	Charles H. Townes, Columbia Radiation Laboratory	1953
	Victor F. Weisskopf, Massachusetts Institute of Technology	1952

For the Reactor Science and Engineering Department:

Chairman,	Thomas B. Drew, Columbia University	1952
	Manson Benedict, Massachusetts Institute of Technology	1953
	Harvey Brooks, Harvard University	1952
	John Chipman, Massachusetts Institute of Technology	1951
	Isaac Harter, Babcock and Wilcox Tube Company	1953
	A.B. Kinzel, Union Carbide and Carbon Research Laboratories, Inc.	1951

project, AUI enjoys the close support and cooperation of universities and institutions thoughout the United States.

Visiting Committees

There are few precedents for the mixture of public and academic interests through which Brookhaven promotes research in the nuclear sciences. In the Trustees' judgment, it is therefore desirable to have an independent means of evaluating the work of the Laboratory. In 1949, when Brookhaven's research program was starting to mature and the recruitment of its permanent staff was largely completed, the Trustees judged the time had come to establish a system of permanent committees to advise the Board concerning the future development and welfare of the Laboratory's research programs and staff.

Many universities have found that visiting committees are quite successful as instruments for the guidance and assurance of their governing bodies. It was logical to assume that they would be equally successful in serving the needs of AUI. Therefore, five visiting committees were established for:

1. The Physics, Instrumentation and Health Physics Departments, and the Accelerator Project
2. Biology Department
3. Chemistry Department
4. Reactor Science and Engineering Department
5. Medical Department

Each year in time for the annual meeting of the AUI Board of Trustees, the visiting committees render a full report to the Trustees appraising the staff, plans and development of the Laboratory departments to which they are attached. In preparing this report each committee is expected to hold at least one meeting of possibly several days' duration at the Laboratory, and, in addition, individual committee members spend as much time as is fruitful in visiting the Laboratory and discussing a department's work with its staff members.

The visiting committees not only spread the influence of Brookhaven but bring directly into her councils a continuing stream of scientists from outside as well as inside the family of AUI. They serve a dual purpose. For the benefit of the Board of Trustees they make an objective appraisal of the staff, work and progress of the Laboratory departments. In addition, they are available to the Director of the Laboratory for consultation and to the chairmen and staffs of the departments for informal advice and guidance.

Beginning with the academic year 1950-51, appointments to the committees will be for a three-year term, starting on a staggered basis until in normal progression one-third of the three-year memberships expire each year. In the next two years, one-third of the appointments will be of a temporary nature for one year, and one-third for two years. A list of the committees with their members and terms of appointments appears on page 4.

Appointment of members on the new basis was not completed until late in the spring. Plans for the regular meetings of the committees were therefore delayed, but reports from all of them will be made to the annual meeting of the Board of Trustees in October. When AUI undertakes other activities which, like Brookhaven, seem likely to benefit from the use of visiting committees as a source of advice and guidance to the Board of Trustees, arrangements will be made to appoint additional committees accordingly.

Organization Study

In March 1950, the Trustees, believing that after four years of operations it would be well to examine the organizational structure of AUI itself and its relationship to management problems of Brookhaven, authorized the engagement of Wallace Clark & Co., management consultants. The firm was instructed to make a survey of the organization and operating policies of AUI in light of the major objectives of the corporation itself and of Brookhaven National Laboratory. This study was completed and final recommendations were presented to the Trustees in July 1950.

The principal recommendations involving organizational changes may be summarized as follows:

1. A chairman of the Board of Trustees should be its presiding officer, selected each year from among the university trustees on a rotating basis.

2. A full-time President should be the corporation's chief executive officer and chairman of the Executive Committee.

3. All research, educational and administrative activities of Brookhaven National Laboratory should be the responsibility of the Director of the Laboratory.

The Trustees accepted these recommendations and they have been effectuated.

Wallace Clark & Co. also suggested various detailed modifications of the machinery for executing particular management tasks, most of which are being undertaken as rapidly as the situation permits.

Organization and Personnel

Effective December 1, 1950, Mr. Eldon C. Shoup resigned his post as Executive Vice-President of AUI. During his four years of service, Mr. Shoup made an outstanding contribution to the successful establishment of AUI as a going concern.

In January, carrying out recommendations made by Wallace Clark & Co., the Board of Trustees filled the newly-created posts of Chairman of the Board and President. Dr. George B. Pegram of Columbia University, one of the original incorporators of AUI and a member of the group which first conceived the need for such an institution, was elected Chairman and took office at once. Mr. Lloyd V. Berkner, for many years a member of the scientific staff of the Carnegie Institution of Washington and consultant to many departments of the federal government, was elected President and took office on a full-time basis February 15, 1951.

At the same time, Dr. Frank D. Fackenthal, who had served for over two years as part-time President of AUI, retired from that post to devote himself to his duties as consultant for the Carnegie Corporation. As its President from October 1948, Dr. Fackenthal successfully guided AUI through a period which witnessed the completion of the major part of Brookhaven's initial construction program, the establishment of generally sound working relationships with the Atomic Energy Commission, and the formulation of its basic research program. In recognition of his valuable service and to assure that his interest and many years of experience would continue to be available to AUI, the Board of Trustees in January elected Dr. Fackenthal an honorary member of the Board.

Contract Negotiations

During the year, the Trustees' committee appointed by the President to assist the officers of the corporation in negotiating extension of the Brookhaven contract met on several occasions with representatives of the Atomic Energy Commission to discuss revisions. Agreement was reached concerning a somewhat more explicit control of the security status of employees of Brookhaven National Laboratory, and a procedure for reviewing construction proposals and joining the efforts of the Laboratory and of AEC in carrying out approved construction plans.

In June, 1951, since negotiations for other revisions of the contract had not been completed, the contract as it stood was extended for one year to June 30, 1952, to permit obligation and allocation of necessary funds for the fiscal year 1952.

Direct Defense Projects

A special committee of the Trustees in 1950 stated that AUI's first scientific objective at Brookhaven was "to seek new knowledge in the nuclear sciences in a program which will emphasize fundamental research but will include applied or engineering research of the kind appropriate to a university environment." In keeping with this objective, a majority of Brookhaven's work lies in the realm of "fundamental research," which seeks primarily the discovery of new facts of nature. Nevertheless, a measurable portion of the Laboratory's work has always consisted of projects of immediate practical interest to the Atomic Energy Commission's programmatic development of military uses of atomic energy. It is the intent and the duty of the Laboratory's management and the policy of the Trustees that such work in the national interest be encouraged and undertaken to the extent necessary without serious prejudice to the maintenance and development of healthy fundamental research at Brookhaven. As the urgency of military programs changes with changes in the international situation, there is a corresponding change in the point at which balance is reached between the fundamental and applied work of the Laboratory. In view of present high international tension, there is a natural and desirable increase in the level of the Laboratory's activity having immediate significance to national defense.

Public Education

In October 1950, a sub-committee of the Board of Trustees which had been asked to review the Public Education Program of AUI completed and submitted a report recommending the continuation of the press relations and educational services provided by the Office of Public Education at the levels of cost and activity which had prevailed since the staff of the office was brought up to strength in 1950. The Trustees expressed their belief that AUI should share in the general program of public education sponsored by the Atomic Energy Commission but should not seek to unduly stimulate interest in AUI as a focal point of such activities in the atomic energy field. The Public Education Office has emphasized the following activities during the year:

Press Relations

1. Service to representatives of the various media of public information who desire information about Brookhaven National Laboratory for stories, articles or advertisements.

2. Preparation of background informational material for use by these representatives and by the inquiring public at large.

3. Preparation of news releases about scientific and other events of importance at Brookhaven.

Educational Services

1. Assistance and guidance to educational institutions and other groups which ask help in planning seminars or institutes for the spread of information about atomic energy.

2. Service as a clearing house of information about speakers upon atomic energy subjects for audiences beyond the circle of the Laboratory's neighbors.

3. Search for means to stimulate the preparation of informational and teaching materials in the atomic energy field both by commercial publishers and by groups desiring to help themselves.

4. Circulation of a sample library of atomic energy books and pamphlets designed to encourage others to equip themselves with some of the material available.

During the year 66 press visitors representing the daily and periodical press, radio and television were serviced and 19 press releases were issued. AUI assisted in the planning or conducting of nine atomic energy institutes and seminars. Of these, four were in Pennsylvania, sponsored by various teacher training institutions in that state.

In addition, the Public Education Office devoted considerable time and a small sum of money to the preparation of an experimental "treatment" for a motion picture about fundamental research at Brookhaven. The final version of the treatment will be used as a basis for determining whether a completed film should be prepared for use in the many instances in which it might satisfy the public interest in Brookhaven and make a visit to the Laboratory unnecessary.

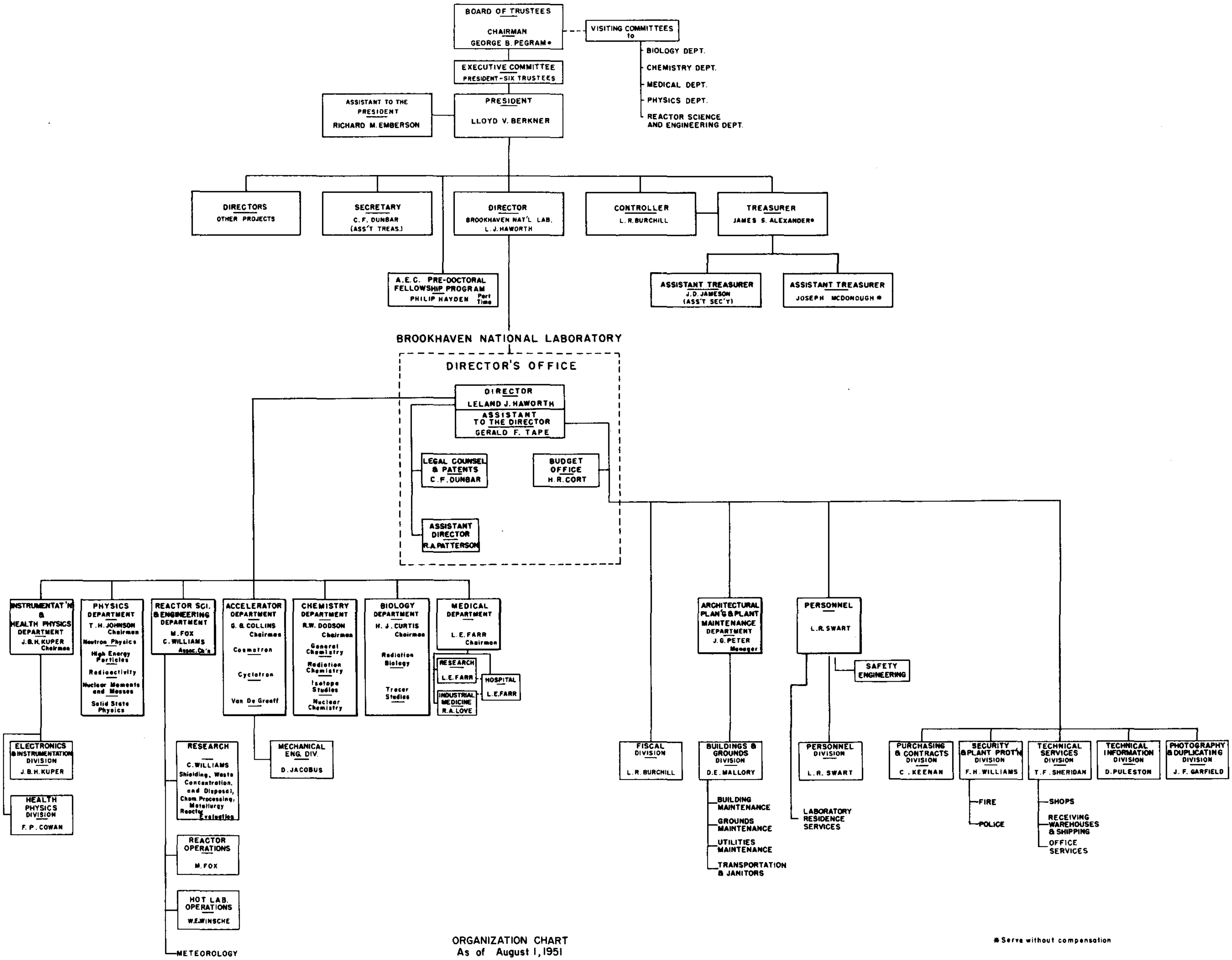
Administration of AEC Pre-doctoral Fellowships

A small but important activity of AUI under contract with the Atomic Energy Commission, which is not associated with the work of Brookhaven, is its administration of the AEC Pre-doctoral Fellowships in the northeastern region for the academic year 1950-51. This program will be completed about October 1, 1951. As of June 30, 1951, nine of the 37 fellows appointed by the AUI Fellowship Boards had received their doctorates or were known to be expecting them in September. Twenty-six others applied for and received renewals of their fellowships. Oak Ridge Institute of Nuclear Studies will administer the entire pre-doctoral fellowship program in the academic year 1951-52. One fellow found it necessary to interrupt his work without making plans for completing his doctorate, and the plans of the remaining fellow have not yet been made. The costs of AUI's share of the Fellowship Program have been less than the sum provided by AEC and less than was budgeted in June 1950.

Fiscal

In October, Haskins & Sells, the corporation's auditors, reported results of their audit of the corporation's books for the year ending June 30, 1950, accompanied by an unqualified certificate. From its inception through the fiscal year ending June 30, 1952, AUI has been authorized by the Atomic Energy Commission to undertake activities, the total cost of which amounts to over $78,000,000. At Brookhaven, AUI is presently responsible for assets conservatively appraised at a value of over $46,000,000. Wages and salaries paid annually to the 1200 or more employees at the Laboratory amount to approximately $5,000,000.

ASSOCIATED UNIVERSITIES, INC.



ORGANIZATION CHART
As of August 1, 1951

* Serve without compensation

PART TWO

REPORT OF BROOKHAVEN NATIONAL LABORATORY

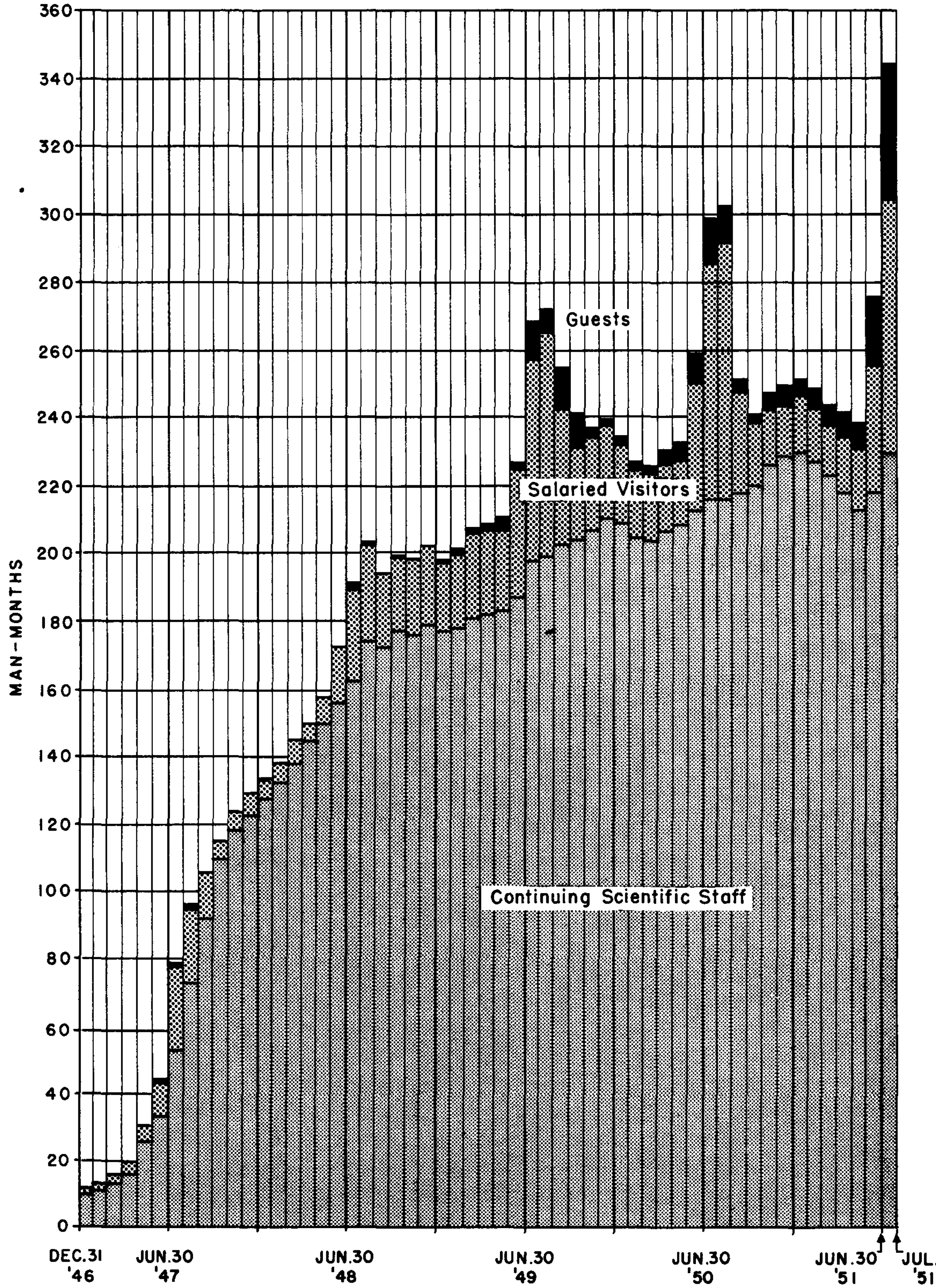
INTRODUCTION

This annual report of Brookhaven National Laboratory describes the activities of fiscal year 1951. The progress and trends of the research program are presented along with a description and summary of the operational service and administrative activities. The scientific and technical details of the various projects are covered more fully in the quarterly scientific progress reports for both the classified and unclassified research activities.

The fiscal year 1951 was characterized by an accelerated research program primarily due to the availability of research facilities at the nuclear reactor. It was on August 22, 1950 that the loading of the uranium had proceeded to a point at which criticality was achieved. During the remainder of the calendar year additional loading of metal was accompanied by detailed experiments on the behavior of the reactor and evaluation of its performance. Soon after the beginning of calendar 1951 the reactor operated on a routine basis for research and for isotope production with relatively little interruption for operational requirements. The last extensive loading of metal which allowed the reactor to be operated at a flux in excess of its design flux and at powers comparable with the design power was achieved in late April. By July 1 some 2342 megawatt days of reactor operation had been achieved. The completion of the first six months of routine operation had proved that the reactor was living up to every expectation and that its facilities for the support of a large and varied research program were adequate.

With the completion of reactor construction, the greatest effort to be applied in the facilities program was that directed toward the completion of the Cosmotron. Extensive thought and study of the vacuum chamber problem throughout the fall and winter of 1950 resulted in a vacuum chamber of simplified design which was ready for construction in January 1951. The last quadrant of the vacuum chamber is expected from the fabricator in November. Advantage has been taken of the intervening time to make extensive tests of the magnetic field and the injector system. The entire Cosmotron program has been rescheduled and it is now predicted that the construction phase will be completed by January 1952.

The cyclotron and electrostatic accelerators have had a somewhat less impressive experience inasmuch as various design and fabrication difficulties have prevented both machines from giving hoped-for performances. The cyclotron, although having had a satisfactory internal beam, has not yet produced a satisfactory externally deflected beam. The electrostatic generator, while performing adequately at lower energies,



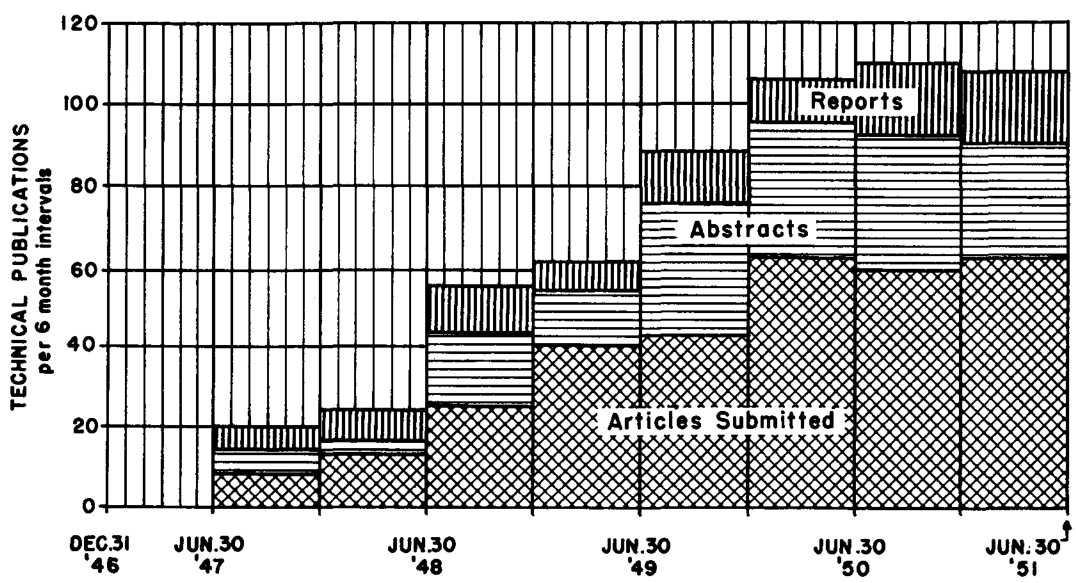
BROOKHAVEN NATIONAL LABORATORY
Scientific Staff

Figure 1.

did not meet the original specifications and a settlement was arranged with the supplier which enabled Brookhaven to undertake a modification program in hopes that the energy could ultimately be increased to 3 Mev. In the meantime research has proceeded.

A change in the relationship between the Laboratory and the Commission with respect to construction was effected during the year and resulted in the Atomic Energy Commission taking a more active part as a contracting authority. The Commission in general now takes prime contractual responsibility for construction. A committee of Commission and Laboratory representatives studies all construction proposals and submits its recommendations to the Commission. During this first year the Commission has contracted for modification of T-480 for use as an Engineering (Metallurgy) Laboratory and for the design of the Biology Laboratories Phase II. These are being followed in fiscal 1952 by contracts for the construction of the Biology Laboratories and the design of a waste concentration plant. During the past year the Laboratory has continued with the construction of facilities already in progress, has completed many miscellaneous modifications to plant, technical changes, and has subcontracted for reconstruction of the bridge on the south road. Although the Commission has assumed greater contractual responsibility, the Laboratory scientists and the Architectural Planning and Plant Maintenance Department still supply the technical specifications and preliminary designs.

The research activities of the Laboratory continue to be directed toward stabilization within the Departments and increased use of Brookhaven's own facilities. The completed researches are evidenced by the continually growing number of research reports submitted for publication. At the same time, due to the world situation, change in emphasis has been required toward the diversion of some effort from fundamental unclassified research toward certain applications in programmatic and development



BROOKHAVEN NATIONAL LABORATORY
Technical Publications

Figure 2.

work. This diversion has occurred to some extent in all of the programs. The results of such programs are published only in the classified reports of the Laboratory.

The programs of the Chemistry and Physics Departments are centered around researches utilizing nuclear techniques both within and outside the field of nuclear energy. A great shift in emphasis has occurred since neutrons are readily available from the reactor and a wider range of isotopes is also obtainable. The present use of particle beams is restricted to the reactor and to the electrostatic accelerator. The time-of-flight equipment for slow neutron velocity work with the cyclotron has not yet been in use since the cyclotron does not have an adequate external beam. The Chemistry Department has made considerable use of its own 2-Mev electron Van de Graaff for studies in radiation chemistry, using both electron and X-ray bombardments.

Applied physics and chemistry research and engineering studies have been carried out in both the Departments of Reactor Science and Engineering and Instrumentation and Health Physics. In the former, most of the work centers around metallurgy and chemical engineering, directed toward reactor design, fuels and fission products studies. Certain specialized programs have been undertaken at the Commission's request to aid in the development of specific reactor designs now under consideration. At the same time, long-range research and development are continuing on certain novel ideas pertaining to future reactor development. An extensive program directed toward the industrial utilization of wastes has been initiated and radioactive gamma sources of cobalt and tantalum, of upwards of 1000 curies, have been fabricated for initial experiments. The Electronics Division has been concerned with the development of instruments and equipment for specialized research. Their diversity of interest and abilities have allowed them to participate in extended activities requiring special instrumentation skills within both the Laboratory and the general Commission program.

The Accelerator Project has continued in its design and construction of the Cosmotron with the majority of the design problems satisfactorily concluded early in the fiscal year. Since January 1951, almost the entire effort of the Division has been centered upon construction activity.

The life sciences programs, including biology, medicine and certain smaller projects in biophysics and radioisotope production, are continuing to progress with the Departments of Biology and Medicine slowly being brought up to full strength. The Medical Department, containing its Divisions of Bacteriology, Biochemistry, Pathology and Physiology, does not yet have completely adequate facilities in their temporary housing but with the partial completion of the laboratories during the year has been able to pursue a vigorous program. The Research Hospital with three wards including some 36 beds available does not have the medical and nursing staffs sufficient to provide continuing care for more than about 24 research patients. It is expected that a full staff will be available by the end of fiscal 1952. A striking advance in the medical application of neutron therapy was announced in April 1951 when a report was made on the first neutron irradiation of a patient suffering from a brain tumor. The technical studies of subsequent treatments of other patients have not yet been brought to a conclusion. Results will be presented in the future.

The Biology Department has been actively pursuing its general program of radiation and tracer biology with special emphasis on plant problems. The addition of a new 200-curie cobalt radiation field has increased these facilities and will improve

ORGANIZATIONAL EXPENDITURES - FISCAL 1950 & 1951 (Includes Operating, Services to Capital Equipment and Facilities, Work for Others)												
		Salaries & Wages	Consultants & Temporary Appointments	Insurance	Travel	Materials & Supplies	Research & Development Subcontracts	Special Power	Miscellaneous	Total Organizational Costs	Capital Equipment External Costs Only
Physical Sciences	1951	1,156,135	54,400	59,594	47,611	325,993	1,393	37,778	14,511	1,697,415	65,536
	1950	1,282,683	47,281	56,110	67,064	450,377	28,514	62,130	21,411	2,015,570	232,435
Life Sciences	1951	526,747	10,310	27,026	16,973	172,806	7,225	-	9,883	770,970	67,718
	1950	338,388	4,835	14,476	13,729	134,473	-	-	406	506,307	66,405
Applied Research	1951	245,056	10,692	12,056	11,748	102,149	27,526	-	23,250	432,477	63,693
	1950	111,394	5,955	5,061	6,031	45,808	1,947	-	9,672	185,868	19,665
Radiation Protection	1951	181,563	738	9,450	3,696	35,101	16,840	4,306	4,748	256,442	6,009
	1950	190,225	490	8,257	3,135	41,979	24,145	-	2,696	270,927	56,364
Supporting Scientific & Technical Services	1951	1,136,806	1,452	58,643	9,042	264,926	-	237,947	4,336	1,713,152	42,201
	1950	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	1951	438,184	-	22,899	186	9,403	-	-	-	470,672	-
	1950	494,276	-	20,691	152	5,286	-	-	(101)	520,304	1,142
Miscellaneous (net of income)	1951	-	-	-	276	64,049	-	-	180,080	244,405	7,720
	1950	-	-	-	-	-	-	-	297,864	297,864	8,295
General & Administrative	1951	1,838,159	1,556	94,913	14,624	422,841	-	-	(106,004)	2,266,089	89,024
	1950	2,038,440	4,634	86,028	15,947	163,914	-	-	(25)	2,308,938	14,270
Laboratory Total	1951	5,522,650	79,148	284,581	104,156	1,397,268	52,984	280,031	130,804	7,851,622	341,901
	1950	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	1951	20,759	-	1,076	1,534	5,346	-	-	96,000	124,715	-
	1950	11,378	-	470	1,235	5,068	-	-	71,000	89,151	-
Total: A.U.I. and B.N.L.	1951	5,543,409	79,148	285,657	105,690	1,402,614	52,984	280,031	226,804	7,976,337	341,901
	1950	5,388,265	74,140	230,541	118,818	1,127,276	59,411	78,448	405,487	7,482,386	477,664
Work for Others	1951	3,903	-	(59)	143	7,944	-	-	7,616	19,547	-
	1950	-	-	-	-	-	-	-	-	-	-
Grand Total	1951	5,547,312	79,148	285,598	105,833	1,410,558	52,984	280,031	234,420	7,995,884	341,901
	1950	5,388,265	74,140	230,541	118,818	1,127,276	59,411	74,448	405,487	7,482,386	477,664

Figure 3.

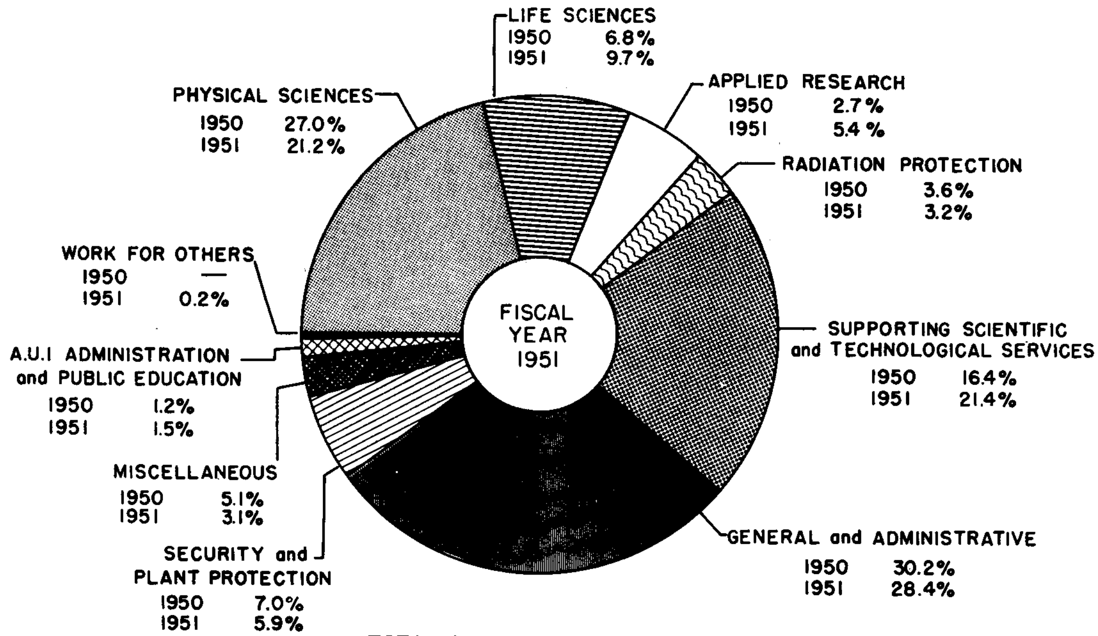
statistics in the problems arising from the irradiation of growing plants. The new Biology building program, in which construction is just beginning, will emphasize laboratories for animal experiments and will include adequate animal quarters. Co-operative studies between biology and medicine during the year have been directed at an emergency program of study of blood substitutes made at the request of the National Research Council.

The individual research programs are rounded out by technical conferences on specific subjects. In addition to regularly scheduled seminars and colloquia in which visiting scientists and Brookhaven scientists participate, several extensive conferences have been held. The Physics Department held a conference on neutron physics on November 10 and 11, 1950 with an attendance of over 100 physicists and graduate students. Its main purpose was to familiarize scientists with the facilities at Brookhaven National Laboratory and to stimulate thinking about experiments performed with neutrons. The Chemistry Department held a conference on physical and chemical properties of the rare earths on January 17 - 19, 1951, with approximately 70 participants. The Biology Department has scheduled its annual conference for the month of August 1951, the subject to be the chemistry and physiology of the nucleus. In addition, the Physics Department is taking advantage of a gathering of experts who are participating in the Brookhaven summer program to present a conference on beta decay and nuclear shell theory in July 1951.

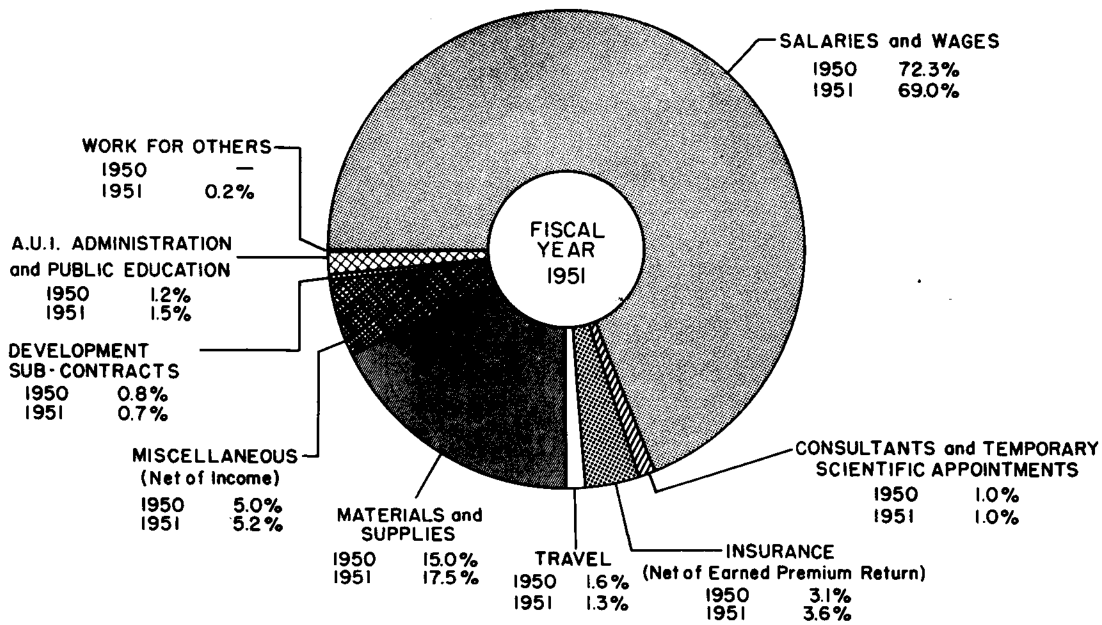
It has been found desirable to acquaint the technical and semi-technical neighbors on Long Island and in New York with the general nature of the Laboratory and its facilities. To this end, Brookhaven has held a Visitors' Day and has on various occasions been host to such organizations as Tau Beta Pi, Eta Kappa Nu, The American Society of Engineering Education, American Society of Mechanical Engineers (Metropolitan Section), Brooklyn Academy of Pediatrics and the Aeronautical Sciences Group.

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. During the course of the year, 37 speakers addressed 83 organizations. Approximately 7,000 people were contacted through this medium. In response to inquiries from a number of organizations, the Visitors' Day was held in May at which time approximately 1200 visitors were in attendance and were able to view some of the activities in connection with health physics and biology, cyclotron, Van de Graaff and Cosmotron studies.

Although the funds available to the Laboratory are listed under the headings Operations, Capital Equipment and Facilities, the organizational cost figure is the best to illustrate the total level of operation and to compare year-to-year operation. The organizational costs include all operations costs and those for services provided in the construction of capital equipment and facilities by the Laboratory organization. Thus in fiscal year 1951 the organizational costs were $7,996,000, an increase of $513,600 over fiscal year 1950. These costs were $190,000 less than the first budgeted figure since this sum was diverted to the new Biology building budget. An operating budget of $8,774,200 has been approved for the fiscal year 1952. When combined with an expected $340,000 for services for capital equipment and facilities, the fiscal year 1952 organizational budget becomes $9,114,200. The major increase in the next year's figure is chiefly toward certain programmatic activities and toward some expansion of the life sciences programs.



TOTAL ORGANIZATIONAL COSTS
1950 $7,482,386
1951 $7,995,884



MAJOR CATEGORIES
of ORGANIZATIONAL EXPENDITURES
1950 $7,482,386
1951 $7,995,884

Figure 4.

At the present time, the Laboratory has contractual arrangements with five industrial companies for the performance of work necessary for 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, the criterion of ability to perform and capability of carrying out the work in a short time are used. The second category of contracts includes those designed to assist other institutions in solving specific problems arising out of the Laboratory's own research interests. These arrangements are made on an individual basis and differ from case to case.

Major personnel changes during the past fiscal year involved the following additions, resignations and replacements. Dr. Gerald F. Tape joined the Laboratory on July 1 as Assistant to the Director. Upon the resignation of Mr. James M. Knox as Assistant Director and Business Manager in April, 1951, Dr. Tape also served as Acting Business Manager. Dr. Howard J. Curtis became Head of the Biology Department in October 1950. Dr. D.D. Van Slyke, Assistant Director for Life Sciences and Head of the Division of Biochemistry, resigned on June 30, 1951 to accept a position with the Lilly Foundation. Dr. Van Slyke will continue to live in the community and will maintain his office at the Laboratory where he will be available for discussions and consultations on Laboratory problems. Dr. Sidney C. Madden resigned as Head of the Division of Pathology to accept the Chair of Pathology at UCLA and will be replaced with the arrival in September of Dr. John T. Godwin, Pathologist at Foundation Hospital, New Orleans. Dr. Lyle B. Borst, presently Head of the Reactor Science and Engineering Department, has announced his resignation effective August 1, 1951; he will assume a professorship of physics at the University of Utah.

Brookhaven scientists are taking on added responsibilities in the over-all Commission program and in the scientific fraternity generally. Drs. Hughes and Kaplan are serving as Chairman and Secretary, respectively, of the AEC Cross Sections Committee. Dr. Richard W. Dodson, Chairman of the Chemistry Department, was selected to serve as Secretary to the General Advisory Committee to the Commission. Dr. Dodson took office in January 1951. Dr. S.A. Goudsmit was elected Editor of The Physical Review at the annual meeting of the American Physical Society in January 1951.

Personnel trends in the scientific staff of the Laboratory are illustrated by Figure 1 showing the changes from December 1946 to date. During the past fiscal year, the continuing staff built up to a peak in January and showed an accelerated decline in numbers in the early spring and summer. This has since been recovered by recruiting and expansion. The turnover during the spring was due primarily to the departure of engineers who had been associated with facility construction. In general these men are being replaced by research scientists who will use the machines in conjunction with the continuing research program.

It is worthy of note that the number of guests who use the Brookhaven facilities and participate in the scientific program has increased markedly. Such guest appointments in July 1951 amounted to three times the number present in July 1950. The increase in the guest category continues to reflect an expanding interest on the part of the scientists to make use of the Laboratory research facilities. A large number of summer visitors is also expected. In addition to the visitors and guest appointments, approximately 15 man months of services have been rendered by consultants under contract to the Laboratory.

PHYSICAL SCIENCES AND ENGINEERING

Three broad categories of investigations are emphasized in the physical sciences 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, proton synchrocyclotrons and reactors. The reactor became critical on August 22, 1950 and reached a maximum power of 26 mw and a central flux of 6×10^{12} neutrons/cm^2 sec during the Spring. It has been in steady operation since January 1951 for research use and isotope production.

Through the availability of the nuclear reactor, the programs in the Chemistry and Physics Departments now show a greater percentage of problems associated with the use of neutrons. Also, the world situation has caused basic research to be immediately followed up by application and development where new ideas have shown promise. As a result, several members of each Department are temporarily diverting themselves to applied problems of interest to the production, reactor and weapons programs of the AEC. The fundamental researches in Chemistry and Physics directed toward the study of the nucleus and the application of nuclear techniques in general are continuing in force. Less use is now being made of facilities at other Laboratories with the greater availability of the Brookhaven facilities. The only extensive uses at other institutions have been with the Van de Graaff machine at the Carnegie Institution and the Columbia cyclotron at Nevis.

The design, procurement and construction of the Brookhaven particle accelerators is in the hands of the Accelerator Project. Currently they have been operating the electrostatic accelerator at energies up to 2 Mev and are planning a program of modification which will allow operation at energies up to 3 Mev and with higher currents than presently obtained. The 60-inch cyclotron is still confined to start-up and shakedown and has not yet produced a satisfactory external beam. Since it is planned to use this machine with a neutron time-of-flight spectrometer for cross-section measurements, the external beam is a necessity. The proton synchrotron or Cosmotron is passing through its major construction period and component-testing period. The only major components still in the construction phase are the vacuum chamber, the pole face windings, the ferrite transformer and associated radio-frequency supply, and the control wiring. The redesign of the vacuum chamber to provide a unit that would be more simple and easier to handle delayed the completion date but at the same time has provided testing time for the magnet and its power equipment and for the injector assembly. The present schedule indicates completion of Cosmotron construction about January 1952.

Applied research to some extent is now being carried out in all Departments. The largest departmental effort is in the Reactor Science and Engineering Department. There researches in reactor component development involve studies in reactor development, physics, chemical engineering and metallurgy. An extensive study of waste fission products is in progress with special emphasis placed on concentration, possible industrial applications and ultimate disposal. This Department also has the responsibility for operating the reactor and the hot laboratory.

The Instrumentation and Health Physics Department has continued its service role in the Laboratory; in addition, it has carried out more long-range development and has participated in several extra-laboratory activities of particular interest to the Commission. It is now apparent that the Electronics and Health Physics Divisions anticipate requirements, and will be ready for the demand, made by higher energy machines and higher intensity sources. To this end research in biophysics and instrument development is under way. The day-to-day design, construction service and maintenance work supplied to all departments of the Laboratory has been invaluable. These services are also provided according to capabilities to Commission projects such as civilian defense activities and the testing of atomic weapons.

Although personnel turnover in the physical sciences has been large especially among engineers, there has been no change in key personnel during the year. However, Dr. Lyle Borst, Chairman of the Reactor Science and Engineering Department, has announced his resignation effective August 1, 1951 to join the Physics Department of the University of Utah.

PHYSICS

The total personnel of the Physics Department as of June 30, 1951 numbered 99 of whom 55 were on the scientific staff. In addition there were 20 temporary and guest scientists present at that date. The corresponding figures for June 30, 1950 were a total of 95 of whom 53 were scientists and 17 were temporary guests.

Resumé of Research

During the past year the Physics Department has continued with the program outlined in the last annual report without major changes of direction. The reactor which started operation in the fall has proved of great value for the studies of neutron interactions, the excited levels of nuclei, and nuclear radiations. The latter studies, which have depended upon irradiations in the reactor with both fast and slow neutrons, have led to significant advances in our understanding of the structure of nuclei. Neutron beams from the reactor have been used in a variety of ways, perhaps most significantly for detailed studies of the scattering and reflection of slow neutrons. Although the research electrostatic generator is still running at low efficiency and below its intended voltage, a few investigations have been accomplished with it and very considerable progress has been made in preparations for future researches. Some of these problems have been carried forward in the interim by the use of facilities of the Carnegie Institution of Washington.

The projected program with the cyclotron for measuring nuclear cross sections vs. neutron velocity is marking time until the cyclotron can be put into operation. The parallel program depending upon a fast neutron "chopper" in one of the beams of the reactor has made the progress expected; the design of the chopper is in an advanced stage and some construction has been done but it is still too early to predict confidently when measurements can begin.

In the field of high energy physics, the analysis of nuclear disruptions and meson production by primary cosmic rays in photographic emulsions has continued at its former pace and some conclusions have been reached regarding the dependence of multiplicity of meson production on proton energy and the nuclear mass. Cloud chambers have been used in several different cosmic ray experiments and a continuously sensitive diffusion cloud chamber has been developed for work with high energy accelerators. With the latter, some measurements have been made at the Nevis cyclotron of Columbia University on the interaction cross sections of hydrogen and helium for π-mesons of various energies. Investigations of penetrating showers and of extensive air showers in the cosmic radiation have continued at the Berthoud Pass station in Colorado and with the use of a B-29 airplane operated by the USAF. As the Cosmotron nears completion, plans are being made to transfer to it much of the effort now devoted to the study of cosmic rays.

In the nuclear moments program, plans are being implemented for an experiment for measuring accurately the magnetic moment of the neutron, a number which will at some time in the future surely have fundamental theoretical significance. The microwave spectrographs have also been used in measuring nuclear moments and masses. Efforts to develop other nuclear mass measuring instruments, dependent upon observation of a frequency rather than a distance, have continued along two lines: an instrument utilizing helical ion paths in a uniform magnetic field has been applied to the measurement of a number of isotopic masses with probable errors of 1 or 2 millimass units, while a flat orbit model has reached a stage in design where it seems to promise the best accuracy of any of the mass spectrometers.

The theoretical group has collaborated with the experimentalists in most of the above programs. In addition a concerted effort has been made by the group better to understand the nature of the divergences which have plagued all attempts to formulate a consistent theory of quantum electrodynamics.

A sizable group within the Department is now devoting part time to a project which cannot be described here because of need for security.

Nuclear Energy Levels

Work in this field is directly concerned with the details of nuclear structure and is analogous in its method to the work in atomic spectroscopy which was concerned with the electronic structure of the atom and gave rise to the modern theory of quantum mechanics.

When an atomic nucleus is disturbed from its ground state, either in the process of being formed from a reaction or by receiving energy from radiation or from a bombarding particle, it either emits a number of discrete gamma rays of sharply defined energy, or a particle may be emitted with an energy such that the balance retained or given off by the nucleus over and above that received from the excitation has a discrete value and belongs to the same spectrum as that observed in the gamma radiation. One concludes that each nucleus, no matter how it is excited, always finds itself in one of a set of characteristic levels, most of which are sharply defined in energy, and that nuclear radiation results from transitions between levels. The lowest level is the ground state. No two of the nearly 1000 known nuclear species, characterized by different combinations of neutrons and protons, have the same spectrum of levels. The situation is complex but when properly understood, one may hope to explain the level structure of nuclei in terms of the numbers of neutrons and protons in the nucleus and the forces between them.

The modes of motion of the many nucleons in a nucleus might have appeared too complex to understand in any detail but one is encouraged by the fact that the number of levels in unit range of energy is much less than would have been predicted from a statistical model. For this reason it is believed that transitions between the lower excited levels involve only one, or at the most a few, nucleons. In fact, a good deal of success has been achieved by a model of the nucleus in which each neutron and proton is visualized as belonging to a different quantum state characterized by a combination of quantum numbers. In this model only nucleons in the higher quantum states which are adjacent to unoccupied levels can participate in the excitation if the available energy is low. In many instances the excited level of lowest energy is thought to be one in which a single nucleon from the highest occupied level has been lifted into the next unoccupied level without disturbing the other nucleons.

In making a transition from one level to another the nucleus will, in general, change both its energy and its angular momentum; because of conservation laws the radiation given off or absorbed must account for the difference in both of these quantities. The energy of the radiation can be measured directly but its angular momentum about the center of the emitting nucleus is more elusive. However, the change in angular momentum of the nucleus is a factor determining both the lifetime in the excited state and the probability that the downward transition will take place by direct transfer of energy to an orbital electron instead of through emission of a gamma ray. (The ratio of direct transfers to gamma emissions is called the internal conversion coefficient for the particular electronic orbit involved.) Both effects can be used to determine experimentally the change in angular momentum of the nucleus during a transition.

The shell model described above provides a scheme for the interpretation of nuclear energy levels, and the development of the scheme is the principal impetus at Brookhaven and elsewhere for present-day programs in this field. The immediate experimental problem is to determine the energy and the angular momenta (spin and orbital) of each level of each nucleus, and to evaluate other factors determining transition probabilities. The analysis of the level structures will hopefully lead to generalizations regarding nuclear forces. An important step in this work, accomplished at the Laboratory and reported in detail in the Quarterly Report (BNL 103 (S-9)) for January 1 - March 31, 1951 was to improve the procedures used to determine the change of angular momentum of a nucleus during a transition from a so-called isomeric state which has a measurable lifetime. Previously the two methods cited above frequently gave different answers. However, relationships have now been established, one between the lifetime and the energy of the transition which contains as a parameter the integral value of the change of angular momentum, the other between the energy and the ratio of the conversion coefficients for the K and L electron orbits, which likewise contains as a parameter the change in angular momentum. Both of these relationships in their present form give consistent values for the change in angular momentum in all cases where they have been compared, and one has confidence that the values given by these methods are correct.

In many cases therefore it has been possible to work backwards through a decay scheme from a ground state, in which the angular momentum is known from other measurements, and to determine the values of the angular momenta of several of the excited levels. In most cases the angular momenta found correspond nicely with those expected in the shell model for the levels immediately above the ground state when the order of levels is calculated from a simple form of the nuclear potential. In some cases, where the order of levels is uncertain from the theory, it has been possible to establish rules which indicate the order of magnitude of the energy associated with the coupling of the orbital and spin moments of the nucleons and that with the coupling between pairs of nucleons in so-called degenerate quantum states (states which differ only in the orientation of their momentum vectors).

Now that one has a method of positively identifying the levels of nuclei and of classifying them according to their angular momenta, attention will be focused on studies of the dependence of the energy of similarly classified levels upon the number of other similar nucleons in the same group of degenerate levels and upon the number of neutrons and protons in the nucleus. Although in the simplest form of the shell model the neutrons and protons are treated as though they were independent of one another, the energy of a nucleon in a particular class of level should depend upon the number of protons and of neutrons in the nucleus.

In summary, this work has given new hope that the interactions between the neutrons and protons within a nucleus can be understood in terms of the shell model, and it has served to define clearly a great many questions which are now ripe for investigation.

The experimental work, as the above discussion indicates, is concerned with the measurement of nuclear lifetimes, the energies of nuclear radiations, the internal conversion coefficients for the transitions, and the determination of coincidences between transitions, the latter being needed to evaluate the decay schemes. The various techniques used in this work were listed in the last annual report and it is only necessary to add that the crystal scintillometer combined with the rapid processing Land camera has proved to be a great boon for the measurement of energies and the evaluation of decay schemes. In some special cases it has been useful to grow scintillating crystals that contain the activity to be studied as an impurity. With improvement in the technique for measuring scintillation pulse heights, it has also been possible to determine energies of the transitions within an error of about 5% which is adequate precision for most purposes. When more precise measurements are required the more time-consuming lens spectrograph is used.

Angular Correlation: When a beta ray and a gamma ray, or two gamma rays, are emitted in sequence the angular momenta of all three states can sometimes be determined from the angular correlation pattern found by plotting the rate of coincidences between two detectors against the angle subtended from the source. Experiments of this type have been started at the Laboratory and when applicable they will be useful for characterizing transitions for which neither the conversion coefficients nor the lifetime is measurable.

Neutron Capture Gammas: Experiments have also been started to measure the gamma rays given off in cascade when a nucleus captures a thermal neutron. In this work the neutrons are brought out through the shield of the reactor to the absorber which is mounted near a scintillating crystal detector arranged for recording in conventional manner. Most of the previous work done on neutron-capture gamma transitions has been concerned with the very high energy gamma rays, but in this work the lower transition energies will also be studied.

Excitation by Charged Particle Bombardment: In the lighter elements the nuclei are conveniently excited by charged particle bombardment with the electrostatic generator. For example, in the bombardment of F^{19} with protons, alpha particle emission results in an excited state of O^{16}. The angular momentum of this state has been determined from the angular correlation of the gamma ray and the alpha particle. The results confirm earlier work of similar character and are of interest in showing the quality of work of this type which can now be performed at Brookhaven. He^4 is a nucleus of particular interest in the shell theory and its first excited state produces a 23-Mev gamma ray. Studies of the cross section for excitation of this state by the capture of protons in tritium give an energy dependence characteristic of the next higher level in the shell model. In another experiment with the electrostatic generator the gamma spectrum of B^{10} was observed when Be^9 was bombarded with deuterons. In this case the gamma spectrum was found to agree with a level scheme established by work at Wisconsin in which the energies of the neutron groups had been measured. However, one of the transitions thus predicted was found to be forbidden because of a large change of angular momentum. Many experiments such as these are on the program since they are needed to fill out the general picture of the excited levels of nuclei.

Fast Neutron Capture

The level densities of the highly excited states of nuclei have been the subject of another investigation with a quite different method of approach. In this work the cross section for capture of fast neutrons has been measured in a large number of nuclei. Since capture can occur only if the newly formed nucleus finds itself in one of its normal modes of excitation, the probability for capture is obviously proportional to the product of the level density w and level width Γ, both quantities referring to levels whose excitation energy is equal to the sum of the binding energy of a neutron plus its kinetic energy. Since the binding energies are known from measurements of (d,p) reactions, the results show how the product $w\Gamma$ varies with excitation energy. A fairly large range of excitation energy can be investigated because of the variations of binding energy from nucleus to nucleus in consequence of the shell structure referred to in the last section. The experiments have been performed with fission neutrons produced in a plate of U^{235} located inside the reactor shield. Since these have an average energy of about 1 Mev, the initial excitation of the nucleus formed by neutron capture must involve many of the nucleons and it may be presumed that a statistical model of the nucleus can be used in interpreting the results. When analyzed in the light of theories based upon this model, the experimental results show that neutrons are captured into states for which the orbital angular momentum is zero (S-states). The variation of the cross sections with energy is also roughly in agreement with the density of levels predicted for this model if a reasonable variation of level width with atomic number is assumed. These experiments are providing data upon which to base more detailed theories of the highly excited states of the nucleus; the situation suggests that further experiments and theoretical studies can significantly advance our understanding of these levels.

Nuclear Interactions with Matter

Thermal and Epithermal Cross Sections: From the standpoint of nuclear engineering and reactor technology it is important to know nuclear cross sections for scattering and capture of neutrons in the thermal and epithermal ranges of energy since these energies make up the major part of the flux of most reactors. From the point of view of understanding the physics of the nucleus, the resonances that occur in this region are no more significant than those in any other range of energy but these are most readily measured. Supplemental to the program at Columbia University and to the work just getting under way at Harwell, England, the Department is embarking upon a double program for the study of these cross sections; the investigations will make use, on the one hand, of the 60-inch cyclotron which will generate neutrons in pulses when the deuteron beam strikes a Be target, and, on the other hand, of a fast operating shutter in a neutron beam emerging from the reactor. In both instances the time of flight of the neutrons to a distant detector resolves the flux into a velocity spectrum and shows the position of resonances in materials through which the beam is allowed to pass; variations with neutron velocity of the process involved in the detector can also be studied.

The circuits have been constructed and installed which are to be used with the cyclotron for pulsing the deuteron beam and for channeling detector pulses according to the arrival time of the neutrons; the research program will be under way as soon as the cyclotron goes into operation. Besides attempting to satisfy the fairly heavy demands of reactor engineers for data on substances as yet unmeasured, fundamental studies will also be made of nuclear resonances in an attempt to determine and to understand their widths, strengths, and distribution in energy. The second apparatus being developed for these measurements, which comprises the fast shutter, will cover about the same range of energy from thermal up to a few kilovolts, but will offer two advantages over the cyclotron method in that much smaller samples of the absorbing material will suffice and the experiment will not interfere with other work being done with a major facility. The design and construction of the shutter device, sometimes called a "chopper," is being carried on at the Laboratory with the help of an outside engineering firm. It has been possible, in this design, to incorporate into a slit system hydrogenous plastic material, which is relatively opaque to epithermal neutrons, and still to achieve enough mechanical strength to allow the system to be rotated at such speed that the neutron beam will be turned on and off in a time of the order of 1 μsec. When the detector is placed down the beam at a distance of 20 m, measurable differences in flight times will resolve energies up to a few kilovolts and there will be enough intensity to carry out the measurements in reasonable time. For further details of the design, the reader is referred to recent quarterly reports.

Slow Neutrons: In addition to the thermal and epithermal neutrons involved in the foregoing studies, the reactor is also an excellent source of very slow neutrons which are needed for studying other modes of interaction between neutrons and matter. To obtain such neutrons from the reactor a mechanically rotated cadmium shutter interrupts a collimated beam and produces short bursts of neutrons which pass through when the shutter is open. The time of flight of each neutron to the detector gives its velocity.

Among the interactions being investigated with slow neutrons are the coherent elastic scattering by solids, liquids and gases; interactions in which the neutron reverses its spin vector, interactions between the magnetic moment of the neutron and the atomic and molecular magnetic fields in the scattering material and inelastic scattering involving quantized energy or "phonon" exchange with the low frequency vibrational modes of the lattice. An interaction with electrons may take place if the neutron is surrounded by a charged meson field. All of these interactions are obscured by incoherent nuclear scattering if the neutron energy is sufficient to dislodge the scattering nucleus from the lattice. In the higher range of thermal energies where the neutron wave length is less than twice the largest grating space of the crystal coherently scattered beams occur in directions other than forward, and the losses suffered obscure the interactions mentioned above.

In this connection it should be recalled that in materials containing elements with more than one isotope, isotopic disorder results in effective grating spaces with a distribution extending up to the dimensions of the crystal so that the elastic scattering has an apparently incoherent component. Experiments revealing spin reversal, the exchange of phonons, or the electron interaction are made with neutrons of very low energy whose de Broglie wave lengths lie in the range 6Å to 25Å. Here all coherent scattering is forward, there is no inelastic scattering from single nuclei, and usually the nearest resonance level is sufficiently remote that nuclear capture is small and accurately proportional to the reciprocal of the velocity, or to the wave length. The experiments are arranged to measure the attenuation of the neutrons in the scattering material as a function of the neutron velocity and of the temperature of the material. After correction is made for neutron capture, which is usually known from other work, the remaining velocity-sensitive component of the attenuation is thought to be associated with phonon exchange since the other effects should be nearly independent of neutron velocity.

Phonon Exchange: In interpreting the results extensive calculations have been made on the basis of lattice theory of the cross sections for phonon exchange as a function of wave length and temperature. In the calculations the important parameter is the deBye temperature which is known for most materials from specific heat measurements. There has been remarkable agreement, but also suggestive differences, between the results of the experiments and the calculations which may be summarized briefly as follows:

In graphite, where there is no spin-dependent scattering, no isotopic disorder, and practically no capture, the scattering cross section was proportional to the neutron wave length as predicted by the theory of phonon exchange. The deBye temperature of graphite is high compared with the neutron temperature and the neutrons gain energy from the lattice. The cross section increased with graphite temperature as expected but the increase was more gradual than the theory predicted, a fact which may be associated with the anomalous behavior of the specific heat of graphite, usually attributed to its plate-like structure.

In beryllium, which is also monoisotopic and captures inappreciably, the cross section was linear with the wave length as predicted by theory, but when extrapolated it had a positive value at zero wave length. This value might have been explained as the cross section for spin reversal were it not for the fact that it also appeared to vary with the temperature of the beryllium. The total cross section for long wave lengths varied with the beryllium temperature in a manner very similar to that predicted by the theory of phonon exchange.

In bismuth, which has a low deBye temperature and is monoisotopic, the cross sections at one temperature, after correction for the known capture cross section, were in agreement with the phonon exchange theory which, in this case, predicts both gains and losses of energy. Work with bismuth at other temperatures is in progress and other substances will be studied. It will be necessary to understand phonon exchange thoroughly before small effects such as spin reversal and electron interaction can be distinguished. These experiments are also providing the first direct measurements of the spectra of lattice vibrations predicted by the theory of specific heats; they represent a new approach to certain problems in the physics of solids.

Mirror Experiments: Neutron beams have also been reflected from mirrors for determination of the critical angle of total reflection from which one gets the index of refraction of the mirror and the average coherent scattering amplitude of the nuclei in it. This method has been applied to liquid hydrocarbons with results that gave the coherent amplitude of hydrogen. More recently the critical angles have been measured for reflection from an interface between a liquid or solid of known index and various gases at high pressure. The coherent amplitudes of the gas nuclei determined in these experiments are the same as the bound atom values, a result which accords with the wave mechanical concept that the reflection is from the interface and not from individual nuclei. Among the solid surfaces studied by this technique is vanadium in which the two spin states have nearly equal but opposite coherent amplitudes and the net amplitude is nearly zero.

Polarized Neutrons: Further experiments with polarized neutrons are planned. For the purpose of producing polarized neutron beams by mirror reflection, an iron-cobalt alloy has been found which is expected to behave like cobalt in giving a fully polarized beam at the same time that it is more easily magnetized than pure cobalt.

Small Angle Scattering: When a sharply collimated beam of slow neutrons passes through solid matter the transmitted and the diffracted beams may become broadened by "small angle scattering." This phenomenon is explained by diffraction resulting from the granular structure of the material. Studies with finely divided powders were reported last year in which the theory of the effect was developed and experimentally checked in detail. Recently, the same effect has been used to study the mosaic structure of metals. It is hoped to use the small angle scattering of neutrons as a means of determining changes in mosaic structure resulting from cold work, and thus to arrive at a better understanding of some of the factors affecting the elastic properties of metals. For this purpose neutron beams have a number of advantages over X-rays, but have not been as extensively used.

Nuclear Forces

The forces acting between nucleons have been investigated in a number of experiments with the research electrostatic generator in which the total and differential cross sections for scattering of neutrons by protons and deuterons have been measured. In these experiments neutrons of various energies have been produced by the electrostatic generator and the intensities of the scattered neutrons have been measured either by observing the recoiling protons and deuterons in the scattering event, or by observing the neutrons themselves through proton recoils in a liquid phosphor counter. In the first method the recoil particles have been observed as they pass through a series of gas-filled proportional counters connected in coincidence so that they discriminate the range of the recoil particle and are not responsive to the general radiation background. A cloud chamber filled with hydrogen or deuterium has also been used for studying the angular distribution of the recoil particles, which is uniquely related to the angular distribution of the scattered neutrons. The liquid phosphor counter has been used chiefly to measure the intensity of the unscattered beam after it has passed through known thicknesses of various materials. From the latter measurements one calculates the total cross section of the scattering nuclei. Measurements have been made with neutrons of 1.4 Mev, 5 Mev, and 14 Mev, with results that have settled some questions in the theory of n,p and n,n forces. However, more careful and more extensive measurements will be informative and continuation of the work is planned. Although the facilities of the Department of Terrestrial Magnetism have been used extensively in the foregoing experiments, it is expected that future work can be done at the Laboratory.

Reaction Energies

The electrostatic accelerator has also been used to measure precisely the energies of a few reactions among the light nuclei from which mass differences can be calculated. In one such experiment a new heavy particle spectrograph was used to determine the energy of the protons emitted with C^{12} was bombarded with deuterons in the production of C^{13}. The technique used permitted a measurement of the 2.7-Mev reaction energy with a probable error of about 4 kev, or one part in three million when referred to the mass of C^{12}. In another experiment a lens spectrograph was used to measure the energy of the beta rays emitted from Al^{28}, produced by bombarding ordinary aluminum with deuterons. In this case the probable error in the energy of the 2.8 Mev beta rays was about 15 kev. Both experiments are valuable in establishing a table of the masses of the isotopes.

Mass Spectrometry: Although reaction energies can establish mass differences of neighbor isotopes with the accuracies cited above, the errors accumulate if the comparison is extended to widely separated isotopes. The masses of heavy nuclei are thus most accurately related to the oxygen standard by mass spectrometry. Spectrographs, depending upon the measurement of the distance of a deflected beam of ions are now, after many years of development, determining masses of heavy nuclei with errors ranging from a few ten thousandths to one or two thousands of the proton mass. Although minor improvements may be expected in instruments of this type, any significant gains in accuracy must be sought in some new principle of measurement. In a mass spectrometer which has been under development at Brookhaven for the past few years, masses are measured in terms of their time of flight around a circular orbit in a magnetic field. Using electronic timing similar to that developed for Loran navigation, a comparatively crude instrument is giving mass values comparable in accuracy with the best obtainable from the deflection instruments; a number of new values have been added to the table. An analysis of the essential limitations of the method show that attainable refinements can result in accuracies considerably superior to those of the deflection instruments. Higher accuracy in mass measurements will be of interest as evidence for shell structure regularities in the total binding energies of nuclei and for comparison with reaction energies. These interests are being carefully balanced against the costs in time and money in an effort to reach a decision on the Laboratory's ability to advance this program.

Nuclear Moments

The most substantial foundation-in-fact of the shell model is its success in explaining the measured spins of the various nuclear species. A recent compilation lists

180 nuclei whose ground-state spins have been measured, but only 13 radioactive species were included. Much experimental work of immediate interest remains to be done, especially with the radioactive nuclei which include nearly all of those whose resultant spins are compounded from both neutron and proton components. The small number of these nuclei which have yielded to measurement, reflects the difficulties in handling highly radioactive materials and of working with the minute quantities available. Because of special facilities at Brookhaven for producing and handling radioactive materials a program for measuring moments of radioactive nuclei has been in progress since 1947. Last year microwave determinations of the spin and electric quadripole moment of S^{35} were reported. Recent efforts have been directed toward similar measurements with P^{32} and the principal difficulties seem now to have been surmounted. The progress has been slow and it is now evident that the chemical problems involved in the microwave method are more formidable than had originally been anticipated. Serious consideration is therefore being given to a new attack on nuclear moments using molecular beam methods.

As a by-product of the work with S^{35}, the microwave spectrograph was used in comparing the rotational frequencies of molecules containing different isotopes of sulphur, thus determining relative masses with high accuracy.

Cosmic Ray Studies with Emulsions

As reported last year, special photographic emulsions have been flown in balloons to very high altitudes where they were irradiated by primary cosmic rays. The radiation there is known to consist of protons with an energy spectrum extending upwards from a minimum energy which depends upon latitude; it has the minimum values of 1 Bev in Minnesota where some of the flights were made, and 8 Bev in the Caribbean Sea where the Navy assisted with other flights. In examining the exposed plates attention has been given to the frequency of occurrence of nuclear disruptions of various types produced in the atoms of the emulsion. From the statistics one attempts to infer what he can about the disruptive process. In classifying the disruptions, or "stars", one can distinguish between those produced by protons, which show a lightly developed incoming track, and the neutron-produced stars which have no incoming track. Distinction can also be made on the basis of the latitude between disruptions produced by protons in the high energy and of the spectrum above 8 Bev which have a median value of 14 Bev, and those produced by the whole spectrum. By subtraction one finds the effects produced by the low energy band extending from 1 to 8 Bev with a median value of 2 Bev.

It has been interesting to compare the effects produced by the high and the low energy bands. Besides the incoming track, three other types of track emanating from the star can be distinguished on the basis of photographic density: very light tracks attributed to mesons created by the impact, medium light tracks thought to be fast secondary protons, and black tracks produced by slow protons. One can also differentiate events occurring in the three light nuclei, C, N or O, that make up the gelatine in the emulsion, from those occurring in the Ag and Br nuclei of the photographic salt. The former never have more than eight heavy and medium prongs while the latter include all stars with larger numbers of prongs along with some of the smaller stars. The actual distributions of prong numbers from the two types of nuclei have been determined by the use of laminated emulsions containing layers of pure gelatine in which only light-nucleus stars occur. The distribution in prong number for the heavy-nucleus stars has been obtained by subtracting the gelatine distribution from the total, using a weighting factor based upon the known compositions.

In comparing the multiplicities of meson tracks in light- and heavy-nucleus stars and in studying their variation with proton energy, evidence was found, as reported last year, in support of the hypothesis that mesons are produced singly in nucleon-nucleon collisions, and the higher multiplicities observed in stars result from the many impacts that occur when a high energy proton passes through a heavy nucleus.

Among the conclusions based upon more recent statistics are the following:

In many of the stars produced by high energy protons, there are no charged mesons produced but the combined energy of the outgoing protons, to which is added an equal amount to account for outgoing neutrons, falls far short of that supplied by the incoming proton. Evidently large amounts of energy may be carried away by neutral mesons.

In heavy-nucleus stars the number of prongs is not sensitive to the incoming proton energy and evidently depends only upon the radius of the impact or some analogous statistical parameter. However, it is found that the meson multiplicity from lightly struct heavy nuclei increases with the incoming proton energy while that from more completely disrupted heavy nuclei is quite insensitive to proton energy. In another way of saying it, the meson multiplicity among heavy-nucleus stars produced by low energy protons increases with the number of prongs but is independent of prong number among such stars produced by high energy protons; in particular, many small stars produced by low energy protons have no meson tracks while the large stars in this category and both large and small stars produced by high energy protons usually contain meson tracks. No plausible explanation for this effect has yet been found.

The mediumly dense, or grey, tracks attributed to fast protons have been studied in stars produced by the high energy proton spectrum and are found to be seven times more frequent in heavy-nucleus than in light-nucleus stars; in the former type of star their frequency increases with prong number.

On some of the flights, part of the load of emulsions was covered by a hemispherical carbon shell 30 g/cm^2 thick in which 30% of the incoming protons made nuclear collisions before reaching the emulsions. Some notable differences in the distribution of prong numbers were observed when stars recorded under the carbon were compared with those in unshielded emulsions carried on the same flights. However, the effects observed were consistent with the hypothesis that protons making nuclear collisions in the carbon produced 1.4 times their own number of mesons (the multiplicity already observed in stars produced in the gelatine) and that the secondary mesons produced small stars in the emulsion with a probability consistent with the geometric cross sections of the emulsion nuclei.

Because of other activities of the Navy, flights carrying plate orientors which had been planned have not taken place and it has therefore been impossible to extend the analyses to stars produced by protons in a still higher energy band. However, the present results will form a useful counterpart to data obtained from the Cosmotron which will overlap the lower energy band investigated in these studies.

Extensive Cosmic Ray Showers

At the Berthoud Pass mountain station, definitive results have been obtained in the experiments designed to understand the generation of the nucleonic component of extensive air showers. These showers are produced by primary cosmic rays in the energy range 10^{13} to 10^{16} electron volts and they consist largely of electrons and photons but a small nucleonic component of about 1% has also been observed. The present experiments were designed to answer the following questions: Do the nucleonic component and the electronic component develop independently after being started at the top of the atmosphere by the same primary ray? Does one component continuously reproduce the other as it develops in the atmosphere? Or do both components reproduce each other? The results show that the nucleonic component always occurs in the same intensity relative to the electronic component and one concludes that the two components are closely interrelated. The compact angular distribution of the shower particles favors the electronic component as the progenitor of the nucleonic component but there is some difficulty in accounting for the intensity of the latter on the basis of photonuclear cross sections. Further experiments are planned to study the development of showers of this type in condensed materials.

Interaction of π-Mesons

Other experiments have been going on at the Berthoud Pass for studying the interaction of π-mesons with nuclei. While some of this work is not yet ready to report, an experiment to measure the production of neutral π-mesons (π^0) by charged π-mesons ($\pi^{\pm}$) has been completed. In this experiment a penetrating shower detector was used to trigger a small cloud chamber and a pair of electrons emerging from a lead plate in the cloud chamber gave evidence for a gamma ray resulting from the π^0 decay. The experiment was ingeniously arranged to give directly the cross section for π^0 production by $\pi^{\pm}$ interaction in carbon; it was found to be less than a fifth of the geometric cross section of the carbon nucleus. The result is of timely interest in connection with current theories of the nature of π-meson interaction. The interaction of charged π-mesons with hydrogen deuterium and helium nuclei is being investigated in a continuously sensitive diffusion cloud chamber which has been developed at the Laboratory as an instrument especially adapted for use with accelerators. In this work the mesons have been obtained at the Nevis cyclotron of Columbia University. The cyclotron has been pulsed every five seconds and after each pulse the cloud chamber was photographed. An average picture contains about ten mesons traversals and with the chamber operated at a gas pressure of 20 atmospheres, a day's run with hydrogen gives a total track length of a kilogram per square centimeter. Although results are not yet ready to report, it may be stated that scatterings in hydrogen are seen but rarely while elastic and disrupting collisions occur in helium with approximately the frequency expected from the geometric cross section.

Theoretical Studies

In addition to the contributions made by the theoretical group to the analysis of experimental problems, a number of unrelated theoretical studies have been completed which are briefly described in the following paragraphs.

The modern theory of electromagnetic fields has been applied to solve the old problem of the scattering of light by light. Experiments have always failed to give a positive effect and it is now shown that the theory predicts too small a cross section to be detected.

Treating the nucleus as a transparent sphere with an index of refraction the angular distribution of scattered neutrons has been calculated with results in agreement with experiments carried out at Berkeley with 90-Mev neutrons.

Further work has been done on the statistical theory of cascade showers which is useful in understanding cosmic radiation and will be applicable to the development of secondary radiation from high energy accelerators.

The theory of multiple scattering of charged particles while passing through matter has been further developed and put in useful form for the experimentalist. This theory has assumed increasing importance because of the use of scattering as a measure of the energy of particles producing tracks in photographic emulsions.

In a treatment of the photo-production of mesons in deuterium it is shown how the spin flip probability of a proton during the meson production process can be experimentally measured by comparing the number of mesons emitted in deuterium and in hydrogen.

Other theoretical studies concern field theories. In a paper by Schwinger largely written at Brookhaven during the summer of 1950, the conventional correspondence basis for quantum dynamics is replaced by a self-contained quantum dynamical principle from which the equations of motion and the commutation relations are deduced. Snyder has discussed charge renormalization in the Hartree approximation and, in another paper, has considered the dependence of quantum mechanical scattering on the adiabatic hypothesis. Neuman has stated a theorem regarding the U operator.

INSTRUMENTATION AND HEALTH PHYSICS

Electronics Division

On June 30, 1951, the scientific staff of the Electronics Division numbered 15 with 29 technicians and other helpers, a total of 44 representing a net increase of one staff member and 4 technicians over 1950. The slow growth of the department reflects the difficulty in recruiting electronic engineers because of the accelerated demand from industry. During the year the Division acquired some additional laboratory space for work on proportional and scintillation counters in the adjacent building (56 Brookhaven Avenue). This arrangement permits the use of various test sources which were jeopardizing the "clean area" maintained in the main building. The latter also underwent some alterations to relocate the offices more centrally.

Research and Development

Among the research and development accomplishments of the year the following are worthy of mention.

Pulse Height Analysis

Studies of pulse amplitude distributions, for example those from a proportional or scintillation counter, are receiving more and more attention because of the information they may give on energies of the incident radiation. Accordingly a large part of the Division activities has been devoted to the circuitry pertinent to this field, and, although the major problems have been solved reasonably well, it is expected that the program will continue for some time to come.

It was recognized early that pulse amplifiers with unusually good overload properties and gain stability were required. It was also found important for good energy resolution to use only moderate gain in the counter tube and correspondingly more in the amplifier, thus further complicating the design of the latter. Many applications have been satisfactorily handled with a non-overloading amplifier using balanced duo-triodes with both positive and negative feedback. The gain is set at 10 per stage with a rise time of less than 0.1 μsec.

To achieve the maximum stability of the counter itself, it was necessary to devise precision-regulated high voltage supplies which would have unusually low drift. Two models, giving outputs of up to 5 kv and 1.5 kv with stability of the order of 0.01% were designed and are now being produced commercially.

Many designs of single- and multiple-channel pulse height analyzers have been used with success in particular problems but no truly universal one is yet available. The difficulty lies in the fact that very widely varying counting rates may be encountered as well as major differences in pulse shape, rise time and decay time. The natural result is some compromise design which will tolerate as wide a range of counting rates and pulse shapes as seems consistent with reasonable complexity and cost. An example of this is to be found in an extremely simple 10-channel analyzer employing only 22 tubes. This circuit will operate only on pulses several microseconds wide and so seems hardly worth further development.

Another vexing problem in this field is the stability of the channel width. If the width does not remain constant throughout an experiment which may last hours, the experimenter may waste considerable time chasing down false peaks appearing in what would otherwise be a smooth energy distribution curve. This is particularly troublesome in the multi-channel instruments.

A design of a single-channel analyzer which is reasonably versatile and should have a width stability of 1% has been worked out (after discussion with Oak Ridge National Laboratory), and the first commercial production run has been supervised. It is expected that this device will fill a long felt need.

As a corollary to this problem special test gear for checking pulse height analyzers has been devised. Among the instruments used are a very stable pulse generator using a mercury switch and a trapezoidal pulse generator. In some types of experiments the total number of events available for study is strictly limited, as in the case where exclusive use of a large machine is required. For these experiments multi-channel analyzers are a necessity and it is anticipated that the future program will be concerned largely with these.

Scintillation Spectrometers

The growing importance of scintillation counters using organic and inorganic crystals as devices for studying beta and gamma spectra is generally recognized. During the past year, studies of these instruments have been carried out with particular emphasis on the factors affecting the resolution obtainable. It is still not clear why some particular crystals are superior to others of supposedly identical composition, although traces of impurities are suspected. The method of mounting the crystal and reflector on the photomultiplier tube has been found important. Also, for satisfactory performance at low energies the crystal should have cleaved rather than polished surfaces.

In addition to the crystal, the properties of the photomultiplier tube are of great importance in this work. Uniformity and sensitivity of the photocathode are significant. In cooperation with the Radio Corp. of America the Division has tested numerous photomultipliers in hopes of developing some simple factory test which would permit selection of those tubes that would make good scintillation counters.

To permit rapid testing of tubes and crystals two types of pulse height analyzers have been employed. One is a single-channel analyzer with a Helipot driven by a timing motor used with a counting-rate meter and recorder. The other is a modification of the photographic method, originated some years ago in Switzerland, which has become considerably more popular since the introduction of the polaroid camera.

Recently, considerable attention has been given to the use of thallium-activated lithium iodide crystals as thermal neutron detectors. Work is continuing on the problems of growing and handling these crystals.

Proportional Counter Spectrometer

Proportional counter spectrometer techniques have been developed to a point where the theoretical limit in resolution is obtained for low energy X-rays. The spectrum of the L X-rays emitted by a polonium source is shown in Figure 1.

Timer for Time-of-Flight Mass Spectrometer

In connection with the precision mass spectrometer using the time-of-flight principle an unusually flexible timer was developed. In its final form the unit uses a 10-mc crystal, a tuned divider to 1 mc, and a series of ring dividers to get lower frequencies. Steps of 0.1 μsec are obtained from a tapped delay line and finally a continuously variable delay line permits direct reading down to better than 0.01 μsec.

Pile Flux Plotter

In order to determine the neutron flux at any point in an experimental hole, a copper wire has been pulled through the hole, left for a desired length of time and then withdrawn and the variation in activity along the wire measured. Because of the difficulties in handling the dangerously active fine wire it was desired to mechanize the process. A device was built which reels the wire up on a shielded spool; provision was made not only for passing the wire at a specified rate in front of a counter equipped with a recording ratemeter but also for storage of the hot spool.

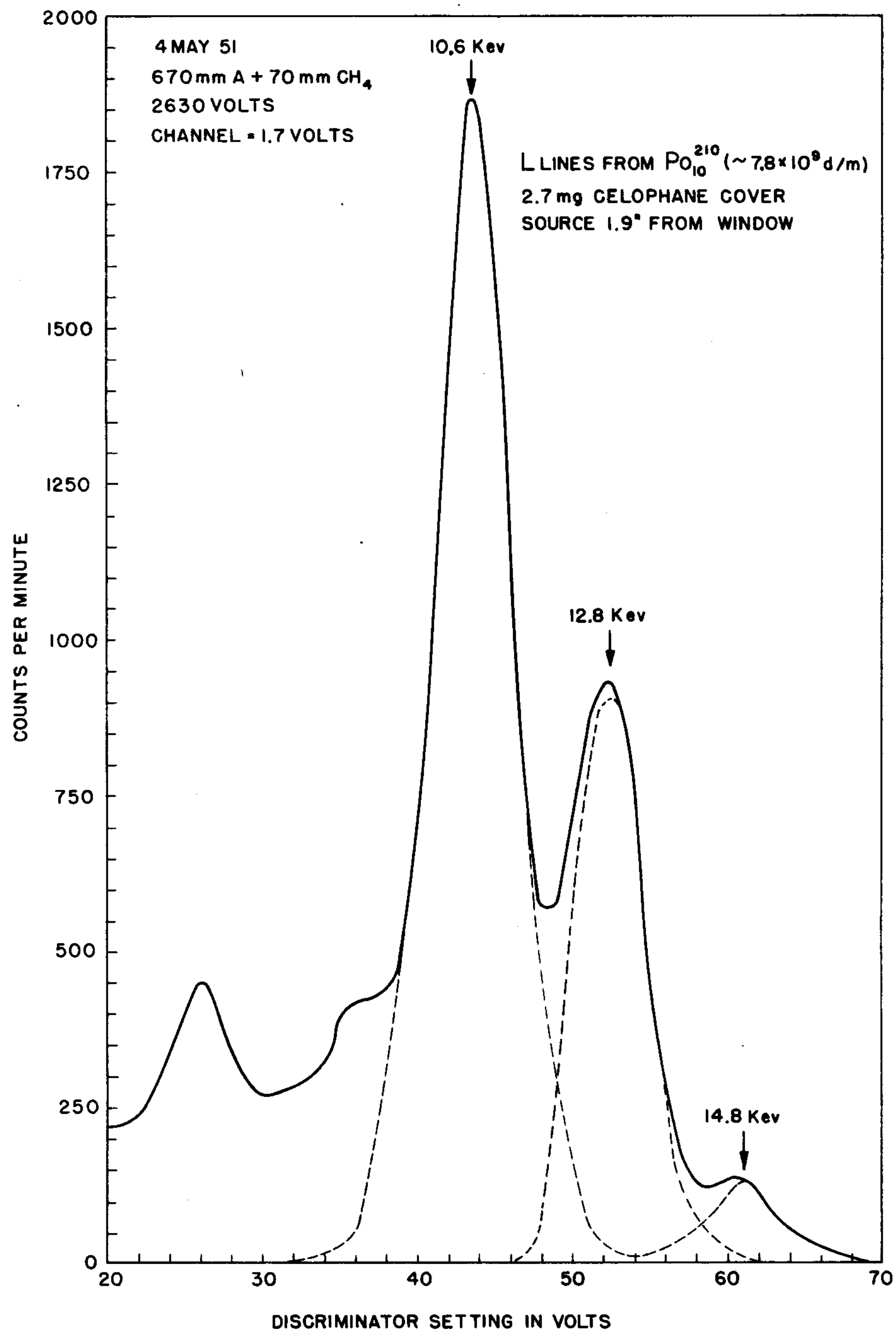


Figure 1. Proportional counter spectrometer record of polonium^{210} L X-rays.
(Courtesy of W. Rubinson)

Logarithmic Ion Chamber Electrometer

An electrometer circuit using two CK 571AX tubes, one as the electrometer and the other as a logarithmic diode, forms the basis of a wide range alarm circuit. Two additional tubes are used in a feedback circuit and a test current is provided for zeroing the instrument. When used with a 50-cc ion chamber the range is 1 to 1000 r/hr, and an auxiliary circuit warning lights at 10, 100 and 1000 r/hr.

Precision Ratemeter

Feedback has been applied to the output voltmeter of a conventional counting-ratemeter to produce an accuracy of 1% or better for use with scintillation spectrometers.

Sample Changer

In Health Physics work it frequently is necessary to count a large number of smears when evaluating the extent of a spill and progress in cleaning up. To facilitate this without requiring an assistant, a simple and inexpensive automatic sample changer has been designed to slide the samples out of one pile, beneath the counter, and into a second pile. Each sample is counted for a prescribed length of time and the total count is integrated and recorded on an Esterline-Angus meter. The operation seems simpler and more dependable than the commercially available devices.

Monitoring Truck

As a part of the AEC Interim Radiological Monitoring Network a surplus fire truck has been equipped as a mobile laboratory for the local team. Provision has been made for alpha and beta gamma counting using a ratemeter or a scale-of-8. Power is obtained from a gasoline-engine-driven alternator and numerous precautions were taken to insure dependability. A two-way radio is provided for communication with the two jeeps carrying the balance of the team.

Logarithmic Amplifier

An amplifier for use with an absorption spectrophotometer must handle a wide range of signal amplitudes and it is often desired to record the output in terms of optical density. A useful range of six decades (10 μv to 10 v at the input) has been achieved using nine non-linear amplifier tubes and a feedback circuit to achieve a logarithmic response. The input signal is AC produced by modulating the light beam in the spectrophotometer and the output is synchronously rectified to minimize effects of amplifier noise, microphonics and stray pickup.

Miscellaneous Devices

Numerous coincidence circuits have been devised for various applications.

Special counter tubes, including some neutron counters of large size, and counter arrays for reducing the background due to penetrating radiation have been built in wide variety. Some work on the factors affecting counter life has been carried on sporadically as time permits.

A directional scintillation counter for medical use in localizing I^{131} and high sensitivity counters for determining iodine in blood and urine samples have been built.

Control circuits for operating a cloud chamber from windowless counters within the chamber presented an unusual problem in that it is required to remove the counter voltage completely in a short time after firing to avoid distortion of the tracks.

The problem of counting alpha particles in tissues (containing boron which was previously administered by injection) subjected to neutron bombardment from the pile has received considerable attention, but is still far from solution. Great progress has been made in reducing the background due to irradiation of the photomultiplier itself but a satisfactory rugged probe design is not yet available.

Other devices somewhat out of the ordinary are:

An unusually sensitive and stable null detector for pH measurement
A beam deflection tube which may have applications in high-speed scalers and direct-coupled amplifiers
A system for removing the modulation from the standard frequency signals of WWV leaving a clean stable 5-mc signal.

Special Projects

An investigation of the possibilities of a scintillation counter as an instrument for radiological monitoring for civilian defense was made at AEC request. It appeared possible to build a portable instrument meeting most requirements but its advantages in the way of stability and long life as compared to more familiar types of monitor did not appear to outweigh inherent disadvantages. Chief of the latter was the strain on facilities for the production of photomultiplier tubes, and it has been recommended that the project be discontinued.

At the request of the Armed Forces Special Weapons Project the Division has accepted responsibility for one classified project and agreed to design and build some equipment for another. The Division has also been asked to take on a second project, which as yet is still in the discussion stage. These activities will probably continue to January 1952.

Service Activities

This Division being in some degree a service division, it might be interesting to give some statistics on the number of services rendered in the past fiscal year.

The Glass Shop continues to turn out a large volume of work, mostly for the Chemistry and Biology Departments. During the year it completed 585 jobs.

The Calibration Section handled a total of about 2800 instruments, including repairs, modifications, battery replacement and routine calibration checks. In order to cut down the considerable expense of replacing 300-v dry batteries in portable equipment a relaxation oscillator high voltage supply is gradually being substituted. This move is being made after extensive tests had shown that much longer battery life and lower servicing costs can be expected than were obtained from the straight battery supply. There has also been considerable work in modifying and installing monitoring instruments for the hot laboratory.

The main part of the Division completed a total of 390 jobs ranging from simple repairs to developments requiring several man-months of engineering time; 238 were completed by the Division Shop.

The total of 390 may be broken down to 180 repairs and modifications, 176 research and development and 34 radiation instrument development projects.

Two major projects were carried through to commercial production: a precision single-channel pulse height analyzer now made by Atomic Instruments Co., and some precision high voltage supplies produced by John Fluke Co.

Health Physics Division

Personnel

The Health Physics staff has grown from 36 to 43 during the past year with three others scheduled to report for work by September 1. Because of a higher than normal rate of turnover, half the staff will be relatively new and will require considerable training. The summer and fall will be devoted to this task.

The high turnover rate is in part a reflection of the fact that experienced health physics surveyors are few in number and in great demand both in industry and in expanding portions of the AEC program. After a few years of the broad experience in health physics work that our younger men acquire, they frequently move on to positions of greater responsibility elsewhere. In this respect we feel that we are performing a valuable training function. Turnover in the technician grades, where we are in competition with local industry, as in Electronics, was rather high also, but recent readjustments in the wage structure should improve this. A physicist experienced in university teaching is joining the staff August 1 to take charge of the various training activities. An analytical chemist has been hired and is organizing a program of radiochemical analysis of urine samples and of biologic forms downstream from the discharge point of the laboratory sewage system.

Health Physics emergency coverage was continued during non-working hours with an average of about 1 call a week. Most of these are concerned with after-hour mishaps in radiation areas in which police, firemen or experimenters need advice or assistance. At meetings of the Radiation Safety Committee, plans for pile start-up, safety procedures for the pile building, corresponding procedures for the hot laboratory and safety arrangements for the Biology irradiation field were reviewed and approved.

Training

The AEC Fellowship Program in which BNL has been participating for two years on a temporary basis has now been established as a continuing activity. Approximately 20 fellows will come to Brookhaven each summer at the completion of course work at the University of Rochester for ten weeks of experience in health physics operations. The fellows spend approximately a week in each of ten major parts of the health physics program and receive instruction in various special problems connected with radiation safety.

Miscellaneous training activities included giving of talks on health physics to various groups of technicians and maintenance workers throughout the laboratory and providing an extensive exhibit for the annual visitors day. A field exercise was held for the BNL radiation monitoring team. Radiation levels characteristic of a hypothetical air burst with downwind fallout area were marked out over a wide area with stakes. The teams reported these levels by radio and an isodose plot was constructed at the headquarters location.

There has been an increasing number of visitors to the Health Physics Division from numerous AEC sites, government laboratories, universities and industrial concerns. Most come for one or two days to discuss special problems connected with radiation safety or to inspect our program. In addition, an increasing number of requests for advice on radiation protection matters are being received by mail. Twenty-nine outside lectures on health physics subjects have been given by members of the Division.

Research and Development

The Health Physics Division has carried on research and development, mostly of an applied nature and incidental to its service activities, ever since it was organized. This work has now been formalized as a program of biophysics research with a separate budget and a more definitive statement of projects. The turnover of staff and increased training responsibilities have severely limited the time available for this activity particularly in recent months, but about 10% of personnel time is currently devoted to it. The research and development program at present is concerned with the following:

1. Test of effectiveness of the BNL sewage filter beds in removing specific radioactive contaminants. A known amount of a specific isotope is added at the input of a filter bed and the activity of the output liquid measured at intervals for several days thereafter. Data on P^{32} and I^{131} have been collected thus far. It is desired to accumulate as much data of this sort as possible before the output of activity from other laboratory operations makes it impossible to do these experiments within the limits set by waste disposal policy.

2. Radiation dosage measurements. The health physics surveyors do considerable work on dosimetry in connection with various hot sources procured and used by the scientific departments. The 200-c Biology field irradiation source and the kilocurie tantalum source are examples.

3. Measurements of neutron fluxes. Methods for determining neutron fluxes with special emphasis on obtaining information about the energy distribution are being investigated.

4. Miscellaneous problems in health physics instrumentation, study of background radiation, protection techniques.

5. Analytical chemistry. Development of methods for testing sewage, biologic forms from the Peconic River and urine for specific radioactive contaminants.

To facilitate the counting of "smears" taken in large numbers during laboratory surveys for checking contamination conditions, an automatic apparatus that will determine and record counts for a series of smears has been designed and a prototype constructed. Performance is satisfactory and several will be made for use in the various survey headquarters.

A number of films have been tested to see if the range of exposures covered by the duPont Type 552 film packet used for personnel monitoring can be extended. The results are favorable and the new packet covering the range from 15 mr to 750 r is being tested in actual use for personnel monitoring and other problems of dosage measurement.

A start has been made on developing some simple methods of urinalysis that will be useful in determining whether radioactive materials have entered the body in significant amounts as a result of contamination incidents. Considerable information can be obtained by simple evaporation of a 50-cc sample and counting of the activity. However, sensitivity is limited by the presence of solids and of potassium-40, a naturally radioactive isotope always found in urine. Some simple methods for reducing the solids and removing the K^{40} are being developed. The standard electrolytic method of urinalysis for polonium is another procedure that has been set up. It has been used in the case of a contaminated prospective employee.

The concentration of radioactive argon in the reactor effluent air was measured using the air sampling chamber developed last year. The chamber was calibrated using some argon gas activated in the reactor. However, only an approximate value was obtained because of the lack of an accurate figure for the neutron activation cross section of A^{41}.

Waste Disposal

Facilities for monitoring the flow and activity of liquid wastes from certain buildings and from the Laboratory as a whole have been completed. The effluent from the Imhoff treatment tanks is of special interest since an average concentration limit of 3×10^{-12} c/cc has been established at this point. The currently measured values are about 3×10^{-13} c/cc which is only 10% of the permitted discharge from the site. As a result of the use of the evaporator at the hot laboratory, it has been possible to keep the activity released from the pile complex to a low value. Iodine residues from the Medical Department, wash water from the decontamination laundry and the contents of hold-up tanks at several locations have accounted for most of the rest of the activity.

The handling and storage of solid wastes has been an increasing problem. An area formerly used for munitions storage has been fenced and several buildings there used for active waste. Part of this can be held until the activity decays and then disposed of in a conventional manner. Thus far it has been possible to store the balance. Some special storage arrangements have been necessary to take care of very active objects left over from certain experiments.

Decontamination laundry facilities were completed and operation by the Architectural Planning and Plant Maintenance Department was started. Monitoring of the clothing for radioactivity and supervision of the liquid wastes is a Health Physics responsibility. Radiation protective clothing is now provided for the whole Laboratory from a central clothing pool administered by the laundry. Garments are sorted into three categories according to the degree of activity and the laundering processes and waste handling procedure adjusted for each group. An automatic sampler and hold-up tanks are provided so that, particularly when washing the more contaminated garments, the release of undesirably large amounts of activity to the sewage system can be avoided.

Survey Problems

The use of very radioactive sources is becoming increasingly common and requires a great deal of attention from the health physics surveyors. The 16-c field irradiation source used by the Biology Department last summer has been supplanted by a 200-c source in a new and larger field. Details of procuring this source from Oak Ridge National Laboratory were worked out, and the source was loaded into its container at the semi-works area of the hot laboratory by the Health Physics group. Safety arrangements for the source have been worked out with the Biology Department. Dosage measurements out to a distance of 50 ft from a 2-c test source have shown that for the field sources there is little disturbance due to scattering to an inverse square law relationship.

Preliminary calculations made last summer indicated that the radiation levels at the edge of the Laboratory reservation due to the 200-c source might be objectionably high. Accordingly, radiation levels due to the 16-c field source were measured as a function of distance out to 500 m and values of effective absorption coefficient were computed. These absorption coefficients include the effect of ground scattering and the degradation of energy occurring with increasing distance. It was found that the absorption coefficient varies with distance and increases from 0.001/m close to the source to a value of 0.007 at distances greater than 300 m. In addition the absorption effect of woods such as surround the new field was measured. When this data was applied to the proposed 200-c installation, very low levels at the edge of the site were predicted. Measurements this spring have verified this, the additional radiation due to the source being small compared with the natural background.

In addition to the Biology field sources, a number of gamma ray and neutron sources of 1 to 5 c are in use. Recently, several sources with activities in the kilocurie range have been manufactured in the reactor. These require very careful supervision if they are to be handled safely. A 70-c source has been in use at the hot laboratory for irradiation experiments of the Medical Department.

Numerous safeguards have been established to prevent the spread of contamination and the significant exposure of personnel as a result of spills. The presence of contamination on surfaces is detected by assaying the activity on smears, pieces of paper that have been rubbed on the surface. When contamination does appear in unwanted localities, the region is isolated and a thorough clean-up by the janitorial staff is instituted. Contamination in the air is detected by means of dust and air samplers. When exposure of personnel to contaminated air is suspected, nasal smears and urinalyses are utilized to evaluate the degree of entry of activity into the body. The Medical Department and the Health Physics Division cooperate closely in such cases. All of the contamination incidents that have occurred thus far have been successfully cleaned up and in no case has a serious personnel exposure resulted.

Start-up of the nuclear reactor during the fall and winter called for special health

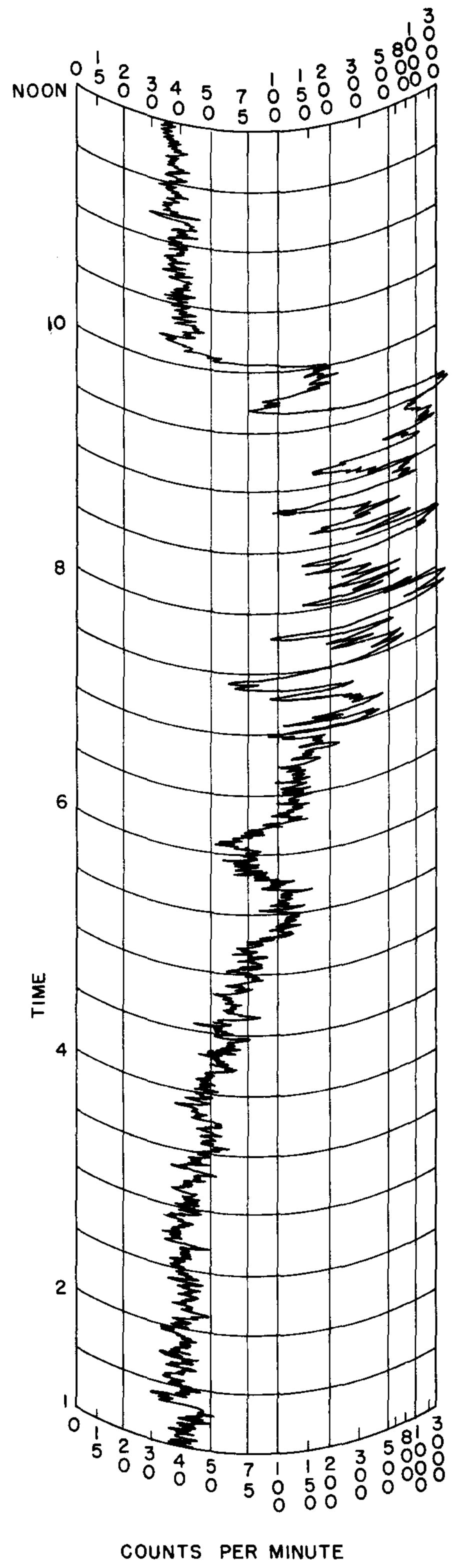


Figure 2. Typical counting rate record from an on-site monitoring station showing effects of pile stack gases.

physics survey activity. In order properly to monitor the neutron fluxes, it was necessary to construct and calibrate a number of neutron-sensitive chambers. Twenty-four hour shift coverage was maintained during part of the start-up period and a health physicist has been on duty during the evenings ever since. Very extensive instrument and film surveys were made of the reactor shield and several flaws were discovered and repaired. Detailed procedures covering the use of personnel monitoring equipment and protective clothing, as well as an emergency evacuation procedure for the reactor building, have been worked out.

Now, that the reactor is being used for various experiments, a series of problems in contamination and exposure control are developing. Roof blocks are removable for experimental purposes and since these, and the areas uncovered, are very radioactive, careful measurements and protective techniques are necessary. Objects are frequently removed from the reactor and whenever this is done, great care is necessary to prevent either exposure of personnel or the spread of contamination. Automatic alarms have been set up at the pneumatic tube area and on the air filters to warn of the presence of undesirable radiation. Maintenance work in the reactor building and associated laboratories is done according to special safety instructions furnished in writing for each job by a health physicist. At the present time, 75 to 100 such instruction sheets are required per month.

Area Monitoring

Operation of the area monitoring stations has continued with an over-all data-collecting efficiency of 85 - 90%. This represents about as high a figure as will be attained since some data is inevitably lost during servicing of equipment and some equipment failure is unavoidable even with good preventative maintenance procedures. A status report on the background radiation monitoring program prior to pile start-up has been issued as report BNL 80 (I-12). This covers the history and instrumentation of the program, discussion of equipment design, an analysis of the cost of the project and a summary of the results obtained in measuring background radiation.

The effect of reactor operations upon instantaneous values of radiation levels in the vicinity has been noticeable. Figure 2 shows a section of chart from the battery-operated ratemeter in an on-site station located a half-mile from the nuclear reactor stack. From 4 to 7 A.M., wind direction was fairly steady and was shifting gradually towards the station. From 7 to 10 A.M., the characteristic gusty daytime wind was blowing in the general direction of the station. After 10 A.M., the wind shifted direction so that only normal background activity was detected. Under gusty conditions, very wide variations in radiation level occur as the direction varies and the active air passes aloft or is brought to the ground in puffs. In interpreting the peaks in Figure 2, one should not lose sight of the fact that a non-linear scale is used on the ratemeter chart so that the largest peaks are approximately 100 times normal background. Variable radiation levels due to radioactive argon from the pile are at times very bothersome to experimenters who are attempting to measure small quantities of radiation.

The variations in wind direction, wind speed and temperature structure of the atmosphere are such that the effect of the reactor on a one-week average of radiation level beyond the edge of the site is small. More data under long continued full-power operating conditions are needed but the results thus far indicate that even the very conservative limits for off-site radiation effects established by the AEC will call for only infrequent shut-down of the reactor.

Personnel Monitoring

There was a sharp rise in the use of personnel monitoring equipment last fall when operation of the nuclear reactor began. During the latter part of the year approximately 1000 film badges per week were worn. About 300 of these, worn in areas where neutron exposure is possible, also contain neutron track film for recording neutron exposure. About one-third of the neutron films are currently being examined for tracks and the others are on file. The emulsion used is sufficiently insensitive to gamma radiation so that up to 1-r exposure would not adversely affect the counting of tracks made by neutrons. The use of pocket ionization chambers currently amounts to 1400 pairs/week. Special films and 66,500 film packets were processed in the darkroom. Among these were 226 5 in x 7 in and 128 14 in x 17 in X-ray films used for a survey of the pile shield. Personnel monitoring equipment is being distributed from 29 locations throughout the laboratory. Because of the irregular working hours of many individuals, it is necessary to visit each location twice daily.

During the year there were only four cases of exposure over the weekly limit of 300 mrep out of the total of 47,900 film badges processed. All of these were non-repetitive cases of less than 1 r and therefore of no physiological significance. As a precautionary measure, investigations are also made in cases where there is indicated exposure of more than 50 mrep in a single day although such exposures are permissible if the weekly limit is not exceeded. There are at present about 20 such investigations each month.

ACCELERATOR DEVELOPMENT AND CONSTRUCTION

The Accelerator Project now numbers 86 persons, of whom 27 are on the scientific staff; on June 30, 1950, the total number employed was 82. The major responsibility of this Department continues to be the construction of the Cosmotron and, during the past year, this has accounted for 80% of the total effort and for 84% of the total personnel.

Part of the group is engaged in the establishment of operation of the 60-inch cyclotron purchased from the Collins Radio Co. When a satisfactory external beam of deuterons has been obtained, this machine will be used primarily as a source of positron-emitting radioactive atoms and high-energy neutrons.

A program for improving the operating characteristics of the research electrostatic generator has been initiated. Interruption of experiments being carried on by members of the Physics Department with this machine will be kept to a minimum.

Although temporarily the recently formed Mechanical Engineering Division has been made a part of this Department, some of these engineers have been designing equipment for other departments of the Laboratory.

60-Inch Cyclotron

In September 1950, the cyclotron produced its first circulating internal beam. Since then, the intensity has been increased to nearly 1 ma after a number of modifications had been made. The major change was the adoption of a master-oscillator power amplifier system instead of the original self-excited system. The new circuit has overcome the effects of ion loading of the dees. Another major change was made in the so-called "shorting bar" which connects electrically the two dee supports. Because of repeated failure due to poor contact and overheating, the original shorting bar was replaced by a more substantial structure which has given no trouble.

Following these modifications and a long list of other minor changes, an extended series of trial runs was made to obtain an external beam. These attempts were unsuccessful. Careful measurement of the magnetic field revealed inhomogeneities that would cause such eccentricities in the circulating beam that the ions would be prevented from coming out of the exit channel. These inhomogeneities have now been corrected and the cyclotron is being reassembled.

Research Electrostatic Generator

After an extended period of troubles, the research electrostatic generator, formerly known as the G.E. electrostatic accelerator, has been in fairly continuous use by members of the research staff of the Physics and Chemistry Departments.

Recently, a new capillary ion source was installed which now yields mass-1 proton currents up to 15 μa. The present accelerating tube limits voltages in the machine to about 2 Mev. A start has already been made on a program to increase the

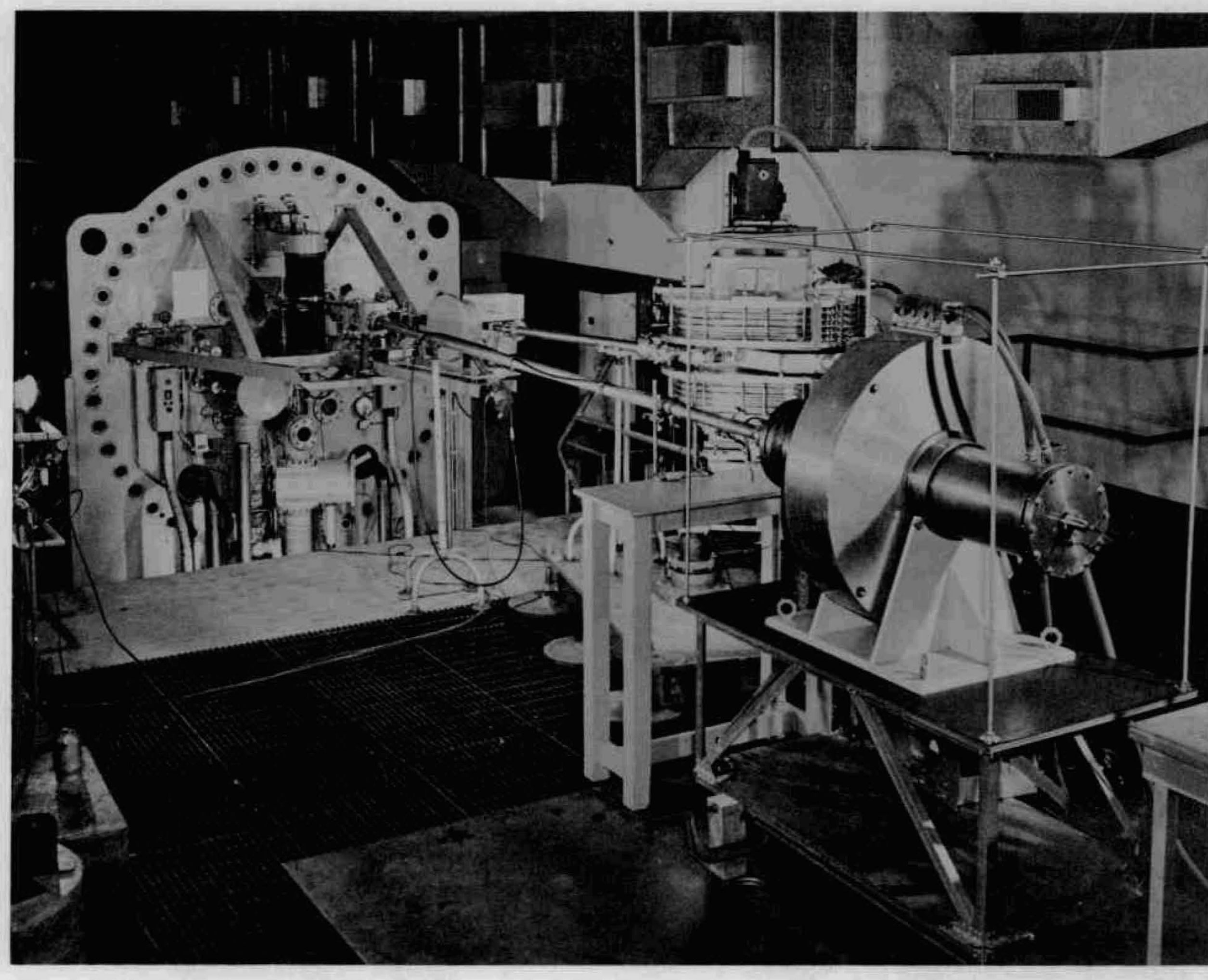


Figure 1. The research electrostatic generator is now in almost constant use for experiments in the energy range up to 2 Mev. Shown in the foreground is a beta-ray spectrometer, and in the center rear a large analyzer magnet for use with this accelerator.

operating voltage considerably by modification and replacement of the accelerating tube and the other components.

Cosmotron

This high-energy proton synchrotron is designed to produce protons of between 2 and 3 Bev for the purpose of studying the interactions of primary particles in this energy range. The accelerator is now in the final stages of construction and physical completion of the machine is expected by the end of the current calendar year. Before a satisfactory beam is achieved, a period of testing and adjusting will follow, the duration of which is difficult to estimate.

A pulse of protons will be injected into the Cosmotron from a 3-4 Mev horizontal Van de Graaff generator. An electrostatic field between parallel plates serves to bend

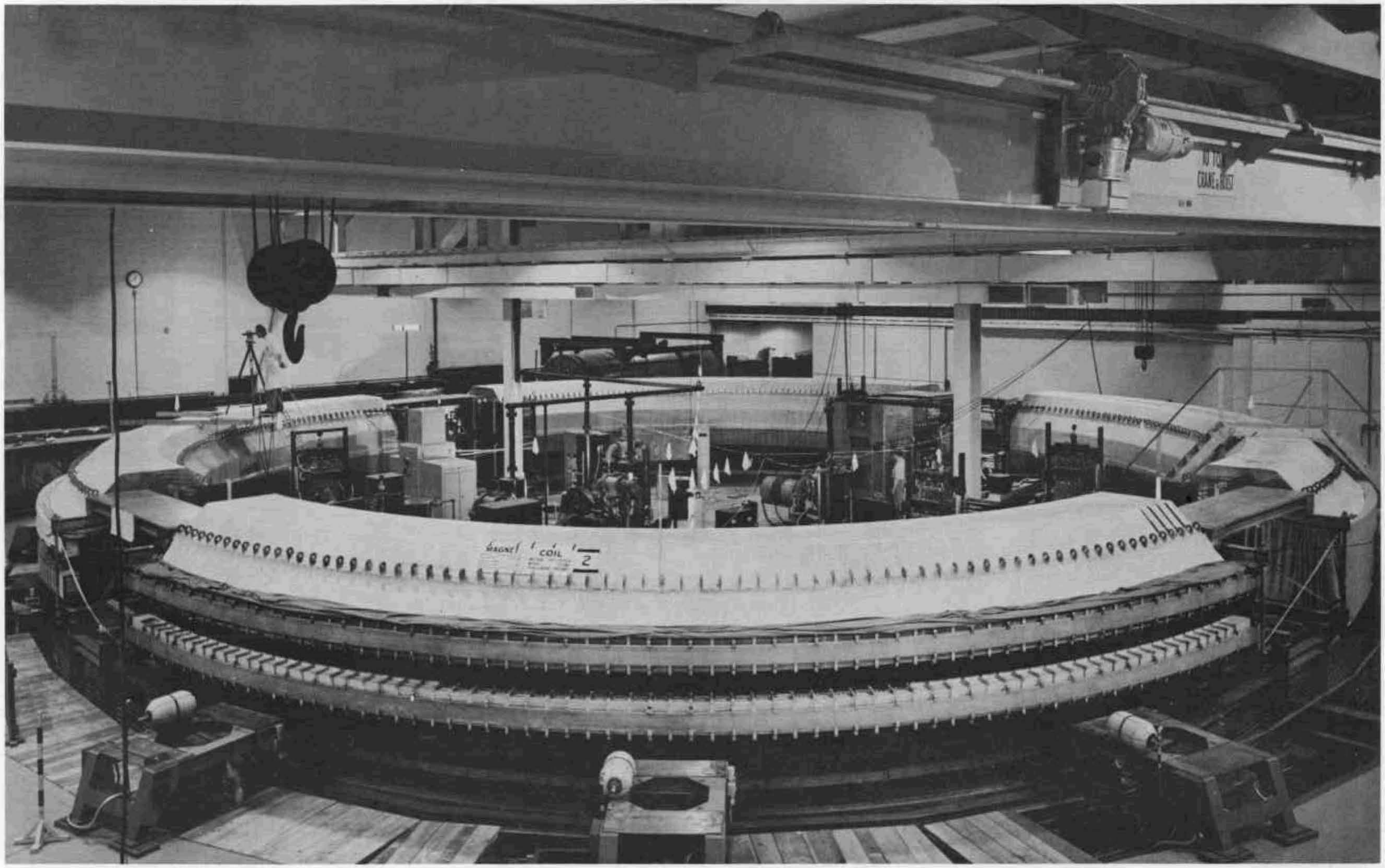


Figure 2. The Cosmotron. The magnet top is now covered with a plastic dustproof film for protection. At the far rear, center, can be seen the injection Van de Graaff. The 20-in diffusion pumps are now in place in the trench surrounding the magnet with the roughing pumps inside the ring. The high-level power amplifier can be seen in its position by the right rear straight section between magnet quadrants.

the protons so that they enter tangent to their roughly circular orbits inside the magnet gap. Timing devices ensure that this injection occurs at the correct value of the continuously rising magnetic field. Because of this magnetic field, the protons are forced to follow a circular path and the rate of increase of the field is such that the orbit keeps approximately the same radius while the protons continue to gain energy. An energy increase of about 1000 v each revolution is provided by an alternating electric field applied at one of the open sections between the magnet quadrants. During the cycle, the frequency of this electric field must increase so as to remain the same as the frequency of revolution of the protons.

At present, final adjustment and testing is proceeding on many of the major components. Already, a steady beam at 3.3 Mev from the injector Van de Graaff has been successfully delivered into the Cosmotron magnet by means of the inflector plates. The magnet has been pulsed many thousands of times up to its peak field of 13,800 gauss. The electronic components of the radio-frequency system are essentially complete. The evacuating system is undergoing final testing and the assembly of the first quadrant of the vacuum chamber is almost finished.

Increasing attention is being given to the problem of extracting the various high-energy beams (protons, neutrons, mesons, and gamma rays) and to necessary shielding. Ports, sealed with thin aluminum plates, have been designed in the vacuum chamber walls so that over 100 linear ft will be available for experiments using the various beams. The shielding, as presently designed, consists of a concrete wall, about 8 ft thick, to separate the target area from the control room and the experimental area.

Below, under appropriate headings, a general description of the major components of the Cosmotron is given in more detail.

Injection

A horizontal Van de Graaff generator, constructed by High Voltage Engineering Corp., Cambridge, Mass., provides a pulsed proton current of about 1 ma in the energy range 3.0 - 4.0 Mev for injection into the Cosmotron. Leaving the Van de Graaff, the protons are sorted out of the beam by an analyzer magnet. The mass-2 portion of the beam regulates the energy through a servo-control system. The protons then pass through a collimating lens unit to the actual injection box, situated at the west straight section between magnet quadrants. An electrostatic field of 30 kv across the 1/2-in spacing of parallel inflector plates then bends the protons to enter the magnetic field of the Cosmotron.

In order that the final accelerated beam of the Cosmotron be as intense as possible, stringent conditions at injection are necessary. The energy of the injected beam must be constant to better than 0.05% and the angular divergence of this beam must be less than 0.05°. Since the delivery of the Van de Graaff machine from HVEC almost a year ago, an extensive program of testing, alignment and adjustment has been undertaken in an effort to meet these conditions. Reasonably satisfactory performance has been realized up to 3.5 Mev with an energy stability of better than 0.1%. Present operation is with a steady beam since minor modifications and life tests on the arc pulsing circuit are in progress.

The injection optical system has been located and aligned by means of surveying

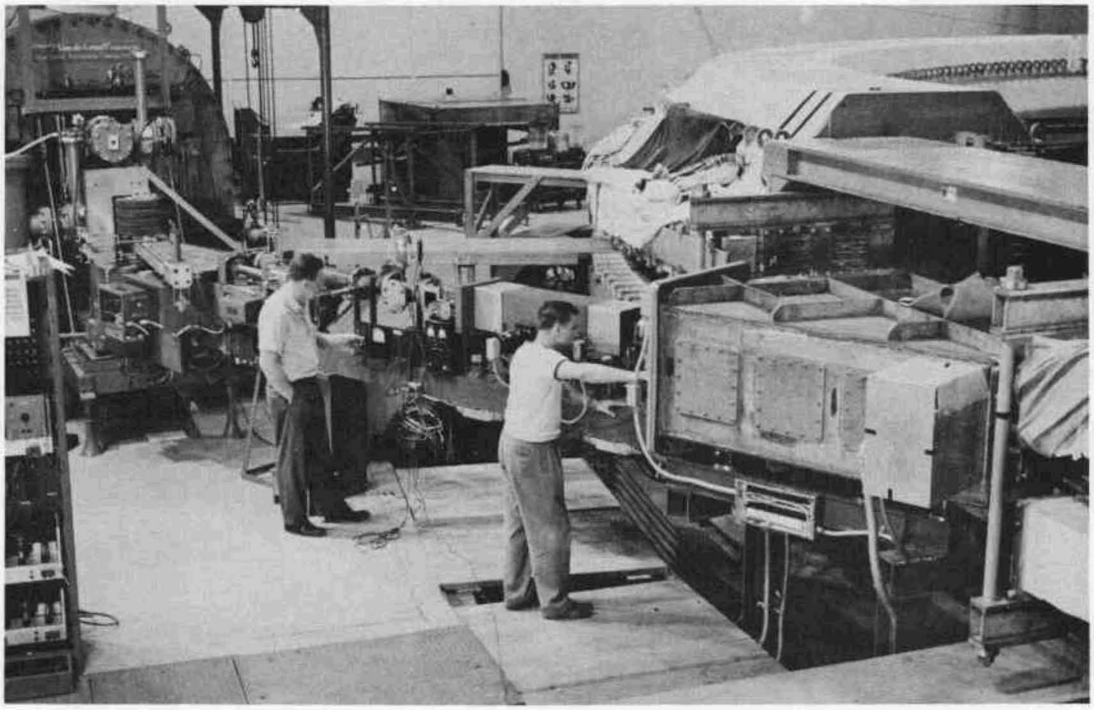


Figure 3. The injection optical system connects a Van de Graaff generator (left, rear) of 3-4 Mev to the injection box (right, front) where an electrostatic field bends the protons into the magnet of the Cosmotron.

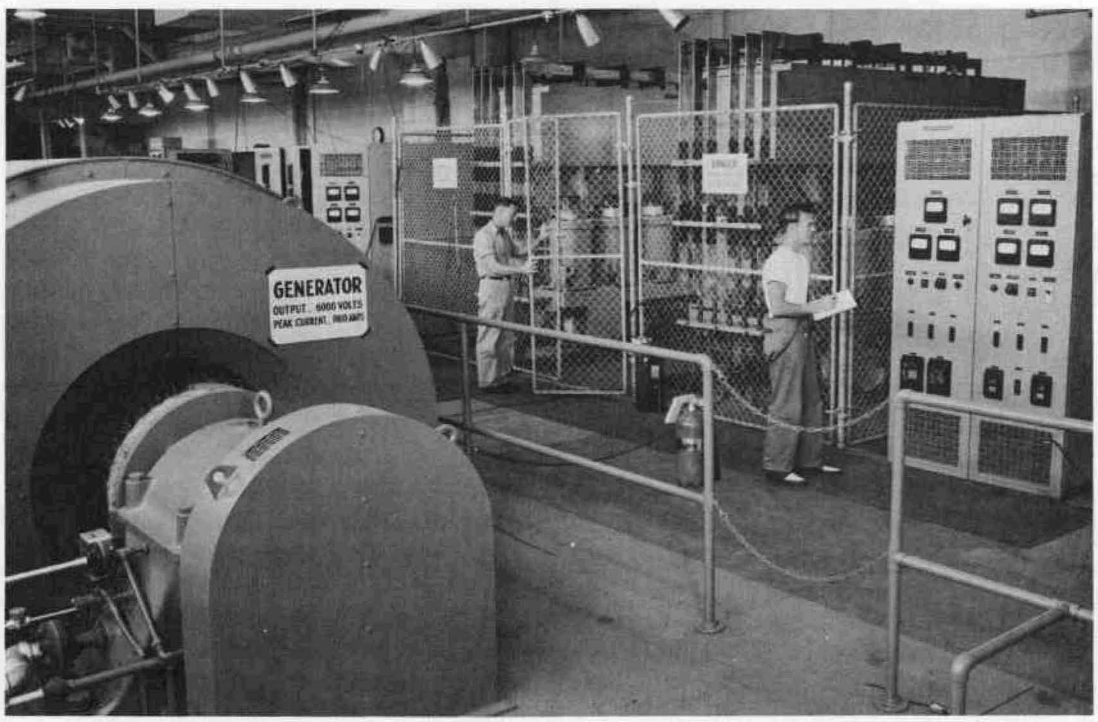


Figure 4. The generator room for the Cosmotron. In the left foreground is the motor-generator-flywheel unit. At the rear, center, are the banks of ignitrons which act as rectifiers and, on firing, start the cycle of operation of the Cosmotron.

techniques. The injection box, housing the inflector plates, is now in position between the magnet quadrants. The power supply for these inflectors has been tested and no difficulty with breakdown was experienced when the high voltage was applied across the plates in vacuum. To allow for complete flexibility of injection, the inflector plates are mounted on a movable carriage, controlled from outside the inflector box, and this mechanism, too, has operated without trouble in vacuum.

Recently a successful test of the whole injection complex was carried out. A steady beam from the Van de Graaff, of approximately 1/4-in diameter at about 3.3 Mev, was sent through the injection optical system, correctly bent by the inflector plates into the magnet gap. The magnet was energized to a constant field equal to the injection value and the beam was then observed on a quartz plate at the far end of the first quadrant. After only preliminary adjustments had been made, the diameter of the beam at this point was less than 1 in.

To study injection problems further, particularly during the period of fabrication and assembly of the final vacuum chamber, a temporary glass vacuum chamber has been designed and fabricated. This consists of a number of glass cylindrical sections, made by the Corning Glass Co.; they are of 8-in diameter, 2-ft length, with the ends properly cut to fit into the circular shape of the magnet. The inside of each glass tube is coated with the electrically conducting and transparent E-C coating of the Corning Glass Co. The sections are connected together by rubber sleeves.

Some of these sections have already been inserted in the magnet gap of the first quadrant to be traversed by the protons, for the preliminary injection test already mentioned. Sections of glass can be added, quickly and easily, to provide for the extension of the beam around its first revolution. Adequate instrumentation has been assembled for observing the behavior of the proton beam under dynamic magnetic field conditions. It is expected that, very shortly, a start will be made on the detailed studies necessary to determine the best conditions for injection.

Magnet

During the past year, the magnet and its associated power supply have been completed. The magnet has been pulsed many thousands of times and operation is now essentially routine.

With the firing of a set of ignitrons, a cycle of operation of the Cosmotron begins. These ignitrons rectify the output of a 21,000 kva, 12-phase synchronous generator and supply energy from a 45-ton flywheel on the generator shaft to the energizing coil of the magnet. At the end of 1 sec, when the current in the coil has reached 7000 a, the ignitrons, acting as inverters, reverse the generator voltage and the greater part of the magnetic energy is returned to the flywheel. Oscilloscope measurements of voltage and current from the generator show that the system is operating as planned and that the cycle-to-cycle reproducibility is good.

The magnet has undergone a considerable amount of shakedown operation with subsequent tightening of the structure, and it now appears to be in a stable condition. Six months after erection of the steel a survey gave no indication, within the limits of measurement, that any unbalanced settling had occurred. Measurements made during the dynamic powering of the magnet showed that there was a small amount of motion of the coil at the ends of each magnet quadrant. Stainless steel restraining beams have been installed and coil motion is now restricted, everywhere, to 0.030 in or less at the peak of the pulse.

At the present time, measurements of the characteristics of the magnetic field, throughout the complete cycle, are under way. Preliminary data give a peak field of 13,800 gauss, in agreement with predictions from the model measurements.

Pole-Face Windings

In the magnetic field range corresponding to proton energies higher than 2 Bev, extra magnetizing windings must be introduced to maintain the correct distribution of magnetic field as the iron in the Cosmotron magnet begins to saturate. These windings will lie in the upper and lower pole faces of the magnet. In addition to adjusting the shape of the magnetic field at its higher values, they can also be used to trim the field distribution during the whole accelerating cycle if such compensation is necessary to maximize the intensity of the proton beam.

The whole pole-face winding complex consists of 20 units of which eight are the flat sections that will lie on the top and bottom pole faces in the four quadrants. The other 12 are return windings, part of which are located in the rear of the magnet gap adjacent to the main coil and part on the main return windings on the experior of the magnet. The distribution of return windings is such as to eliminate undesirable coupling effects between the main magnetic field and the pole-face winding.

Fabrication of the pole-face winding units is in progress at this laboratory. The windings, which are 3/8-in x 7/32-in copper bars, are wrapped in Fiberglas cloth, set in forms, then cast in a cold-setting polyester resin matrix. The resulting structure is strong, easily handled and is more than adequate electrically. To date, all of the return windings have been cast and trial fittings to the Cosmotron magnet have shown that their dimensions are correct. The first of the large flat windings that will lie on a pole face has been cast.

These windings will be powered by four 40-kw generators for use in correcting the field shape at high fields, and four 1.25-kw generators for shifting the plane of magnetic symmetry, if this proves to be necessary. These machines have been ordered from the Westinghouse Electric Co. and will be delivered during the spring of 1952.

Radio-Frequency System

Acceleration of the protons in the Cosmotron takes place in the north straight section between magnet quadrants. Here is applied an alternating electric field whose frequency agrees accurately with the frequency of revolution of the protons. Since this frequency changes by a factor of 12 as the proton energy increases and since the proton energy, in turn, must keep in step with the magnetic field, the frequency of the accelerating field must be controlled from the magnetic field. For this purpose, a pick-up coil is mounted in the magnetic field. The output of this coil, after passage through an electronic integrator, yields a signal proportional to the magnetic field in the Cosmotron magnet. This signal is the input for a simple electronic computer whose output

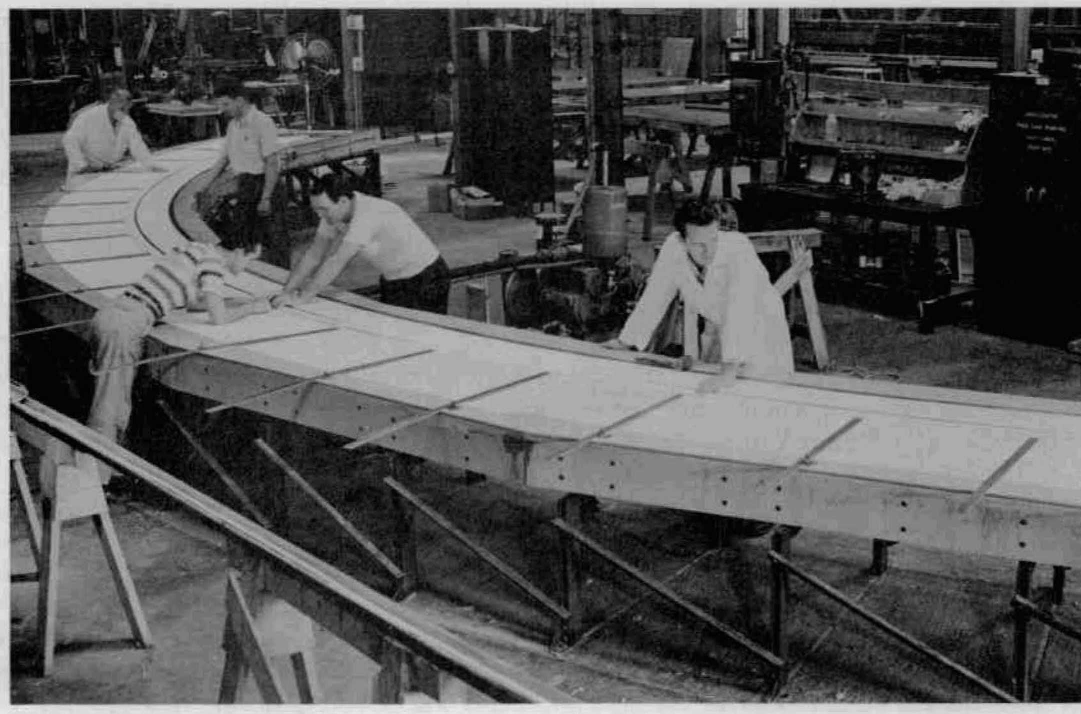


Figure 5. The windings for correcting the magnetic field at the top energy levels of the Cosmotron are shown here as they are being fitted to a form prior to final casting in polyester resin. These windings will lie on the top and bottom pole faces of the magnet.

Figure 6. The first quadrant, now almost completely assembled, of the vacuum chamber of the Cosmotron. Stainless steel, 1-in thick, side walls support a grid of stainless steel bars, 2-in wide. Over this grid, top and bottom, is stretched an airtight sheet of Myvaseal rubber.

is the frequency control voltage for an electrically tuned oscillator. The computer, which is merely a non-linear distorting network, is preadjusted so that the frequency has at all times the value appropriate for the magnetic field.

The components of this system are essentially complete. The electrically controlled oscillator, the integrator, and the computer have been built and tested. The pick-up loop in the magnetic field is an integral part of the pole-face winding structure and so is not yet in place.

Between the controlled oscillator and the accelerating unit is a power amplifier which amplifies the oscillator signal from about 2 v at high impedance to about 2000 v at a 50 ohm level. This amplifier, including controls, safety devices, automatic volume control and gating circuits, is now complete and has been tested at levels approaching those to be reached in final operation. It is located in its final position on the Cosmotron floor.

The accelerating unit itself is a large radio-frequency transformer so arranged that the transformer secondary voltage appears at the accelerating gap. The transformer core is made up of about a ton of ferromagnetic ferrite and is laminated to permit operation at frequencies up to the top frequency of 4 megacycles without the appearance of spurious resonances. The accelerator structure, which includes the straight section vacuum box with an insulated but vacuum-tight gap, the ferrite and a large copper shield, is now being assembled. Upon its completion, expected shortly, the excitation of the accelerating transformer by the power amplifier can be attempted.

Vacuum System

A modification of the vacuum chamber for the Cosmotron which was described a year ago has resulted in mechanical improvement along with simpler construction. The chamber now consists of 1-in thick, solid stainless steel side walls to which are bolted, at top and bottom, stainless steel bars about 2-in wide. Covering this grid structure is an airtight sheet of Myvaseal, a new rubber of low vapor pressure. Fabrication of the steel parts of the chamber is in progress at the Wellman Engineering Co., Cleveland, Ohio, with one half of the total structure already complete and received.

Assembly of the chamber is taking place at the Laboratory. The first quadrant of the vacuum chamber is now almost complete and ready for leak-testing. The equipment for handling and inserting the quadrant-long sections of the chamber is ready for use.

Larger vacuum boxes for the straight sections between magnet quadrants have been especially designed to house the necessary equipment at each of the four locations and these have been leak-tested. Ports of various sizes have been designed not only for these straight sections but also in some of the outer walls of the main vacuum chamber for the insertion of beam detectors, targets, and for the emergence of various particle beams.

To evacuate the vacuum chamber, twelve 20-in diffusion pumps are located in the trench that surrounds the magnet ring. These pumps are backed by fore-pumps situated in the center of the ring. This fore-vacuum system is now all in place and operating. All of the 20-in diffusion pumps have been conditioned and have been given trial installation at their respective locations. Steel frames span the trench above each diffusion pump to support the associated 16-in high vacuum valve. The valves are mounted on rectangular transition boxes which connect the valve to the vacuum chamber itself. These units are all assembled and are undergoing final testing. One of the diffusion pumps is now in continuous operation evacuating the injection box and the first section of the temporary vacuum chamber.

Controls and Wiring

The Cosmotron will be operated from a control console located in a room on the mezzanine overlooking the main floor. Remote control wiring radiates in raceways from this console to all of the components of the Cosmotron. Meter and indicator wiring then returns from the components to the console. Flexibility is retained by wiring from components to a main terminal box on the Cosmotron floor directly below the control room and from the box to the console. Cross connections are then made in the terminal box.

The wiring from the Cosmotron components to the terminal box, about 100 miles in all, is now essentially complete. The frame of the console is in place and a detailed panel layout has been planned. These panels are now in process of fabrication. When they are in place, the short wiring runs from the main terminal box to the control room can be completed.

The initiation of the Van de Graaff injector pulse and the radio-frequency cycle, both of which are governed by magnetic field values, will depend on "peaking strips" which provide a signal at the exact time that the magnetic field passes through some specific value. Peaking strips will also provide check points for the diode network that computes the required radio-frequency. Precise time-marker pulses will be needed throughout the operating cycle. A master timing system, which proves such pulses with microsecond accuracy for synchronizing much of the Cosmotron equipment, has been assembled and is now in final tests.

CHEMISTRY

As of June 30, 1951, the continuing staff of the Chemistry Department numbers 48. Of these, 34 are members of the scientific staff, 10 are technical personnel, including technicians and machinists, and 4 are administrative and clerical personnel. Corresponding figures for June 30, 1950 were 30, 10, and 4 respectively, totaling 44. Four terminations occurred during the year.

Summer visitors, on-leave personnel, and other transient guests are not included in the above figures. During the report period 25 such persons have used the facilities of the Department. This number includes 10 summer visitors who began work shortly before the end of the report period. Five of the remainder were graduate students working on thesis problems.

During the year a substantial fraction of the Department's effort has been diverted to classified work, undertaken in the light of the needs of national defense. As yet, such work has been carried out by members of the existing staff, rather than by new recruits employed directly for classified investigations. The over-all effort on basic research has been correspondingly decreased. The number of persons involved in classified work is 9, or about one-fourth of the scientific staff. The classified part of the Department's program is not described in the present report.

No large new facilities have been acquired by the Department during the year. However, laboratory furniture has been installed in the one-half wing (of the six laboratory wings) which was not occupied a year ago. The small radiochemical laboratory associated with the 60-inch cyclotron has been completely equipped, except that the shielded dry box in which cyclotron targets will be processed has not been completely outfitted with gadgets. In addition, the neutron spectrometer has been completed and put into operation.

The general outlines of the research program have been described in quarterly progress reports and in the previous annual report. In brief recapitulation, the program consists of investigations of chemical problems related to the development and use of atomic energy, and of other problems which can be pursued to special advantage with the aid of the major facilities of the Laboratory. Thus, the chemical effects of high energy radiations and nuclear transformations are studied; neutron beams and isotopic tracers are applied to a variety of chemical problems; the chemistry of substances of interest for atomic energy developments is investigated; and chemical techniques are applied to a variety of nuclear problems, mostly ones involving radioactive nuclei.

General Chemistry

The properties of the rare earths and heavy elements are subjects of continuing interest. Experiments are carried out in the Department aimed at characterizing the electronic configurations of ions of these elements from their magnetic and spectroscopic properties.

The availability of a very pure sample of praeseodymium fluoride prompted a measurement of the magnetic susceptibility of this compound. PrF_3 was found to obey the Weiss-Curie law over the temperature range 76° K to 295° K. The Weiss constant, which is a measure of crystalline field effects and exchange interactions between the paramagnetic ions, was found to be 54° K, the same as for neodymium fluoride. The magnetic moment of the Pr^{+++} ion in the solid trifluoride was found to be 3.62 Bohr magnetons, in agreement with the theoretical estimate of Van Vleck for the $4f^2$ configuration of this ion. The magnetic susceptibility of cerium trifluoride has been redetermined with results in agreement with earlier work, and with theory for the 4f configuration of Ce^{+++}. The nature of the interactions responsible for the Weiss constant (62° K) was studied through measurements on mixtures of CeF_3 with LaF_3, which is diamagnetic. It was found, in contrast to similar measurements on isomorphous mixtures of MnF_2 and ZnF_2, that the Weiss constant was independent of mol fraction, suggesting that in CeF_3 this term in the temperature dependence of susceptibility arises from the crystalline field effect rather than from Heisenberg exchange. The magnetic susceptibility of UCl_4 has been carefully redetermined, with results in disagreement with a previous investigation elsewhere. The present results support the assignment of a $^3H_4$ state to the U^{+4} ion in this compound, corresponding to a $5f^2$ configuration. This conclusion is in agreement with those drawn about the several other salts of tetravalent uranium which have now been investigated.

The absorption spectra of UCl_4 and UCl_3 crystals and liquid solutions have been observed at low temperature (77° K) and found to exhibit lines resembling those of rare earth spectra. It has been found that UCl_4 is photochemically reduced to UCl_3 by ultraviolet irradiation of the solution at low temperature. Similar spectral measurements have been made on the rare earth salts, gadolinium bromide and europium chloride. An interesting technique has been used for the tiny crystals studied in this work which were too small to permit direct spectral examination of a single crystal. Their property of birefringence was employed; by placing the specimen between the crossed nicols of a microscope, all light except that passing through the crystals was blocked and only the light transmitted through the crystals was passed into the spectrograph.

The general survey of chemical behavior in liquid solutions at low temperatures (down to 77° K) has been continued, with further study of the compounds, as spectroscopically observed, formed between iodine and unsaturated hydrocarbons. The work is aided by the fact that at low temperatures it is possible to observe weakly bonded compounds not stable enough to be present in detectable amounts in a reacting system at higher temperatures. Addition compounds characterized by a strong absorption in the ultraviolet have been observed between iodine and the olefins propene, cis-butene-2, trans-butene-2, butadiene-1-3, 2-methyl-butadiene-1,3, and between iodine and cyclopropane as well. It is believed that the binding between the iodine and the hydrocarbons may result from polarization and London dispersion forces.

The refinement of spectra which accompany reduction in temperature also prompted measurement of the absorption spectra of solutions of chlorophyll a, chlorophyll b, and chlorophyll b' over a range in temperatures from 75° K to 300° K. New features were found in the spectra which are interpreted as indicating that each of the chlorophylls a, b, and b' is itself an equilibrium mixture of two isomers. The relative amounts of the isomers in chlorophyll b, and b' vary with temperature in such a way that the over-all spectra, which are practically the same at room temperature, are greatly different at low temperature.

Radiation Chemistry

The program in radiation chemistry, i.e., the chemical changes brought about by high energy ionizing radiation, has been continued with studies on the problem of accurate dosimetry, on the decomposition of solid salts, and, principally, on the reactions caused by radiation in aqueous solutions. The problem of dosimetry has two aspects: the accurate determination of relative doses, and the determination of the absolute dosage in terms of energy input to the irradiated materials. The second of these questions is currently being attacked by calorimetric methods. The first has been carefully studied by ionization chamber measurements and by chemical dosimetry. Ionization chambers proved unsatisfactory because of aberrant readings; a frequently used chemical method based on the oxidation of dilute air-saturated solutions of ferrous sulfate in sulfuric acid gave results reproducible to about 2%. Some indication has been found, however, that the response is non-linear, i.e., that the amount of

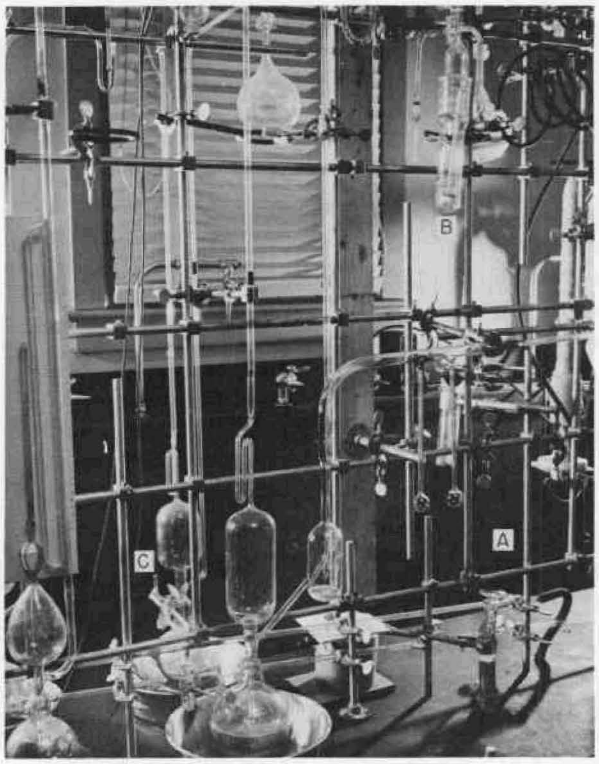


Figure 1. Vacuum system for preparation and analysis of aqueous solutions for radiation chemistry. (A) Sample preparation system. (B) Irradiated sample bulb ready for analysis. (C) Analysis system, containing Toepler pumps, McLeod gauge and combustion furnace.

reaction per unit energy input drops at high radiation intensities. In parallel with the ferrous sulfate dosimetry, a research investigation is being carried on with respect to similar reactions initiated chemically, through the production of hydroxyl radicals from ferrous iron and hydrogen peroxide. The hydroxyl radicals react quantitatively with an organic compound, present in relatively high concentration, to form organic radicals that react with oxygen and ferric iron. It is hoped from kinetics studies of these reactions to gain a better insight into the radiation reactions, which also involve hydroxyl radicals as primary products.

The work carried out in this Laboratory so far on the radiation decomposition of pure water is in accord with the work of others, which indicates that the decomposition, even after high dosages, does not exceed 8-10 $\mu\underline{M}$ per liter of hydrogen plus some oxygen. In contrast to water, a dilute neutral solution of KBr or KI shows considerably more decomposition, and the results are more reproducible. The decomposition does not reach a steady state up to 350,000 r, the highest dosage which has been employed. In the early stages of the work, a lack of material balance between hydrogen and oxygen suggested that some oxidized state of the halide might be present. However, it was later found that a heterogeneous reaction occurs on the glass surface, producing excess hydrogen and an equivalent amount of carbon dioxide, so that the material balance is satisfactory without postulating oxidized halogen.

Since hydrogen peroxide is present in irradiated aqueous solutions, the reactions in which this compound participates are of interest. These are being studied in solutions to which H_2O_2 has been added before irradiation. The amount of H_2O_2 decomposition at given dosage was found to be proportional to the square root of the H_2O_2 concentration; the yield is about 2.5-fold greater in the presence of 10^{-4} $\underline{M}$ KI. Hydrogen is initially evolved at the same rate in solutions of widely varying H_2O_2 concentrations and from KI and KBr solutions not containing added H_2O_2. The hydrogen evolved is believed to come from the solvent and not from the H_2O_2. These reaction kinetics studies are being continued; indications are that the situation is complicated.

Chemical Applications of Nuclear Tools

In last year's report (BNL 74 (AS-4)) it was mentioned that the exchange reaction between ferrous and ferric iron in aqueous solution was being investigated with the aid of radioactive iron tracer. This study has now been completed; the results are incorporated in a doctoral thesis. It was found that the reaction is first order in the total concentration of each oxidation state, and that, as in several other electron transfer exchanges between metallic ions, the rate is increased by decrease in the acidity. This effect has been quantitatively interpreted in terms of reaction between the hydrolyzed species $FeOH^{++}$ and ferrous ion. It was also found that chloride accelerates the exchange, through the intervention of the $FeCl^{++}$ complex, and possibly $FeCl_2^{+}$. Other systems in which electron transfer exchanges have been studied are the ferrocyanide-ferricyanide system, and the tris-(5,6-dimethyl-1,10-phenanthroline) complexes of ferrous and ferric iron. In each of these the exchange was found to be too rapid to measure with the techniques employed. Oxidation-reduction exchanges in organic systems are also being studied, in particular, the exchange between hydroquinones and the corresponding quinones. The methyl-substituted compounds duroquinone and durohydroquinone, labeled with C^{14}, have been studied. It is found that in solution the exchange reaction proceeds at a rapid, measurable rate, but that in the solid duroquinhydrone complex there is no exchange. The latter observation disproves the formulation of quinhydrones as symmetrical complexes in which the oxidized and reduced states lose their identity.

The program of study on the effect of isotopic substitution on the rates of chemical reactions has been continued, with special reference to decarboxylation reactions. It had been found earlier that the fractionation of carbon isotopes in the decarboxylation of malonic acid was explicable in terms of the theory of such processes developed at this Laboratory. Precise determinations have now been made of the relative rates of decomposition of isotopic mesitoic acid molecules and of isotopic trichloracetate ions, by mass spectrometric measurement of the $C^{13}O_2/C^{12}O_2$ ratio at various stages of reaction. In each case the C^{12} molecule decomposes about 3% faster than the C^{13} molecule; the results lend additional support to the previous conclusions about malonic acid.

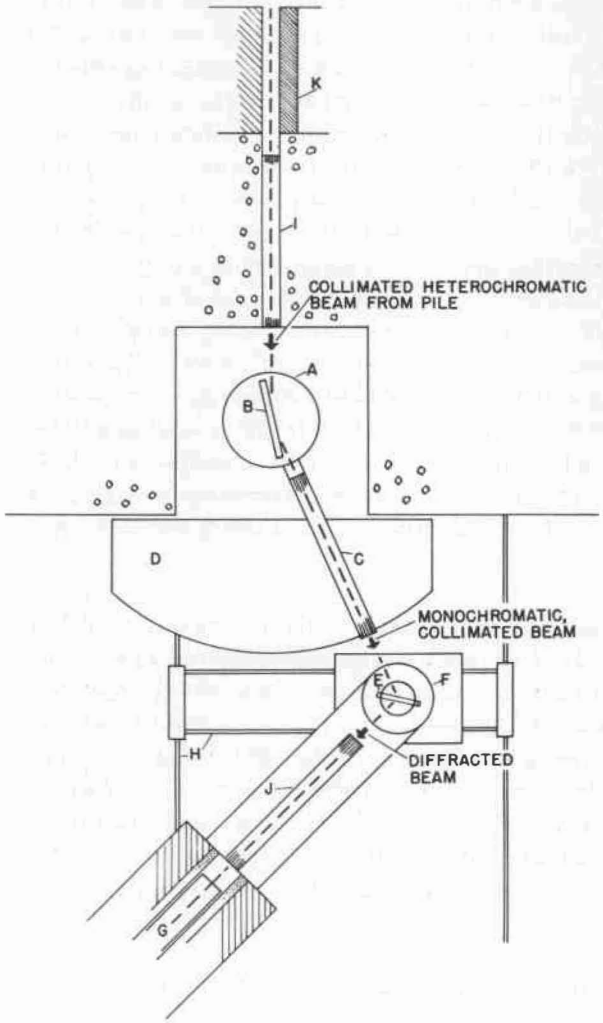
The mechanism of the reaction between hydroxylamine and nitrous acid to give water and nitrous oxide,

$$H_2NOH + HONO = 2H_2O + N_2O ,$$

has been studied with the aid of stable nitrogen and oxygen isotopes. The following conclusions were drawn: In neutral solution most of the nitrous oxide is formed by dehydration of a symmetrical intermediate, probably hyponitrous acid. In acid medium, dehydration of an unsymmetrical intermediate plays an important role. Mechanisms involving nitroxyl, NOH, have in the past been proposed but were found to be untenable.

In a biochemical tracer study the permeation of human red blood cells by C^{14}-tagged alcohol (methanol and n-butanol) has been measured. The attainment of distribution equilibrium was found to be very rapid. Calculations based on the equilibrium concentrations of alcohol inside and outside the cells showed that, within the experimental accuracy, all of the water inside the cells is free. This conclusion was verified by similar distribution experiments using water enriched with O^{18}.

The research in organic chemistry is concerned with tracer study of organic reactions and the synthesis of isotopically labeled organic molecules. Studies on the Willgerodt reaction have been continued, and it has been conclusively proved that



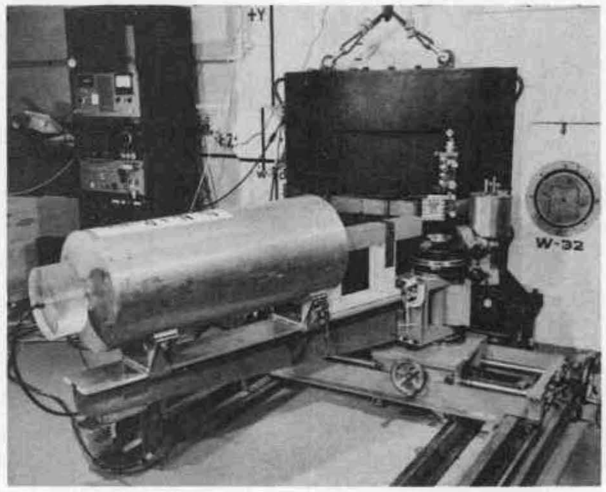


Figure 3. Photograph of neutron spectrometer.

Figure 2. Neutron diffraction apparatus. (Schematic.)

neither in the phenylacetamide (as previously reported) nor in the phenylacetic acid produced does a rearrangement in the carbon skeleton occur. The Curtius rearrangement of 3,5-dinitrobenzazide has been investigated with N^{15}. In this work, the currently accepted mechanism, involving elimination of molecular nitrogen from the compound $RCO\text{-}N{=}N_2$, with rupture of the $N{=}N_2$ bond as written here, was confirmed. Carbon-14 has been used in an investigation of the Faworskii reaction, in which alpha-chlorocyclohexanone rearranges to form cyclopentane carboxylic acid. An earlier conclusion that the reaction proceeds through a cyclopropane intermediate received additional support from this work.

On the synthetic side, the use of light metal carbonyls for incorporating C^{14} in various compounds has been further pursued. It has previously been shown that the black compound resulting from the direct combination of metallic potassium and carbon monoxide affords a convenient route for the synthesis of mesoinositol, an important vitamin. It has now been found that the white sodium or potassium carbonyl prepared from carbon monoxide and a solution of the metal in liquid ammonia can be used in a very satisfactory synthesis of labeled glycolic acid, an important substance in plant metabolism.

A problem of considerable interest is the preparation of radioactive vitamin B_{12}, for use in assay procedures and research on its mode of biological action. The vitamin contains cobalt strongly bound in the molecule. The preparation has been accomplished elsewhere by biosynthesis in the presence of radioactive cobalt. It has now been found possible to prepare the radioactive vitamin (containing cobalt-60) by direct neutron irradiation. Although neutron capture generally results in decomposition of the molecule in which it occurs (because of the resulting recoil), it was found that a sample of crystalline B_{12}, purified after irradiation in the Chalk River reactor, retained 80% of the induced cobalt radioactivity and 100% of its original biological activity.

Tracer experiments with stable isotopes, such as many of those mentioned above, rely heavily on mass spectrometric analysis; the Department operates three mass spectrometers for this and other purposes. Special problems of mass spectrometry are occasionally undertaken. Following a study of methods of reducing systematic instrumental errors, the relative abundances of the isotopes of krypton and neon have been redetermined, with results which are thought to be more accurate than data previously published. An improved method for the determination of deuterium in water has been developed which reduces a number of difficulties encountered in the conventional method of converting the water to gaseous hydrogen, which is then analyzed in a mass spectrometer. The new method is based on the quantitative conversion of hydrogen to ethane through reaction of the water with zinc diethyl. The resulting ethane is used instead of H_2 in the mass spectrometer.

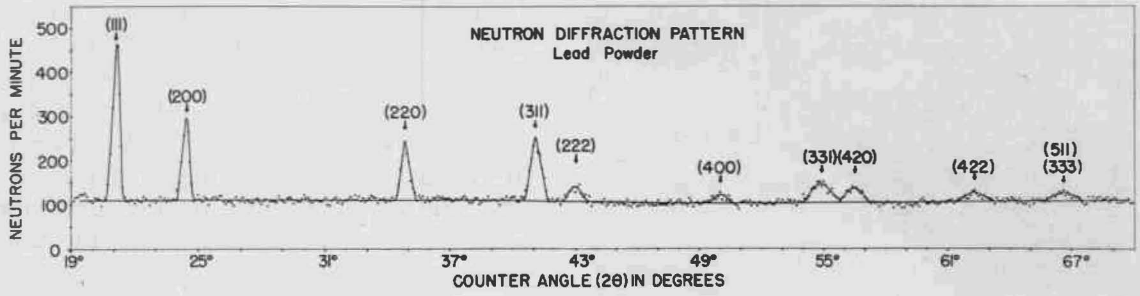


Figure 4. Neutron diffraction pattern for lead.

In concluding this section on chemical applications of nuclear tools, mention should be made of the neutron spectrometer, which has been completed and put into operation during the past year. The instrument has been designed primarily for structure determinations, by neutron diffraction, on powders, single crystals and liquids, but can also be used for the study of crystal imperfection, measurement of cross sections, etc. Numerous tests using substances of known structure have been made to determine the resolution, intensity, counter characteristics and mechanical performance of the instrument. The resolution compares favorably with that of the older Norelco X-ray diffraction spectrometer, although it falls short of that claimed for the latest G.E. and Norelco X-ray instruments. An important experimental quantity in structure work is in the integrated intensity in a diffraction peak. In test experiments quite satisfactory agreement between calculated and observed relative intensities was found.

As in the previous year, the research in nuclear chemistry, or radiochemistry, has emphasized study of the radiations emitted by radioactive isotopes. Considerable use has been made of proportional counter-pulse height analyzer combinations for X-ray spectrometry, also of scintillation counters, and coincidence techniques.

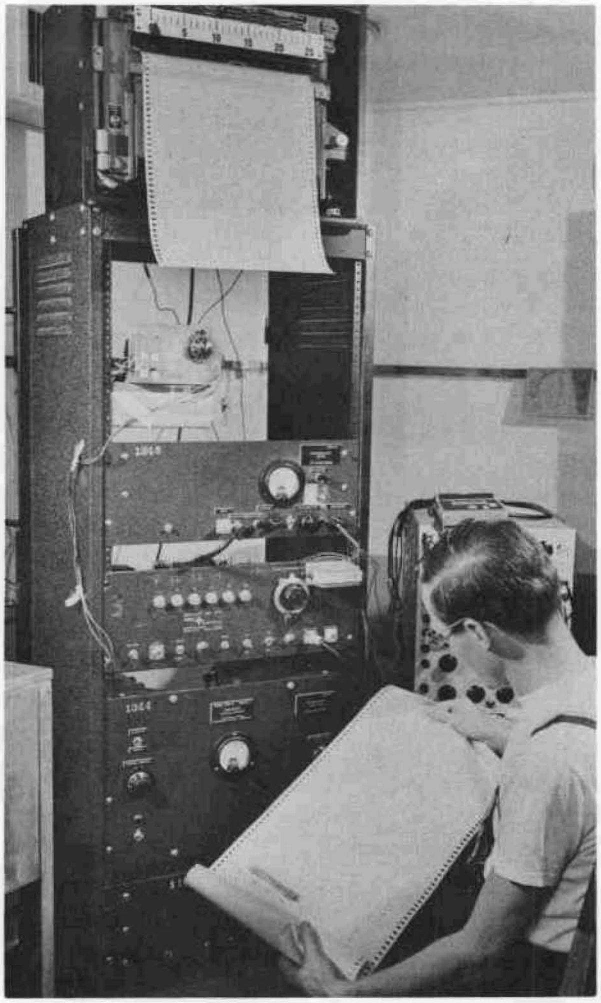


Figure 5. X-ray spectrum of polonium being recorded from proportional counter pulse height analyzer.

The 58-day isomer of Te^{125} decays in two steps, the second of which is a partially converted 35.4-kev gamma ray. The fraction of these transitions in which an orbital electron is ejected (internal conversion) instead of a gamma emitted has been determined by measuring directly the 35.4-kev gamma rays and the X-rays which are emitted after ejection of a K electron. The multipole order of the transition was determined from the results and the theory of internal conversion, and was found to agree with the shell structure model of M.G. Mayer.

The decay scheme of I^{126} was investigated, and it was found that this isotope decays by electron capture and by positron emission as well as by beta emission. The yields of the various branches were established. The data made possible a revised calculation of the (γ, n) yield for the production of this isotope. The new yield figure is in better agreement with the measured neutron yield than the previous estimate which did not take the electron capture decay branch into account.

The decay of I^{125} has also been studied. This isotope was found to decay entirely by electron capture, with a half-life of 60.0 days. By proportional counter and coincidence measurements it was established that all transitions go to the 35.4-kev level of Te^{125}, mentioned above. From the ratio of L_I to K capture it was calculated that the energy difference between the ground states of I^{125} and Te^{125} is about 115 kev, and it was concluded that the decay is an allowed transition.

In a study of the radiations from the beta-emitter Cu^{66}, two beta-ray groups were observed, the lower energy group leading to a 1.044-Mev excited state of Zn^{66}. This level appears to be the same as one which was reported to be involved in the decay of the positron-emitter Ga^{66} and was stated to have a half-life greater than 10^{-6} sec. However,

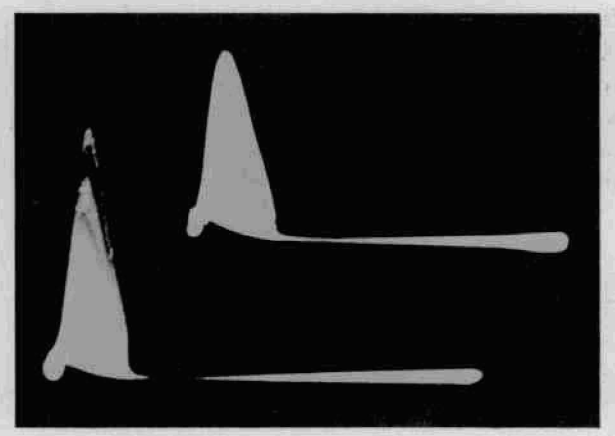


Figure 6. Photograph of scintillation counter pulse distribution for Cu^{66} as displayed on an oscilloscope screen. Photo-peaks and Compton distributions of the 1.04-Mev gamma ray of Cu^{66} and of the Cu^{64} annihilation radiation can be seen. The Cs^{137} pulse distribution is shown at the right, for comparison.

the present work showed the lifetime to be less than 10^{-7} sec. This result leads to a modification of the decay scheme of Ga^{66} which is in closer agreement with nuclear energetics data.

It was mentioned in last year's report that the half-life of I^{129} was being measured by a procedure involving absolute beta counting, mass spectrometry and chemical analysis. The half-life has been found to be 17.2 ± 0.9 million years. This result has been made the basis for a calculation of the age of the elements. The assumptions involved will not be discussed in detail here, except to say that it was assumed that most of the Xe^{129} now present on the earth originated from the decay of I^{129} after the formation of the earth and that the original cosmic abundance of I^{129} was about equal to that of the stable I^{127}. The calculated value for the time interval between the formation of the elements and the formation of the earth is 2.7×10^8 yr, corresponding to a total age of the elements of 3.6×10^9 yr.

The high neutron fluxes available in nuclear reactors make it possible to form isotopes by the successive capture of two neutrons in detectable amounts. The properties of the new isotopes produced and their formation cross sections are of interest. One such isotope under study is A^{42} formed from A^{40} by irradiating tank argon in the BNL reactor. The A^{42} is detected through its K^{42} daughter activity, separated in successive extractions. The half-life of A^{42} appears to be greater than a year. This and similar investigations are being currently pursued, and additional data will doubtless be given in next year's annual report.

REACTOR SCIENCE AND ENGINEERING

The total staff of the Department of Reactor Science and Engineering numbers 182, of which number 58 are members of the scientific staff and 6 are summer visitors. This year (fiscal 1950-1951) brought to completion the major part of the construction activities of the Department with the completion of the reactor August 11, 1950 and the official opening of the hot laboratory January 15, 1951. As a result, the activities of the Department can be divided roughly into research and development and the operation of the reactor and hot lab and associated meteorological, isotopes-handling and ground-water-monitoring responsibilities. Radioactive waste-handling for the entire Laboratory is part of the hot laboratory activities. Of the total scientific staff, roughly 75% are engaged in research and development; the other 25% comprises the technical operating staff.

Detailed reports on the various classified phases of the research and development work of the Department are covered in the Classified Progress Reports for this period. This includes work in chemistry, chemical engineering, metallurgy and reactor physics on various types of reactor components and processes. The unclassified work is described briefly in the following sections on the various aspects of fission product utilization and disposal, radioisotopes production and physics.

Reactor Operations

Introduction

This report is intended as a brief summary of the reactor's operating history. Operating levels, problems, and conditions will be discussed in general terms and will cover the period of July 1, 1950 to June 30, 1951.

Operating Levels

Prior to August 13, 1950, the H.K. Ferguson Co. was completing certain changes in the steel structure of the reactor and in the air ducts. After that date, the fuel installation program began and this work proceeded as dictated by the reactor evaluation program. Measurements were taken more frequently as the reactor approached critical size. Criticality was achieved August 22, 1950. By October 10 of the same year sufficient fuel had been installed to permit operating at megawatt power levels and use of the reactor for research purposes has been on the upswing since that date. As the reactor evaluation work was complete by then, the pile power was increased in steps, allowing time to make structural temperature and strain measurements. By late January of 1951 the reactor was operating at the design flux of 4×10^{12} neutrons per square centimeter per second, though not at the design power of 28 mw.

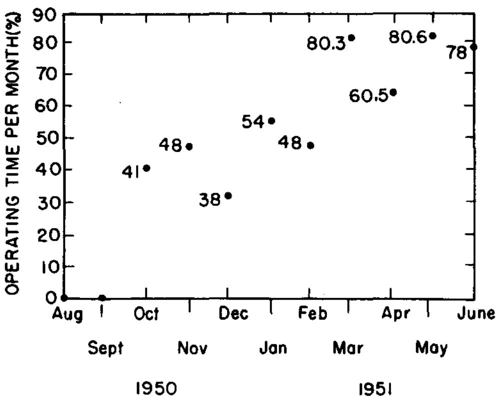
Operating Continuity

Since late January of 1951 the reactor has been operating near the design flux approximately two-thirds of the time.

During the months of February and April more fuel elements were charged to increase the excess reactivity of the reactor in order to accommodate an increasing research load. Some of the down time of the reactor, a small percentage, was required to replace unsatisfactory fuel elements.

Some of the down time is directly chargeable to maintenance. However, for the past four months nearly all of the down time has been required for research work, that is, for the installation of research equipment, the preparation time required before special runs and the installation of samples for irradiation.

A chart which follows indicates the trend is toward more operating hours per month though this curve has probably reached a peak and may drop as the research load of the reactor increases.



Although the reactor was actually operating during August and September of 1950, it was operated at watt and low kilowatt levels. For the purpose of the chart, which is intended to indicate the percentage of time of use for most of the experimental work being carried on, August and September are shown as having no operating time accumulated.

During the early period of reactor operation, a large amount of down time was required for the charging of fuel elements. Since February this requirement has decreased and some pattern of operating reliability and continuity has been established. Based on the past four months or so, it seems reasonable to expect that the reactor will be shut down for maintenance work only a small percentage of the time.

Use of the Reactor

In the past few months, after the reactor reached megawatt power levels, much of the research potential of the reactor has been utilized; the use of the reactor appears to be increasing. At present, 14 of the available 62 experimental openings (both ends of 31 holes) are in use with 11 assigned to be used in the near future. In addition, 4 facilities are in place on top of the reactor with others contemplated. The core hole has been assigned and equipment for external installation has been assigned. Long-term exposures are being made in the pneumatic tubes as well as in the bottling machine. The reactor is committed to certain service irradiations each week for hospitals in the Northeast. In addition to the regular experimental facilities some of the charging channels have been used for irradiation of high activity samples. Examples of this type of irradiation are the 1000 + curie sources of cobalt and tantalum which have been produced.

The neutron flux pattern and value have been determined in some of the experimental holes, the bottling machine, the thermal column on top of the pile, as well as in the animal tunnel. Plans are underway to map the flux in the pneumatic tubes.

Limiting Conditions

During the period in which the pile power was being gradually increased, measurements of structural temperature and strains were made. It was found, after the exit air reached approximately 60°C, that excessive stresses were being developed in the steel encasement of the reactor in the area of the central wall plates. This condition was remedied by remotely removing a weld in the plenum chambers which was thought to be restraining some of the thermal movement in this area. Strain gauges were installed on internal members at this time.

As additional information became available it was recognized that the stresses in this questionable area were greatly affected by the control rod pattern. By carefully adjusting the rod pattern these stresses did not seem to be a serious limiting problem. It is expected that the temperature to which the aluminum jacket on the fuel assemblies may be raised will be the final limit to the power and flux obtainable.

Operating Problems

While alterations and repairs were made in the construction of the reactor, the time was well used in correcting instruments and equipment difficulties as well as providing training for operating personnel. Therefore, as previously indicated, few operating difficulties have been experienced which required the loss of reactor operating time.

There were a number of difficulties encountered, some of which were with components which could be corrected without materially affecting reactor operation. A brief description of the major problems will follow.

A. Cooling System

1. Primary Fans: These units in general have operated satisfactorily although a gradual settlement of the foundation necessitated the raising of three of the units. This settlement is common to all such structures and is expected to decrease gradually.

During an inspection it was discovered that the shaft end buttons which space the fan shaft from the motor shaft, so that the motor runs approximately on its magnetic center, had been left out of three of the units and the two that were installed were not of the proper dimensions. The coupling is of the limited end thrust type with the inboard fan bearing taking the thrust of both fan and motor. This correction was made by welding the proper size thrust buttons in place without disturbing the alignment of the units.

The bearings on one of the fans were found to be in poor condition after a few months of use and were replaced.

2. Fan Discharge Valves (48-in double disk non-rising stem Chapman valves): These valves began to give trouble after about 140 operations of opening and closing. The threads on the spindle nuts were found to strip or wear out allowing the disks to drop into the closed position. No serious curtailment of operations resulted from this since it was possible to remove a valve and insert a spool in 6 hr. The mode of operation was changed slightly to allow the fans to be started under no-load conditions since, even though the valves have been repaired and replaced, it was considered advisable to use these only when necessary to seal off the fan during maintenance.

3. 1500-hp G.E. Fan Motors: These motors operated without difficulty until the middle of January 1951 when an operator noticed a slight tinkling sound in one end of the # 2 unit as it was coasting to a stop after a shutdown. Investigation revealed that, in nearly all the motors, some of the stator wedges had come loose. These were replaced by G.E. and the windings painted with shellac.

4. Emergency Fan: This unit did not operate satisfactorily in that the engine

drive seemed to be somewhat underpowered for this use. On March 31, 1951 the suction valve, while the actuating pressure switch was being tested, was allowed to open when the main fans were on. This allowed the fan to rotate backwards at high speed and damaged the wheel, shaft and housing. The requirements for this unit were investigated on the basis of actual operating data. The unit was determined to be unnecessary as the stack draft turned out to be greatly in excess of design anticipation. In view of this the fan was not repaired and operating procedures changed to take advantage of the stack draft during shutdown periods.

B. Canal

The canal has been the source of considerable difficulty though it has never caused curtailment of operations.

Upon testing it was found to leak considerably. The larger leaks were sealed by grout or special sealing compounds and, as predicted by consultants, the smaller leaks seemed to seal themselves over a period of time. At the time of high level operation the canal was essentially leak-tight.

The canal is designed to be a closed system in that there is no make-up water or effluent except under special conditions. The water is continually circulated through filter units. During the first few months of operation a number of fuel elements were placed in steel storage tubes and stored in the canal. Apparently considerable iron hydroxide was produced and bacteria grew rapidly enough so the filters were unable to keep up, resulting in high turbidity of the water. The canal was drained, flushed, new water added, and a bacteriacide added. This condition of turbidity will probably persist at times until the steel storage tubes are removed. Plans are underway to remove them. At present the canal water is clear and the activity has risen to about 1×10^{-11} c/cc. The filter media seems to concentrate activity to some extent.

C. Instrumentation

In general there have been no major instrument difficulties though a great many individual components have undergone revision to correct troubles. As an example, the galvanometer system has undergone the following changes:

1. Shock mounting changed to eliminate vibration of the spot.

2. Several cables shielded or moved to eliminate pickup from other electrical lines.

3. Drift was a problem until an insulated box was provided as a housing and the mechanical zero was supplemented by an electrical circuit by which the meter may be zeroed.

4. The differential chamber suffered whenever the reactor was shut down since it would drive off scale badly; this was remedied by incorporating a relay which shorts the galvanometer except when the shutdown relay for the reactor is energized. An interlock was installed to require the return of the galvanometer shunt to zero.

Nearly all of the instrument circuits have undergone some change to improve their operation.

Hot Laboratory Operations

This past year saw the opening of the hot laboratory, Building 801, official announcement of which was made on January 15, 1951. During this year all of the facilities of the building (with the exception of the decontamination cell) have been tested and put to good use. As of July 31, 1951, the building was occupied to 88% of its capacity and already the need has been sharply felt for a facility which is not presently available -- viz., a shielded room designed primarily for the physical manipulation of very hot sources. More than adequate space was left in the hot area for the construction of such a room.

The hot cells, a new design which is a distinguishing feature of the hot lab, have been found to be very satisfactory from an operation standpoint, -- even more so than was hoped for when they were designed. They provide for easy, safe, and efficient chemical operation on radioactive material in the 1-200 c region.

The closed dissolver system for use with irradiated uranium has been completed except for final testing. A cave housing an 80-c cobalt source was designed and built and put into operation in this building primarily for use by the Medical Department. It gives a uniform radiation level of more than 750 r/hr over an area 11-in square. Work has been started on a 150-250-c source for the AEC.

Two new valves were invented, one a diaphragm valve and the other a pinch clamp type, both for remote operation in the hot cells. They are compact and have operated satisfactorily, and approximately 100 of each are being built for use on remotely operated systems.

A nomogram which simplifies shielding calculations on Co^{60} was constructed and published. Another nomogram for calculating the activity of a fission product has been constructed and will be published shortly.

Isotopes and Special Materials

The functions of the BNL Isotopes and Special Materials Group have remained essentially fixed during the fiscal year 1950-51, i.e., procurement and distribution of isotopes, special materials and arranging for pile irradiations, but its activities have greatly increased as a result of the reactor start-up.

Isotopes Program

The following tables serve to indicate the growth in activities of the isotope program over the past years and during fiscal 1950-51. In addition, Table 5 shows the various installations that have received service irradiations from BNL.

In order to cope with this rapid growth in six months, another technican was added and additional laboratory space in the reactor building wing acquired to process service irradiations for shipment and delivery. Additional space is now used as a receiving point for processing incoming radioactive materials and the storage of surplus activity.

Table 1

Service	Fiscal Year 1948	1949	1950	1951
Isotopes ordered	48	96	189	170
BNL service irradiations (Internal users)	0	0	0	638*
BNL service irradiations (External users)	0	0	0	184*
Isotopes shipments	0	13	22	141

*See tables below.

Table 2

Bottling Machine Irradiations for External Users (Fiscal 1951)

Month	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
Number	1	0	5	11	22	31	24	30	124
Charge($)	12	-	142	387	709	1033	756	935	3974

Table 3

Service Irradiations*

Irradiations		Fiscal Year 1951 March	April	May	June	Total
Pneumatic Tube, External Users	Number	12	0	12	36	60
	Charge ($)	60	-	150	50	260
Bottling Machine Internal Users	Number	41	18	57	22	138
	Charge ($)	1337	1639	3684	1773	8433
Pneumatic Tube, Internal Users	Number	34	84	52	41	211
	Charge ($)	170	420	260	205	1055
W-36 Slot, Internal Users	Number	35	19	6	2	62
	Charge ($)	175	95	30	10	310

*No records of charges have been compiled on irradiations prior to March 1951. Approximately 227 irradiations were done in the bottling machine prior to this date.

Table 4 Summary for Fiscal 1950-51		
Irradiations	Number	Charge ($)
External Users	184	4234
Internal Users	638	9798*

*Covers charges on irradiations made after March 1, 1951 only.

Policies for handling service irradiations for external users were set in agreement with the AEC and formally issued in a booklet during February 1951. These services and policies are also included in the new Oak Ridge AEC Isotopes Catalog No. 4. One of the most difficult policies to formulate concerned the charges for service irradiations. A suitable formula was finally evolved which gave satisfactory agreement with the Oak Ridge pricing policy, thereby minimizing competition. A further step was an agreement to charge the same price for irradiations as Oak Ridge in cases where BNL is essentially duplicating an Oak Ridge unit. It is this factor coupled with the free irradiations for cancer research which make the total charge for bottling machine irradiations for external users much less than that for internal users, even though the number of each is about the same.

Since the irradiation services at BNL for external users are primarily for short-lived isotopes, an important shipping problem is presented. For the most part the Laboratory has employed the services of Island Air Ferries at MacArthur Airport with charter flights to Logan Airport in Boston and courier service to the New York City area. In addition some material is picked up at BNL by the users, and the Group has available its own surburban truck for direct deliveries when necessary.

A supply of shipping pigs (ten each) of 1-in, 2-in and 3-in lead shielding was designed and built. Also, 30 wooden shipping boxes with angle-iron bracing were constructed adaptable to any size pig. An inspector from the Bureau of Explosives reviewed the shipping containers at our request to insure that they would meet I.C.C. specifications. Since the pigs were not suitable for shipping radioactive solutions, this practice has been discontinued until new pigs are available.

Sources and Special Materials

There were a total of 48 special material requests submitted during the fiscal year 1951. In addition, several surveys were submitted to the AEC covering the Laboratory's estimated requirements for various materials.

Since there are charges for some special materials, the Group is now placing standard purchase requisitions to cover special material requests when necessary. In this way, the funds may be committed properly against the budget concerned. This Group assumes the authority to place such requisitions upon receipt of a properly authorized request, in the same manner as isotopes are ordered.

Table 5

Shipments Made to Various Laboratories and Installations During the Fiscal Year of 1951

Destination	Material	No. of Shipments
Columbia University Medical Center	Bromine 82	1
Columbia University	Mercury 203	1
" "	Antimony 122	1
" "	SI - Triphenylphosphine	1
Columbia University College of Physicians and Surgeons	Sodium 24	9
" "	Potassium 42	9
Harvard University	Sodium 24	3
Harvard University Medical School	Sodium 24	10
" " " "	Potassium 42	10
Iowa State College	Carbon 14	1
Johns Hopkins University	Strontium 90	1
" " "	Chlorine 36	1
" " "	Sodium Sulfate	1
" " "	Sodium Phosphate	1
Knolls Atomic Power Laboratory (General Electric Co.)	SI - Uranium Foil	1
" "	SI - Fe, Co, Ni, Mn, U_3O_8 samples	1
Massachusetts General Hospital	Potassium 42	3
" " "	Copper 64	10
Massachusetts Institute of Technology	SI - Al metal	2
" " " "	SI - Cu-Si alloy	1
Montefiore Hospital	Bromine 82	1
National Bureau of Standards	Carbon 14	2
New Brunswick Laboratory, AEC	SI - Hafnium, Zirconium	1
New York University College of Medicine	Sodium 24	16
"	Potassium 42	13
Peter Bent Brigham Hospital	Potassium 42	2
" " " "	Sodium 24	2
Princeton University	SI - Zinc Sulfide	1
University of Illinois	Carbon 14	1
University of Michigan	SI - Cobalt Metal	1
University of Oregon	Carbon 14	1
University of Wisconsin	Carbon 14	1
Veterans Administration Hospital	Sodium 24	10
" " "	Potassium 42	10
Washington University	Carbon 14	2
Watertown Arsenal	SI - Steel samples	1
Yale University	Copper 64	1

(SI - Service Irradiation)

S/F Accountability

During the fiscal year 1951, this Group submitted to the AEC nine inventories monthly on a routine basis. These covered the normal uranium, enriched uranium, depleted uranium, plutonium, thorium, tritium, heavy water, beryllium and zirconium on hand at BNL. The complexity of the uranium inventories was greatly increased by reactor start-up, since it is now necessary to calculate the plutonium produced in the reactor.

Meteorology

The personnel structure and organization of this group have undergone little change. The staff has decreased to a total of 14; one Weather Technican and one Weather Analyst have terminated without replacement. The division of the work into categories of Instrumentation, Statistical Analysis and Computations, and Forecasting, under the supervision of the three members of the scientific staff continues, as it has since 1948.

On April 1, 1951, the Meteorology Group began issuing predictions for actual reactor operations as a daily routine, thereby inaugurating the meteorological control phase of the reactor program. Prior to this date, the relatively low power and frequent shut-downs of the reactor had made it unnecessary to consider the possibility of radiation in excess of the operating level.

The initial comparisons between oil-fog and radiation data accounted for the major portion of Group effort during the past year. These have involved (1) obtaining more accurate and complete oil-fog data, (2) joint operations with the Health Physics Division in which both oil-fog and radiation measurements have been made, and (3) the elimination of significant unknowns in the radiation data. Considerable work remains to be accomplished in all three categories.

Instrumentation

Few changes have been made in the basic instrumentation during the past year. The modification of equipment necessary to reactor operations was completed by June, 1950. Since that date emphasis has been placed on (1) a more complete determination of instrument characteristics, and (2) the development of labor-saving computing devices.

Eight Bendix Friez Aerovanes have been tested in one or both of two wind tunnels. The opportunity for these evaluations arose from the cooperative relationships between Brookhaven, the National Advisory Committee for Aeronautics, and New York University. The tests were made at Langley Field, Va., in December, 1950, and at the College of Engineering in June, 1951. Detailed results of these tests are to be published in the near future. The BNL bivane has been equipped with an annular tail assembly (see Figure 1), whose free period is less than that of the original flat plate tail. The damping coefficient has not been significantly altered.

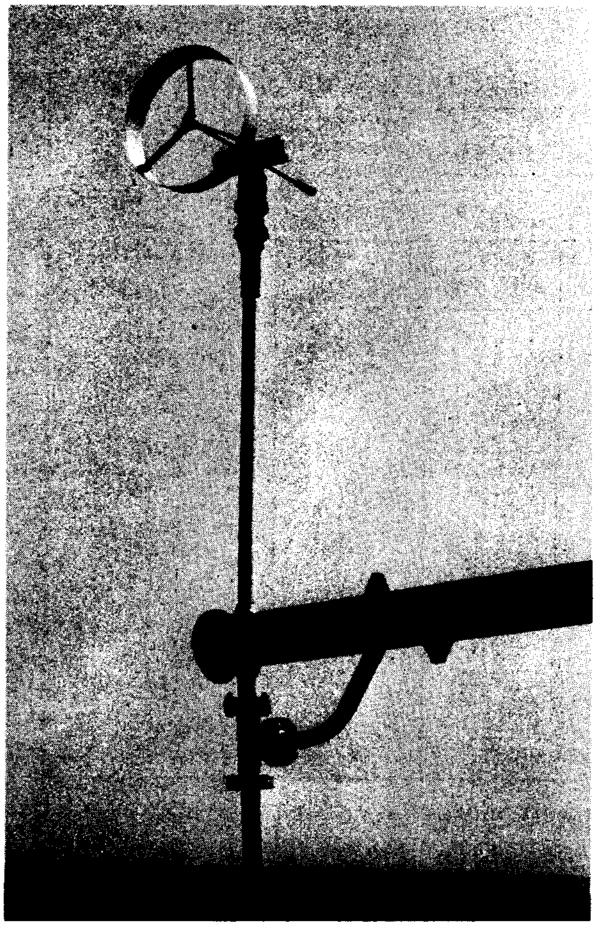


Figure 1. The BNL bivane equipped with the annular ring tail assembly.

More than 100 tests have been conducted to determine the effect of the rate of air flow on the response of the Leeds and Northrup thermohms; with a line flow of 21 ft sec^{-1} past the element, the resistance thermometers have a lag coefficient of 66 sec.

Several developments that will effect savings in computation time have been accomplished. An aerovane transmitter, which normally gives instantaneous values of wind speed, has been altered to provide short-term means. The most important progress in instrumentation has been the vast improvement in the photometric densitometers. The new instruments are durable, stable and extremely sensitive. The oil-fog data now obtained are believed to be accurate within 25%.

Oil-Fog Tests

During the twelve months ending June 30, 1951, fifteen oil-fog tests, using the 355-ft meteorology stack, were completed. A number of meteorological conditions were investigated during these tests, as shown in Table 1.

The purpose of these tests is to extend knowledge of diffusion by measurements of ground concentrations at distances greater than 20 stack-heights downstream, and to investigate transitory meteorological conditions such as the change-over from inversion to lapse and lapse to inversion. These tests have also provided a check on previous results because of the greatly improved characteristics of the new densitometers.

The oil-fog measurements have assumed greater importance because the Health Physics monitoring stations provide no quantitative measure of the beta contribution to the dose-rate from the A^{41} in the reactor cooling air. The short range of the beta radiation in air makes it possible to approximate the dose-rate from that source, if the ground-level point concentrations of oil-fog are known.

During several tests, simultaneous measurements were made of the A^{41} dose-rate and oil-fog concentrations. The oil-fog plume provides a visual reference by which the mobile radiation monitoring unit can be correctly located with respect to the reactor stack. While the data obtained thus far are qualitative, further joint tests are planned which should make possible adequate quantitative comparisons.

Table 1

Wind Direction, Speed, and Stability Conditions during Oil-Fog Tests*

July 1, 1950 to June 30, 1951

Wind Direction	Wind Speed, m sec^{-1}				Stability
	1 - 3	4 - 7	≥ 8	Total	
NW	2	2	1	5	Lapse
	2	-	-	2	Inversion
NE	-	1	-	1	Lapse
	-	-	-	0	Inversion
SE	1	2	-	3	Lapse
	-	-	-	0	Inversion
SW	2	1	3	6	Lapse
	-	1	1	2	Inversion
Total	7	7	5	19	

*Certain tests were made during changing conditions so that the total exceeds 15.

Reactor Radiation Data

In January 1951 the reactor operating level reached a sufficiently high value to give noticeable readings at the fixed Health Physics monitoring stations. A preliminary check indicated that the theoretical dose-rates based on meteorological data were too high by a factor of approximately 2 for inversion conditions and by a factor of 3-4 for lapse conditions. The large number of uncertainties in both theory and measurement made it inadvisable to adjust the theoretical values downward until a thorough investigation had been made. The following uncertainties were investigated:

Uncertainties in Measurement

1. Emission rate of A^{41}
2. A^{41} beta dose-rate
3. Efficiency of monitoring station dynamic condenser electrometer for A^{41} gamma radiation
4. Variability of natural background
5. Slow neutron cross section of A^{41}

Uncertainties in Theory

1. Neglect of energy degradation of scattered gamma radiation
2. Neglect of scattering from the ground
3. Inadequate general theory of atmospheric diffusion

At the request of the Meteorology Group, the Reactor Operations Group and the Health Physics Division made independent measurements of the A^{41} emission rate.

Good agreement with the theoretical value was obtained. Both theory and measurement, however, depend on the slow-neutron activation cross section for A^{41}. Since the published values for this parameter differ by a factor of 2, an uncertainty of this magnitude remains in the estimation of the A^{41} output from the reactor stack. It is expected that this uncertainty will shortly be reduced.

A study of the efficiency of the dynamic-condenser electrometer in the monitoring stations is in progress, using a Co^{60} source to approximate the A^{41} gamma radiation.

The mathematical theory of the dose-rate from a diffusing radioactive cloud has been revised, using the concept of a build-up factor to take account of the energy degradation of scattered quanta.

When the efficiency of the dynamic-condenser electrometer and the output of A^{41} from the reactor stack have been determined, it should be possible to use the revised theory to determine the meteorological parameters of importance from the dose-rates measured at the monitoring stations and the mobile unit, and reduce the over-all uncertainty in dose-rate to less than a factor of 2.

Reactor Operations

In the first few months of reactor operations, there was no possibility of radiation dose-rates exceeding the operating level. During this period the Meteorology Group participated in several of the tests designed to determine various characteristics and coefficients of the reactor. Special forecasts were made for the tests of barometric and temperature coefficients.

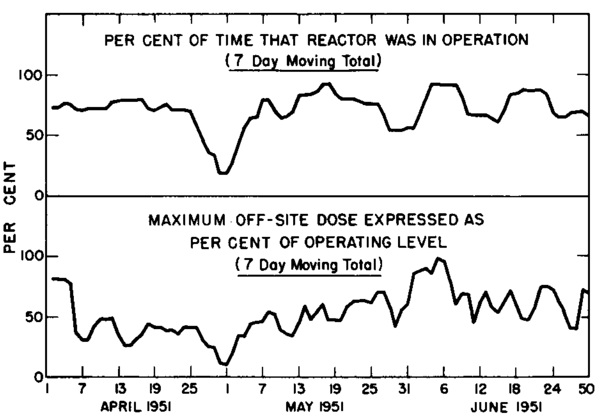


Figure 2. The graph provides a comparison of the maximum off-site radiation dose and the operating time of the reactor during April, May and June of 1951. The latter is one of five factors influencing off-site radiation.

On the basis of the uncertainties described above, it was decided that the original meteorological calculations of radiation from the A^{41} would be used initially for the control program. The predictions for reactor operations, inaugurated on April 1, have probably indicated higher dose-rates than actually existed. Even with this overestimate, it has been necessary to recommend shut-down of the reactor on only one occasion.

In a very real sense, the restrictions of reactor operations to an intermediate power level during the night and the rather frequent routine and non-routine shut-downs have served as a control. The small contribution of the reactor to off-site radiation dose-rate in a 7-day period is a function of power level, operting time, wind direction, wind speed and gustiness. Figure 2 shows the relationship between the calculated maximum off-site radiation and the percentage of the time during which the reactor was in operation. The importance of this factor is clearly indicated.

Although of little future significance, it is interesting to note that shut-down was recommended on 1% of the days during April, May and June, 1951. The reactor was in operation 71% of the time, but at less than full power in more than half of the operating hours.

Geology*

The principal purpose of the investigations at Brookhaven National Laboratory and surrounding areas is to determine the best course of action to follow in case of an accidental spilling and infiltration into the ground of liquid radioactive material. A second purpose is to protect the Laboratory from any unjust accusations that its actions had impaired the quality of the water resources of the area.

It is recognized that the rate and concentration at which the radioactive solutions can move through the soil and underlying geological formations is greatly affected by absorption and ion exchange with the formation they percolate through. However, it appears that the contamination cannot move faster than the percolation velocity of the liquid through the interstices of the soil or geological formations. Therefore, it appears that the movement of the ground and surface waters of the area set a limit as to the maximum rate at which contamination could move and the areas that can be affected.

In order to determine rate, direction and distance of movement of the ground and surface waters, a detailed and comprehensive study of the geology and hydrology of the Laboratory and adjacent areas has been undertaken. This work has been in progress for about three years. During the 1949 and 1950 fiscal years the work was directed largely toward the collection of geological data through an extensive test hole drilling program, the construction and establishment of approximately 60 observation wells, seven of which were equipped with automatic water stage recorders and the remainder of which have been measured at monthly intervals. A large amount of instrumental leveling was done to determine the elevation of the measuring points of observation wells in order to prepare contour maps of the water table. Samples of ground and surface water were collected for chemical analysis and radioactive determinations. Experiments were conducted on the suitability of tracers and methods for measuring ground water velocities.

During the 1951 fiscal year the observation well program was continued and expanded slightly. A study was begun regarding the correlation and interpretation of hydrologic data collected to date. A perched water table above the main water table was found to exist in approximately the eastern third of the Laboratory area, and extending into the Manorville area. Work has been started to determine its extent and connection with the main ground water body. The effluent from sewage treatment plant is disposed of partly by infiltration to ground water from the filter beds, partly by infiltration to ground water from the perched channel of the upper Peconic River, and at times a part of its flow downstream in surface channels toward the Peconic Bay. The direction of surface flow is to the east while ground water movement is to the south. Thus, radioactive waste allowed to enter the sewage system may follow widely different routes depending on hydrologic conditions at the time.

*Hydrologic and geologic investigations conducted by the U.S. Geological Survey at Brookhaven National Laboratory.

A rather extensive pumping test was conducted to determine the permeability and specific yield of the glacial sands and ground in the Laboratory area. This was done primarily to determine the quantity and average velocity of the ground water moving through the glacial sands. The mathematical treatment dealing with unsteady state condition of ground water flow is analogous to that derived for unsteady state of heat flow towards a sink, in which the hydraulic gradient, permeability and specific yield are analogous to thermal gradient, thermal conductivity and specific heat. Actual conditions depart considerably from the ideal conditions assumed in the derivation of these formulas, as the formation is not homogeneous and isotropic; there appears to be considerable variations in the permeability within short distances, and the horizontal permeability is greater than the vertical. The specific yield is not a constant as assumed in the formula but is a function of time and several other governing variables. The pumping well was not screened throughout the entire thickness of the water-bearing formation, but had a 20-ft screen, which is about 13 % of the saturated thickness of the aquifer. Thus, horizontal radial flow did not exist as is assumed in the mathematical treatment. Recharge from the surface and leakage through the underlying Gardner's clay also had to be considered. Thus, considerable time was given to the study of the data obtained in this test, in order to devise methods for making allowances or corrections for conditions departing from the ideal assumptions made in the formula, and to determine the general accuracy and suitability of the pumping tests for obtaining the true values of average permeability and specific yield under water table conditions.

During the 1951 fiscal year a system for routine monitoring of ground and surface waters was established and samples of water are now being collected at selected points for determination of chloride and nitrate content, pH, conductivity and radioactivity. Some time was also devoted to the study of the water analyses made to date, to determine if the waters fell into several general classes and what constituents would be the best indicators of a change in the character of the water due to contamination.

A method was developed for testing observation wells to determine the degree of connection between the well and the formation and thus determine how accurately the water level in the well represents that in the formation, aiding in determining the suitability of the well for the purpose intended.

The preparation of a report dealing with the pumping test previously discussed is in progress and nearly completed.

Fission Product Utilization, Waste Concentration and Ultimate Disposal

Concentration of dilute liquid radioactive wastes is necessary for economical waste-handling and storage. A further problem is the disposition of the radioactive concentrate. At all AEC sites this potentially valuable material is at present being stored or dumped in the ocean. Fixation of radioactive wastes on clays for ultimate disposal is being studied here by one group. The Fission Product Utilization and Waste Concentration Groups, in addition to completing the development and process design for the BNL waste concentration plant, have undertaken a long-range research program to find industrial uses for the energies available in radioactive fission product wastes and to devise methods for preparing stable high-level radioactive sources from available wastes.

Pilot Plant Studies

During the past fiscal year the semi-works compression still was installed and put into operation at the hot laboratory. After 8 months of research using P^{32} activity, data and experience were obtained with the unit and its important components -- Fiberglas vapor filter, Roots steam compressor, cyclone separator, and vapor dome separator. The evaporator was repiped for concentration of Laboratory D waste on an interim basis; between April 1 and July 1 in cooperation with the Waste Control Section, about 9000 gal of D waste were concentrated. The effluent water has been well below the activity level set by the AEC of 3×10^{-12} c/ml, and the concentrate has been stored in polyethylene-lined drums for ultimate disposal. Concentration factors of between 30 and 40 have been regularly achieved. The semi-works still has been turned over to the Waste Control Section for intermediate concentration of D waste. When the full-scale plant is completed (summer of 1952), the semi-works still will be used for concentration of halogen-containing liquid waste.

Process Design

Based on the experience gained from the semi-works still, process designs of five equally feasible concentration schemes were drawn up. A cost estimate was made for two of the process designs: BNL vapor compression and KAPL forced circulation process; the BNL vapor compression process showed both low first cost and low process cost, and was recommended to the AEC in BNL 112 (T-23). This process design has been approved and contract negotiations for a mechanical design agent are in progress.

Waste Utilization Program

To initiate studies in fission product utilization, cobalt and tantalum tubes, 2-in O.D. and 13-in long, were canned in aluminum and irradiated in the reactor to obtain kilo-curie sources of gamma radiation. These tubes were made to simulate sources which in the future may be manufactured from radioactive wastes. Suitable lead pigs to contain the sources were designed and fabricated. Irradiation of various materials, batchwise or flow, is performed within the lead shield by a removable plug arrangement. Brookhaven is supplying cobalt sources and pigs to AEC contractors; participating organizations are M.I.T., Yale, Columbia, University of Michigan, and the General Electric Co. These organizations, as well as BNL, will study among others the effects of gamma rays upon food preservation and the initiation of chemical reactions. The BNL group has already obtained results in the uncatalyzed polymerization of plastic monomers by high-level gamma irradiation.

Some of the source facilities at BNL are set aside for service irradiations for industry. This service is set up on a fee basis to help defray the costs of source preparation.

The Group has also begun work on the concentration of the fission product activities which are formed as by-products in the various reactors. These fission products are discharged from the fuel processing plants in the various process streams, and are mixed with large quantities of stable inorganic salts and other chemical compounds which are introduced into the separation process.

Research is being directed toward isolation of the fission products by selective adsorption on ion exchange resins or by selective chelation and solvent extraction. After isolation from the other salts and acids the fission products will be "fixed" in a small package which will be usable as a radiation source.

Ultimate Radioactive Waste Disposal

The rapid development of the national nuclear energy program is dependent to a great extent upon a successful solution to the problem of the ultimate disposal of radioactive wastes. At Brookhaven, an investigation of an inexpensive and readily available natural clay (montmorillonite) has revealed that the longer-lived fission wastes can be removed from solution and chemically bound by the clay in an irreplaceable form. The study has consisted of the determination of the feasibility of fixation, by thermal dehydration, of individual and mixed fission products in montmorillonite as well as factors influencing the efficiency of the process. An insight into the mechanism of fixation is being gained through X-ray diffraction studies of heated clays; a supplementary project at Yale University has been concerned with the kinetics of ion exchange reaction in clays.

Radioisotope Production

A group in the hot laboratory has had under investigation for some time the problem of making available for medical and biological research short-lived I^{132} and investigating the possibility of producing other useful isotopes not now available. During this year, work on I^{132} production has progressed from tracer runs in equipment outside of the hot cells to full-scale runs in the hot cell. Although several improvements have been made in the separation process, more experience and some further modifications will be required before production can be put on a routine basis. Permanent processing equipment, employing heavy wall pyrex pipe and fluorothene filter disks, is under construction, and although it is designed primarily for the I^{132} process, it will be possible to use it to a limited extent for separation of other radioisotopes.

The LiCl-KCl melt containing tellurium is more corrosive than was realized at first. After trying stainless steel and gold-plated generators and after running corrosion tests on a wide variety of samples, e.g., inconel, monel, hastelloy, rhodium, gold and platinum, an iodine generator is being fabricated with a solid platinum liner. Preliminary work indicates that sodium nitrite would be a better melt; this is being investigated further. Attempts are being made to eliminate altogether the tellurium carrier which is the primary cause of corrosion. A mock-up of the shipping shield has been made but construction is being held up pending a satisfactory generator.

Scouting work is in progress on the production of other radioisotopes which are unavailable at present. Among those being studied are carrier-free Ga^{72} and $Cl^{36,38}$. Preliminary work with non-radioactive chemicals indicates that a satisfactory process has been found to use for rapid stand-by production of I^{131}, in case the source of that isotope should again be temporarily cut off as it was once before this year.

Double Crystal Spectrometer

In December 1950 the double crystal spectrometer for neutrons was mostly completed and installed. Since that time, measurements with the instrument have included double-crystal rocking curves to evaluate the usefulness of various crystals, measurement of the critical angle for total reflection with a monochromatic beam, and total cross section vs. energy for several elements.

The present program consists of total cross section measurements in the range from 1 ev to 10 ev using very high resolution.

Double Beta Decay and Rare Multiple Processes

A program has been started to investigate phenomena that involve the appearance of two or more particles in a single event (e.g., double beta decay, multiple meson production, electron-positron pairs). Because events of this type are very rare, a special type of cloud chamber, which triggers only when a multiple process occurs inside, has been built. This chamber and its associated magnetic field are now operating, taking pictures of multiple processes. The projection apparatus for carefully analyzing these pictures is now being built.

LIFE SCIENCES

Research in the life sciences is divided between the Departments of Biology and Medicine. In both Departments, the work can be characterized under two broad headings: namely, the study of the biological effects of radiation and the use of isotopes and radiation as tools in the study of biological processes and in diagnosis, therapy and pre-clinical investigation in medicine. Whereas the work of the Medical Department is pointed toward ultimate application to human beings, the researches in biology cover a wide variety of subjects in the plant and animal kingdoms. Biological research at Brookhaven is characterized by work in mammalian physiology, plant physiology, general physiology, metabolism, biophysics and genetics. In the Medical Department, research is carried on in the four divisions of bacteriology, biochemistry, pathology and physiology on both pre-clinical and clinical levels. The Research Hospital is maintained as a part of this program.

Several changes in key personnel have taken place during the fiscal year. Dr. D.D. Van Slyke, who has served as Assistant Director for Life Sciences and as Head of the Division of Biochemistry, resigned on July 1, 1951 to accept a position with the Lilly Research Foundation. Dr. Van Slyke will maintain his office at Brookhaven and will continue as a guest scientist in the Medical Department. He expects to be available for discussions and consultation. Dr. Howard J. Curtis, formerly Professor of Physiology at Vanderbilt Medical School, became Chairman of the Biology Department on October 1, 1950. Dr. John T. Godwin, Pathologist at Foundation Hospital of New Orleans, has accepted appointment as Head of the Pathology Division, the position vacated by Dr. Sidney C. Madden. Dr. Godwin will arrive at the Laboratory on September 1, 1951.

The program for the completion of temporary laboratory facilities and the provision of new permanent facilities is continuing. The Biology Department has cooperated with the Architectural Planning Division and the AEC in the planning of the second phase of the Biology building program. The plans were finished and bids received by year end. Construction is to start in August on this addition which will provide laboratories, offices and animal quarters. The Medical laboratories are nearing completion with bacteriology and biochemistry laboratories in full operation. The physiology and pathology laboratories, while in partial use, will be completed in the next year. These laboratories are in the Medical Complex and were converted from Army hospital wards.

Specialized facilities made available to biological and medical research during the year include neutron beams from the reactor, a 70-curie Co^{60} gamma source for small animal irradiation, a 200-curie Co^{60} source located in the center of a 5-acre growing field and a greenhouse for irradiation of hot-house plants.

BIOLOGY

The staff of the Biology Department numbers 48 as of July 1, of which 20 are on the scientific staff; in addition, there are 11 scientists and 3 supporting members for the summer of 1951. This is about the same number as was on the staff on July 1, 1950. However, these figures give an erroneous impression of the growth of the Department, since a number of people have been added to the staff who will start work in the summer or early fall.

Some members of the staff are scientists on fellowships, students working toward advanced degrees, or university faculty members on leave. It is anticipated that the numbers of people in these categories will increase considerably as the possibilities for collaboration become better known to biologists generally.

Because of the fact that the ramifications of the atomic energy program reach into practically every phase of biology, and since an attempt is being made to have all phases of the subject represented at the Laboratory, biologists having very varied backgrounds have been added to the staff. The activities of the Department reflect the varied disciplines of biology represented. The specific problems attacked are dictated almost entirely by the interests and training of the individual scientist. Some of the disciplines are not yet adequately represented, and it is anticipated that as the staff expands toward its planned size, these deficiencies will be removed. Eventually it is to be hoped that any university biologist, who might find it advantageous for his work to utilize the ideas and techniques of atomic energy, could come to the Laboratory for a limited stay and find at least one staff member well acquainted with his work and ready to help make his stay here as profitable as possible.

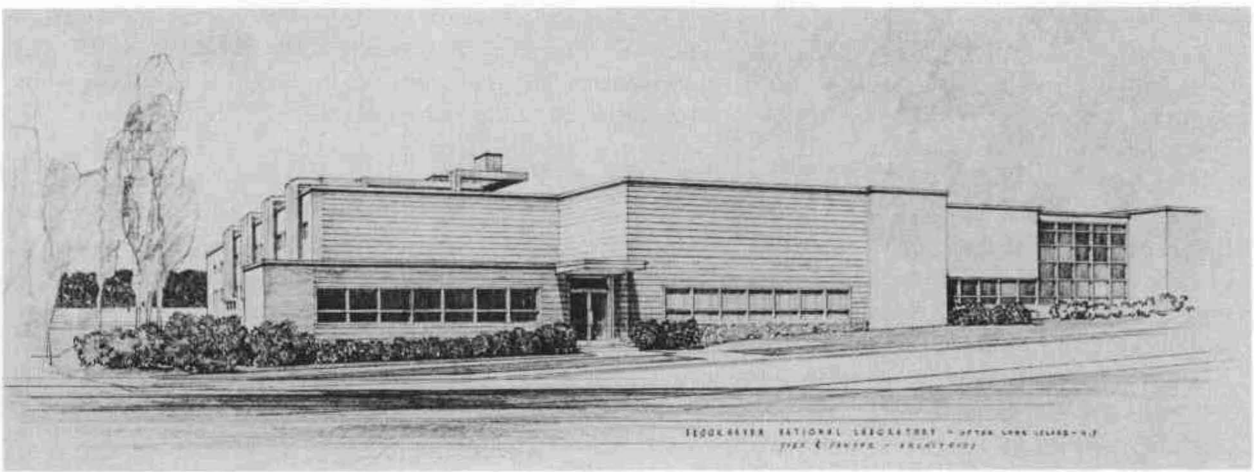


Figure 1. Sketch of the new biology wing now under construction.

During the year the second phase of the Biology building program has been planned and construction will start shortly. This building will be attached to the present biology building (see Figure 1) and the two will comprise a single working unit approximately twice the size of the present structure. The latter was designed primarily for botanical work, with adequate greenhouse facilities; the new wing is designed for animal work, with adequate animal quarters. Facilities common to both will be located between them. When the building is complete the entire Department will be housed under one roof for the first time, and it is anticipated that there will be enough room to adequately accommodate the staff when it reaches its planned size.

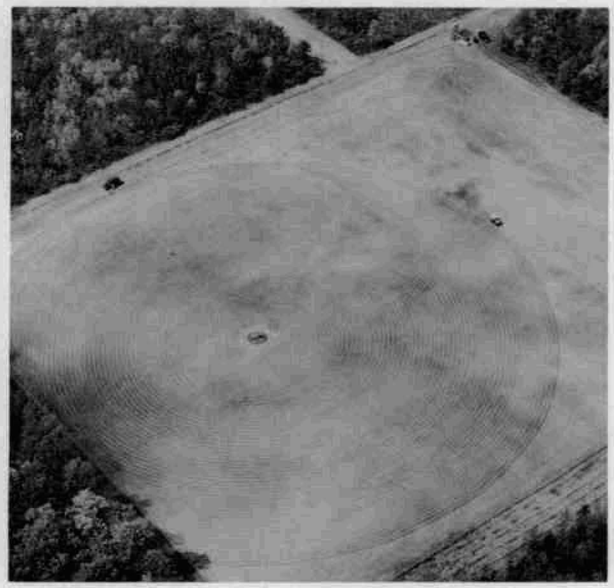


Figure 2. 200-curie cobalt-60 radiation field. The source is located at the center of the circles and the control house can be seen in the upper part of the picture. Close to the source are the pie-shaped sectors that hold potted plants which can be watered from the control house by remote control.

The Biology laboratories in the pile building are now complete and have been put in service. As the Biology program at the reactor expands, it is anticipated that these rooms will be used extensively.

A new "gamma field" comprising a 200-curie cobalt gamma-ray source in the center of a 5-acre field has been put into service during the year. (See Figure 2.) This field is in addition to the 16-curie gamma field which has proved so useful in past years. Control mechanisms and safety precautions had to be considerably improved and present indications are that the new field will be even more useful than the old.

A new 250-k.v.p. X-ray machine has been installed and is used almost constantly as a radiation source. A new greenhouse is now in construction and should be ready for service in a few weeks. It is to be used as a place in which plants can be subjected to gamma radiation over long periods of time and should serve the same function for greenhouse material as the gamma field does for field plants. The hot laboratory of the Biology building has been finished and is now in service.

Research Program

The research centers around special facilities provided by the Laboratory, since the staff is anxious to exploit new techniques in the solution of fundamental biological problems. The problems under investigation are largely determined by the interests and background of the individual scientists who utilize the special facilities.

There are two general techniques which have so far been found most useful. The first is a study of the biological effects of ionizing radiations, and the use of these radiations for the study of biological processes. This is being attacked both by a study of these effects in single cells, and also by studying the effects of these radiations on the entire organism in the higher plants and animals.

The second is the use of radioactive isotopes in a study of biological processes. The value of these isotopes for such studies can hardly be overemphasized, and they are used here in a variety of different problems in both plant and animal work.

These techniques obviously overlap a great deal and are supplemented by many others which are not unique to this Laboratory. The individual problems can best be discussed under six headings.

Mammalian Physiology

The work in this field has been concentrated mainly on the changes that take place in the endocrine glands as a result of X-irradiation. It was observed some time ago that there were two periods of diuresis following irradiation. This gave a strong indication that there was an endocrine unbalance as part of the radiation syndrome, and a good deal of effort during the past year has gone into analyzing this phenomenon. The amount of anti-diuretic substance in the blood was measured and found to be somewhat below normal, indicating that the pituitary gland was not functioning properly. Further, when the pituitary glands were removed from rats and they were allowed to recover, they did not show this period of diuresis, and there was no change in the blood levels of the anti-diuretic hormone. Further, when the pituitary gland alone is subjected to X-irradiation, there is a marked change in the hormone content of the gland, showing that the gland is itself sensitive to the radiation; these effects are probably not indirect effects of the radiation.

At the same time, investigation has continued of the role played by the adrenal gland in the radiation syndrome. If this gland is shielded, the rat can survive a much larger dose of radiation. If, however, the adrenal is removed and the animals carried on a maintenance dose of adrenal cortical extract, they will succumb to much smaller doses of radiation than the normal animals. The dose of extract must be increased 2-1/2 fold for about 3 days after the radiation before the animal responds to radiation as does a normal animal. This gives strong support to the idea that the adrenal gland plays a very significant role in the response of the body to the insult of radiation, as it does to many other stresses. It is a curious fact that even though the rat may not die until 3 weeks after the dose of radiation, it is the increased activity of the adrenal gland within the first 3 days which helps the animal survive.

There is every indication that the response of the adrenal gland following a dose of radiation may be an indirect effect, and caused by the pituitary gland increasing its output of adrenocorticotrophic hormone (ACTH). Apparently this effect may be either a direct action of the radiation on the pituitary gland, or an indirect effect, presumably mediated through the nervous system.

Plant Physiology

The work in plant physiology has involved two general phases of the field. The first is a study of the cytological and morphological changes which take place in cells as a result of radiations and the second, a study of the mechanism by which plants synthesize sugars (photosynthesis).

The first phase involved the elaboration of an instrument capable of measuring the absorption spectrum of small parts of single cells. Next it was necessary to show that the absorption spectrum of certain colorometric reactions would uniquely identify a particular chemical constituent in the cell and permit photometric estimations of its content. By means of this technique a study of the nucleic acids of various cells has been undertaken. In certain plant cells there appears to be no change in the amount of nucleic acid present even after severe doses of X-radiation. Furthermore, there seemed to be no change in the degree of polymerization of the highly polymerized nucleic acid. This is quite contrary to what has been reported for animal tissues, so a series of animal tissues were examined in an effort to determine the discrepancy.

Certain of these tissues showed a change both in total amount and in degree of polymerization of the nucleic acids, but the study only partially confirmed the previous reports. Thus it is not possible to draw any generalizations at the present time from this work, and one can only say that different cells respond differently to radiations, with respect to their chemical constituents. Since many people feel that the nucleoproteins are, or are closely related to, the chromosome structure of the cell, it would seem that this study is of fundamental importance for an understanding of the action of radiation on living matter.

On the cytological side, it has been possible to show that cells receiving a severe dose of radiation show a delayed mitosis, and that this is quantitatively related to the number of chromosome breaks one can observe. One cannot say that these two phenomena are causally related, but it would be rather surprising under the circumstances if such were not the case.

Plants will also show rather gross abnormalities as a result of radiation. Plants exposed to chronic irradiation in the "gamma field" are often severely stunted or killed (see Figure 3). Others show curious floral or foliar abnormalities. One such plant is shown in Figures 4 and 5. This curious growth abnormality seems to be a characteristic response of this plant to radiation injury. It is probably a physiological rather than a genetic change, since the abnormal shoots can be rooted to produce normal-looking plants. Different plant species show markedly different susceptibilities to radiation, and a study of the relation between the degree of susceptibility and the cytological structure of the cell is in progress.

Figure 3. Plants growing in the gamma field close to the source. In the 3M row, corn plants can be seen which sprouted but were killed by the radiation. At 4M, the plants lived but were severely stunted. At 6M, corn plants appear grossly normal. Corn is one of the most radio-resistant plants which have so far been planted in the gamma field.

The problem of photosynthesis is one of the most fundamental in biology, and radioactive tracers, especially C^{14}, have proved extremely useful in an attack on this problem. By placing plants in an atmosphere of $C^{14}O_2$, exposing them to light for definite lengths of time, and analyzing the resultant compounds, it is possible to trace the formation of sugars from the elementary carbon. It is found that light can energize the formation of the three-carbon compound, phosphoglyceric acid. Through a series of intermediate reactions, two molecules of phosphoglyceric acid combine to form a six-carbon sugar. The details of this reaction

Figure 4. Abnormal growth of irradiated Tradescantia plant during recovery period following 114 days of gamma irradiation at 30 r/day. Length of recovery period: 47 days. New growth in this plant is arising entirely from previously formed, but much modified, flower bud clusters.

Figure 5. Unirradiated Tradescantia showing normal flowering and growth of new shoots from underground portions of plant.

are still under intensive study, but the broad concepts seem well established.

Since the synthesis of these sugars is probably closely related to the way in which they are degraded, a study of this mechanism has been in progress for the past year. For sometime it has been assumed that this degradation involved the formation of equimolar parts of lactic acid, ethyl alcohol and carbon dioxide. Tracer techniques have shown that this reaction is correct for fermentation by yeast and certain molds. Further, it has been shown that this is accomplished by first splitting the hexose in half, and then splitting a CO_2 from one of the halves to form alcohol.

However, when some other bacteria ferment sugars it has been found that they do so by an entirely different mechanism, even though the end result is the same. The phosphorylated intermediates are different in the two cases, indicating that different enzyme systems must be operative in the two cases.

General Physiology

The work in this field has centered so far chiefly around the problem of trace element metabolism in plants and insects. Radioactive tracers are ideal for this study, and the radioautographic technique has been developed to give precise localization of the isotope within the organism.

Intestinal absorption in the insect has been studied and it is found that food passes readily through the lumen of the gut within the peritrophic membrane, but may remain relatively long periods of time in the space between the peritrophic membrane and the epithelium. This finding presents a set of wholly new and quite unexpected possibilities, both as to the physiology of absorption from the insect gut and the function of the peritrophic membrane.

A wide variety of sponges has been examined in an attempt to establish a pattern of mineral accumulation. Far from accomplishing this, it was found that each species of sponge exhibits a pattern of accumulation characteristic to that species. Some specimens were found to concentrate nickel by a factor of more than 100,000.

Metabolism

The work in the field of metabolism has fallen into three parts: first, the general problem of iron metabolism; the second, the role of phosphorylation reactions in glucose metabolism; and the third, a study of protein synthesis using labeled amino acids.

The work in iron metabolism concerns itself largely with red blood cell physiology. It has been found that red cells continue to take up iron *in vitro* and to incorporate this iron into the hemin molecule. It seems highly improbable that this could be an exchange reaction, so it must be concluded that the red cell continues to synthesize hemoglobin after it enters the blood stream. It has been found that this effect is more prominent in birds than in mammals.

In a study of whole body X-irradiation on the metabolism of duck erythrocytes, it has been found that blood drawn during the first few days post-irradiation has a decreased oxygen uptake. This suggests the presence of a toxic substance in the blood stream of irradiated animals since blood irradiated in vitro does not exhibit this phenomenon.

Phosphorylation reactions are being studied in an effort to determine the energy-yielding reactions of glycolysis. These reactions are being studied in vivo both in liver and in muscle. Results to date clearly indicate that reactions that occur in the living cell may be of quite a different nature from those indicated by previous studies of isolated enzyme systems.

In the study of protein synthesis, a number of labeled compounds have been fed to mice and the fate of these compounds followed by tracing the radioactivity. In order to carry out this study, it was necessary to develop an extremely sensitive method for the determination of C^{14}, since most compounds that enter into the normal metabolic pattern of the animal are tremendously diluted. With the aid of this counting method, many new types of study are now possible.

One of the first compounds studied was glucose. This compound was fed to mice and the fate of the sugar molecules determined by analyzing the excreta and by sacrificing animals at different times after the administration and analyzing the tissues. A very large fraction was found to be burned to carbon dioxide and excreted through the lungs. However, some of the carbon from the original sugar was found in practically every tissue, including bone and fat. Even in bone the carbon is not fixed but is eliminated at a relatively rapid rate.

Another study has involved the metabolic fate of Periston which is a possible plasma protein substitute. This problem is, of course, of tremendous interest for national defense. It was found that this compound is not metabolized at all, but part of it is excreted rather rapidly by the kidneys and the rest very slowly through the liver. Surprisingly enough, a good deal of it is found stored in the skin. On the basis of this work it can be concluded that this would make rather a poor plasma substitute since it would certainly cause liver damage.

Biophysics

Work in this field has concerned itself almost entirely with a study of the effects of radiation on aqueous solutions. It has been found that when a solution of the protein fibrinogen is irradiated there is a marked increase in its ability to form a clot. This wholly unexpected result has led to a study of the molecular changes taking place in this reaction. It shows that the radiation actually does break up the fibrinogen molecules into smaller fragments, but at the same time causes others of the molecules to coalesce (polymerize) to form larger molecules.

Another phase of this study has concerned itself with a study of agents capable of at least partially protecting the proteins from the radiation. It has been found, in a general way, that the compounds able to afford the greatest protection are those containing sulfur, such as cysteine.

A method of chemical dosimetry is being investigated which promises to be more accurate and more suited to biological problems than current physical methods. The method involves the analysis of the amount of oxidation taking place in a suitable solution, such as the oxidation of ferrous to ferric iron.

Genetics

One of the most important tools in the study of genetics is radiation, and the radiation facilities of the Laboratory have been used extensively for this purpose. The gamma field has proved extremely useful for this, and, in accordance with Laboratory policy, a good many outside investigators have sent seeds to be grown in this field in order to observe the mutations produced in the various plants.

The principal plant genetic work carried out at the Laboratory has been that on corn. This is a very favorable material, since an ear of corn, representing about 500 individual kernels, can be examined almost at a glance for as many as 10 different genetics characteristics. About 300,000 individual kernels have been examined this past year in this way.

Most of the corn examined was from ears grown in non-radiation fields, which had been pollinated from corn grown in the gamma field. In this way it is possible to interpret the results more accurately, since only the paternal germ cells have received radiation.

The most significant result so far from this work is the finding that there is not a linear relationship between the mutations produced and the dosage rate. On theoretical grounds, one might have supposed that there would be such a relationship, and the failure to find it indicates that when plants are grown under continuous radiation different effects are produced from those caused by a single dose of radiation. Another interesting result from these experiments is that the characteristics that show a high spontaneous mutation rate do not necessarily show a high incidence of radiation-produced mutations. This gives a further indication that continuous radiation may yield genetic effects by a somewhat different mechanism from those produced by other agents.

A study of the genetic factors involved in sucrose storage in corn plants is well started. The way in which the sucrose concentration of the plant varies throughout the growing season has been studied, as well as the relative concentration in different inbred strains of corn.

In the field of bacterial genetics, a study has been undertaken to determine the effect of cell division on the susceptibility of the cell to radiation. By adjusting the amount of food available to a bacterial culture, it is possible to regulate growth. Bacterial suspensions growing at different rates were subjected to continuous radiation and the number of mutants produced in each was noted. There was no difference in the number of mutations found in any of the cultures. The conclusion which seems warranted from this work is that bacterial cells differ from those of higher organisms in that the number of mutations produced seems to be independent of cell division.

During the second year of its organized existence, the Department has continued to grow steadily. As of June 30, 1951, the scientific staff totaled 21 members, including one Rockefeller fellow and one AEC fellow. Eighteen are full-time and 3 are part-time; all of the latter are in the Industrial Medicine Division. Total personnel in the Department as of this date was 101. One year ago the scientific staff numbered 14, three of whom were part-time, while total personnel numbered 73. Further expansion is anticipated during the coming year in accordance with plans adopted for orderly growth to final authorized numbers.

During this year there has been a great increase in the work done on problems involving the use of radioactive isotopes and the use of the nuclear reactor. The experience gained is proving to be a valuable foundation for further considerable increase in this type of work now in progress and planning. The operation of the nuclear reactor has been a very real stimulus to interest in this field, as will become apparent in certain details reported below.

The program for remodeling temporary buildings for present use has continued during the year. Two buildings remain to be remodeled to provide suitable laboratory space and it is hoped this may be accomplished during the first half of the present fiscal year. The experience being gained at present is enabling the Department slowly to crystallize the formulation of its operational needs to be met at a future date by new buildings.

At the close of the fiscal year Dr. S.C. Madden's resignation became effective. Dr. Madden left to take the chair of pathology at the University of California, Los Angeles. Dr. John T. Godwin of the Ochsner Clinic, New Orleans, Louisiana, has been appointed to succeed Dr. Madden as head of the Division of Pathology. The emphasis of the work done in the Division of Pathology will change during the coming year reflecting in part the different interests and approach to problems of the new Division head. On June 30, 1951, Dr. D.D. Van Slyke took up his duties with the Lilly Research Grants. Although Dr. Van Slyke requested to be relieved of all administrative duties in the Laboratory, he has consented to continue to direct scientific work in the Division of Biochemistry and to continue work in the laboratories of the Division as a guest scientist. It is particularly felicitous that Dr. Van Slyke's new duties permit him to retain his office and further to develop his scientific interests at Brookhaven.

In September 1950, at the request of the New York State Department of Health, the Medical Department acted as host for a conference for training instructors in civilian defense. The conference lasted four days during which the speakers and participants explored the medical aspects of civilian defense today. Several outside speakers together with members of the Medical Department and the Health Physics Division provided the instruction for some 50 physicians at this meeting.

On October 20, 1950, a meeting was held at Brookhaven of the Committee on the Use of Radioactive Isotopes in Children of the American Society for Pediatric Research. Participation in the work of such groups by the Department is of great value in furthering the general program of university and institutional collaboration. An extension of this program for collaboration occurred in January when, at the request of the National

Research Council, work was begun in the Department on certain aspects of problems concerning the selection of blood substitutes. This is discussed further in the report of the Division of Biochemistry.

Two other of the more notable dates during the past year are December 4, 1950, when the Department received a radioactive isotope prepared for the first time in Brookhaven's own nuclear reactor, and February 15, 1951, when for the first time anywhere a nuclear reactor was used directly as a radiation source for treatment of patients. The visit on May 23, 1951, of 55 members and guests of the Brooklyn Academy of Pediatrics for their annual outing program is testimony of the interest of nearby physicians in the Brookhaven program for medicine.

During the year the Department has continued its desirable and stimulating association with the Memorial Center for Cancer and Allied Diseases. Weekly visits to Brookhaven National Laboratory Hospital by Drs. R.W. Rawson and J.E. Rall have made it possible for our group and those on the research staff at Memorial Hospital to follow patients satisfactorily during periods of specific study of particular interest to each institution, and expeditiously to return patients to the Memorial Hospital when the vicissitudes of their disease required the facilities of that hospital.

In December 1950, a collaborative research project was set up between certain members of the Department and members of the Department of Biochemistry of Johns Hopkins University School of Hygiene and Public Health. The project is designed to carry forward studies on the effects of certain accessory food substances and resistance or susceptibility to radiation. The work in radiation is done at Brookhaven and the chemical and nutritional studies at Baltimore. It is hoped this project will be the forerunner of similar projects with other universities in the area.

Division of the Hospital

The Division of the Hospital has grown and matured during the past year. On January 8, 1951, a third ward was opened for patients. This brought into activity the entire physical plant although thus far the staff has not been augmented enough to permit all possible beds to be filled. As of June 30, 1951, the patient capacity was rated at 25 beds. At full complement this will rise to 36 beds. During the past 12 months there were 112 admissions and 114 discharges as compared to 84 admissions and 74 discharges for fiscal 1950.

Use of beds available through the year has been at a satisfactory level but it is hoped that experience in further operation will permit a tighter schedule to be followed for patient admission and discharge. It is our policy to avoid a waiting list in so far as possible.

At the present time the nursing staff of the hospital totals 27 as against 16 one year ago. The increase has more significance than the mere increase in numbers since at this time practically every nurse on the staff has been trained and indoctrinated in the use of radioactive isotopes so that it is possible to carry on a much more active program than could be done 12 months ago. The extraordinary devotion of the nurses to their professional duties has brought the level of patient care in Brookhaven National Laboratory Hospital to a very enviable position. This has been made possible by a

Figure 1. A patient just admitted to the hospital enters one of the wards.

careful initial selection by the Superintendent, together with a full recognition by all members of the Department of the significant role played by the nurses in the over-all development of the medical program. The dietetics group has provided each patient with tasty and nutritious meals to his liking which has played no small role in maintaining the patient's morale during the hospitalization period.

As was noted in the last annual report, all activities relating to the patient's social welfare, recreation and education were centered in occupational therapy. A full and productive program has been developed in this area making available to school age and adult patients the following activities: leather work, wood work, weaving, lucite plastic work, copper tooling, typing, rug hooking, aluminum etching, gardening and dressmaking. In addition, movies have been shown bimonthly on the hospital premises.

The Red Cross Grey Ladies volunteers have developed their contribution as a part of this program and have provided finger painting, bingo games and other recreational activities as well as assisting in the celebration of patients' birthdays and making provision for suitable recognition of other general holidays, especially Christmas. The Grey Ladies' help in ameliorating life in the hospital is sincerely appreciated by both patients and staff. Our thanks are due also to the Young Peoples Fellowship of Christ Church Episcopal in Bellport, the Brightwaters Girl Scouts and various other groups and individuals who have assisted in the patients' welfare and recreational program. The Kiwanis Club of Milford, Connecticut, generously donated a television set for one of the adult wards. With the addition of this set, there now is available a set in each ward.

Participation of the patients in various activities of occupational therapy totaled 2,259 units compared with 1,155 units for the preceding 11 months. Because of the increased demands on this group and the desirability of having school teaching available for 12 months of the year, it is planned to add another occupational therapist with teaching experience to the staff. She will replace the present school teacher, available only during the school year and only for half-time, and will also assume responsibilities for the general program. The flexibility which will be gained by such an arrangement will be particularly helpful in meeting the changing requirements occasioned by changes in the hospital's population. On April 24, 1951, the occupational therapy unit was moved from building T-301 to T-358 which provided more suitable space in a

Figure 2. Some of the varied activities of the occupational therapist and the patients.

location adjacent to the hospital wards and much more readily accessible by the patients. This has been reflected in an increased use of the facilities by the patients, particularly those with more marked physical disability. As has been noted before in the annual report, the program for the patients' recreation, social welfare and education assumes greater than usual importance at Brookhaven where patients are isolated to a degree from their families and their normal social and entertainment contacts. A well-rounded program such as is under way in the hospital reduces to a minimum mental discontent and enables a much better psychological attitude to be maintained by the patient towards his disease and the measures being taken to combat it.

Statistics for the patients in the hospital are shown in Table 1. It will be noted that the number of research patient days has increased over the preceding year by 2,796 patient days, or 74% , and by 15 times over the patient days for fiscal 1949. Employee and dependent patient days decreased to 232 in fiscal 1951 from 344 in fiscal 1950.

Research patients during the year were admitted with diagnoses of:

- Cancer of thyroid
- Nephrosis
- Multiple myeloma
- Thyrotoxicosis
- Polycythemia vera
- Uranium poisoning
- Uterine cancer
- Glioblastoma multiforme
- Chondrosarcoma
- Leukemia
- Nodular thyroid gland (type undetermined)
- Cancer of ovaries
- Pharyngeal epithelioma
- Bronchogenic cancer
- Cancer of breast
- Reticulum cell sarcoma (of pleura and peritoneum)
- Lingual thyroid

Table 1

Hospital Statistics

Item	July 1- Dec. 31 1949	Jan. 1- June 30 1950	Fiscal 1950	July 1- Dec. 31 1950	Jan. 1- June 30 1951	Fiscal 1951
Total patient days	1414	2689	4103	3156	3631	6787
Research patient days	1208	2551	3759	3022	3533*	6555
Employee, compensable, pt. days	0	0	0	28	0	28
Employee, non-occupational, pt. days	180	77	257	20	41	61
Employee dependents, pt. days	26	61	87	86	57	143
Total admissions	31	53	83	51	61	112
Total discharges	29	45	74	56	58	114

*Ward 304 opened 1/8/51

The counting room of the hospital has developed into a suite of two identical operating rooms wherein patients can be given large or small doses of isotopes as necessary. Multiple scalers with appropriate counting devices permit simultaneous scanning of different portions of the body while physiological and biochemical observations are being made. The organization of the counting room has worked out very well as a separate nursing unit. A single nurse is charged with responsibility not only for materials and supplies but also for training new nurses in rotation in the duties and responsibilities there expected of them. One or more of the rooms is used daily and additional equipment is planned for the future.

Patients with thyroid carcinoma have received more intensive therapy than at any time previously. Thus far no significant adverse effects of radiation have been noted in any individual. The problem of rapidly repeated adequate doses of the isotope has not yet been solved. It would appear considerable work must yet be done to obtain maximum effects of iodine radiation even in the most favorable cases. Effects on the blood are studied not only in the patients with carcinoma but also in the patients with hyperthyroidism in an endeavor to develop suitable screening techniques.

The past year has seen patients with a variety of other malignancies admitted. In each instance, after an application has been received, the patients's history and findings are carefully studied to determine if any possible benefit to him is likely through isotope administration and what new information or valuable scientific data may be so obtained. When the answers to both questions are favorable and the isotope falls within the group used by Brookhaven, the patient is admitted.

On the basis of experience gained over the past two years, a definite program is developing to exploit the uses of short-lived isotopes. For this purpose the plant and facilities of Brookhaven are admirably suited. It is expected that this program will begin in July 1951, and develop thereafter as rapidly as possible.

Five patients with glioblastoma multiforme were admitted during the year. To further this program and provide even better care, it is planned to have one of the neurosurgical residents of the Massachusetts General Hospital on leave for the first quarter of fiscal 1952. If this arrangement seems mutually satisfactory it is hoped it will be possible to continue it on a rotation basis. The unauthorized publicity which this project received has occasioned many letters, phone calls and personal inquiries by physicians, friends and relatives of patients. The medical profession at large understands the situation and that considerable more time must elapse with improvement of procedures before it will be possible to render a significant report.

Division of Industrial Medicine

As of June 30, 1951, personnel of the Division comprised a total of 16 as compared with 20 one year ago. The reduction reflects a transfer of some personnel from this Division to the hospital to which they are more properly attached. The professional staff remained as of last year at 2 full-time and 3 part-time physicians, one of whom is a roentgenologist. Efforts are being increased to recruit the full-time staff of physicians to four but the standards required are high and as yet none of the applicants has qualified. It is hoped that the AEC fellowship program in industrial medicine may in time supply one individual to the staff on a rotating basis. This will be dependent on the general training program followed by these men after their specified first year of training.

The statistics of the clinic are shown in Table 2. In this table it will be noted that there was a decrease in the total number of clinic visits. This is largely accounted for by a decrease in visits for loss-of-time prevention measures: e.g., of the total reduction of 1,664 visits, 1,285 are in this category. With only a relatively slight change in total personnel employed by the Laboratory and its subcontractors, this decrease was unexpected and the reason is not yet clear. With the Division at only half-strength professionally, this decrease was most fortuitous. However, this very favorable situation cannot be expected to continue indefinitely. The beginning of termination examinations for all employees on February 1, 1951, has materially increased the responsibilities of the Division for service.

In Table 3 are shown the statistics for X-ray services during the past year. The total number of films taken is approximately the same as for the preceding year with most of the reduction appearing in those charged to annual and pre-employment physical examinations. This would appear to suggest a desirable stability in the employee population. As a result of employee examinations and routine chest films, seven patients with pulmonary tuberculosis were discovered, of whom two were found at the time of their pre-employment examination.

Eighteen contamination accidents required medical services, but in no instance was there evidence of a serious health hazard after decontamination procedures were effected. The revision of facilities to provide emergency decontamination quarters received a test shortly after its installation and all personnel concerned were pleased with the effectiveness and rapidity with which necessary measures could be instituted without hazard to vital Medical Department areas.

During the year lens examinations with a slit lamp were instituted for all employees whose work was of a nature in which radiation cataracts might occur.

Table 2

Statistics on Clinic Visits

Visits	July 1- Dec. 31 1949	Jan. 1- June 30 1950	Fiscal 1950	July 1- Dec. 31 1950	Jan. 1- June 30 1951	Fiscal 1951
Occupational Causes:						
Compensable illness, accident, etc.	538	696	1234	561	546	1107
Loss-of-time prevention	2723	2037	4760	1649	1870	3519
Pre-employment examinations	194	97	291	156	278	434
Annual examinations	491	804	1295	469	581	1050
Termination examinations	--	--	--	--	113*	113*
Sub-contractors	151	230	381	160	53	213
Total Occupational Visits	4097	3864	7961	2995	3441	6436
Dependents	442	407	849	339	366	705
Total Clinic Visits	4539	4271	8810	3334	3807	7141

*Started February 1951

Table 3

X-ray Examinations

Subject	July 1- Dec. 31 1949	Jan. 1- June 30 1950	Fiscal 1950	July 1- Dec. 31 1950	Jan. 1- June 30 1951	Fiscal 1951
Employees, occupational:						
Compensable illness, accidents, etc.	52	83	135	61	52	113
Annual and pre-employment exam.	638	917	1555	593	840	1433
Total films for occupational causes	690	1000	1690	654	892	1546
Employees, non-occupational:						
Employees	93	100	193	100	89	189
Dependents	43	36	79	49	31	80
Total films, non-occupational	136	136	272	149	120	269
Hospital, Research	78	125	203	64	84	148
Hospital, Personnel Medical Care	9	14	23	12	14	26
Total Hospital	87	139	226	76	98	174
Total X-ray Examinations	893	1275	2168	879	1110	1989

Throughout the year the physicians in this Division have frequently consulted with and been assisted by other members of the Medical Department whenever their services were needed. With a marked strengthening of the hematological services during the past year it is believed that now the Division can meet in a highly satisfactory manner all the demands for various medical services which it may be expected to develop.

Division of Pathology

During the past year the Division under Dr. S.C. Madden has continued work on the influence of body injury upon the production of body proteins. This project required the full-time efforts of three scientists, six persons on the technical staff, and a secretary. Previously, injury in dogs had been produced by subcutaneous injections of turpentine, but throughout the past year, the influence of fractures has been studied. This problem is being brought to a conclusion since Dr. Madden's departure, and until all the experiments have been completed, the data cannot be analyzed. In developing suitable procedures, further studies were done on the pathways of protein synthesis in standardized dogs fed test doses of labelled glycine under conditions of protein feeding and protein fasting. The incorporation of N^{15} in the plasma and red blood cells and the excretion of N^{15} in the urine was observed. Preliminary analysis of the data is now going on and at this time it appears that the protein-fasted animals incorporated slightly more labelled glycine into the blood proteins and excreted slightly less than the comparable protein-fed dogs. During the spring months Dr. Madden was away from the Laboratory to participate in the Eniwetok tests.

The future program for the Division under Dr. Godwin's direction has not yet been definitely established.

Division of Bacteriology and Virology

The staff of this Division comprises three scientists with Dr. W.M. Hale as the head, six on the technical staff and one secretary.

The work of the Division has been concerned with the effects of gamma radiation on certain bacterial enzyme systems and upon the immune mechanisms as exhibited to bacterial, viral and parasitic challenges. The enzyme system studied was the transforming substance of pneumococcus type III. It has been found that exposure to 100,000 r, with cobalt-60 as the source, causes a marked loss of biological activity, while 10,000 r does not affect the original activity of the material. The transforming substance in this instance is desoxyribosenucleic acid and it has been found that 25,000 r given to 1 mg in 1 ml caused inactivation. When the concentration was increased to 5 mg per ml, 100,000 r was required to cause an equivalent loss of activity. Other concentrations were similarly treated and the preliminary data suggest the relationship is direct.

In the studies on the effect of gamma radiation from cobalt-60 on the immune mechanisms of the Swiss mouse, over 600 mice were used during the past year. The experiment was so designed that it tested the ability of the previously immunized animal to restore his immunity as evidenced by antibody production following a pick-up stimulating injection of the proper antigen. This procedure is much more sensitive and can be measured more accurately than can the primary production of antibodies. The experimental results, although obtained as a part of a study for fundamental knowledge, also have a practical importance in that they shed light on the capacity of animals to respond to booster immunizing doses of tetanus, influenza and typhoid after varying amounts of radiation. The data show clearly that radiation does not alter nor affect antibodies formed prior to radiation. Radiation given at the proper time before and after injection of the antigenic substance, in this instance influenza vaccine, can almost completely inhibit antibody formation. Thus an LD-50 of radiation given 2 hr, 1 day, 2 days or 3 days after the antigen injection, inhibited antibody formation to a significant degree. When a similar irradiation was given to groups of mice 6 days, 4 days or 2 days before the administration of the antigen, there was a reduction in antibody production noted in those groups radiated 2 and 4 days before immunization but not in those animals irradiated 6 days before the treatment. When mice were irradiated 2 to 24 hr before antigen was injected or from 2 to 8 hr after injection, antibody formation was almost completely inhibited. When, however, the radiation was delayed to 16 and 24 hr after injection, some antibody was produced but not in significant amounts.

Further studies on immunity to pneumococcus type III in which the irradiated mice had received two to six times the protective dose of serum showed that those receiving only an 84% of an LD-50 dose of radiation succumbed, while the non-irradiated mice receiving the same challenging infective dose all survived. Conversely it was shown that mixtures of pneumococci and other specific antibodies which are harmless to non-irradiated mice are lethal when given to mice receiving 84% of an LD-50 dose of radiation. Although evidence as given shows that bacterial immunity may be profoundly affected, preliminary experiments on radiation effects in immunity to influenza as a typical virus suggest that this immunity is uninfluenced. Further testing is necessary to validate this result.

It is believed that in some instances, at least, the failure of transplants of tissue from one animal to grow in another may be due in part to stimulation of immune mechanisms. In a study on the effect of spleen and lymph node transplant viability in irradiated and non-irradiated animals, these tissues were transplanted into the anterior chamber of the eyes. It was found that a sublethal exposure to gamma radiation of the animal receiving the transplant increased the viability of the transplant from 17.5% to 32.9% for lymph nodes and from 16.3 to 44.5% for spleen.

As a corollary of this experiment, a study was done to determine the effect of these spleen and lymph node fragment transplants in the anterior chamber of the eye on the survival time of mice given a large exposure to cobalt-60 radiation. The donor tissue and the receptor mice were each 4 weeks of age at the time of radiation. The transplantation was done within 3 hr of completion of radiation. The exposure in this instance was LD-60. With 65 mice in each group it was noted that 41.5% of the non-treated mice survived, and 46.8% of those receiving the lymph node transplants and 69.3% of those receiving spleen transplants survived. This work is progressing to determine what specific effects may be noted on the maintenance or lack of it of the various blood cells.

When immunity to parasites was tested in a somewhat similar manner it was found that immunity to trichinosis was markedly broken by an LD-25 dose of gamma radiation. One hundred percent of the radiated animals died while only 20% of the control group died. Work is progressing on the immune mechanism affected in this instance by gamma radiation to determine if it may be identical with that concerned with bacterial immunity or not.

In the study of tumor and tissue transplants it is important to be able to be certain that the primary characteristics of the transplant are maintained in the viable descendant. It has been generally accepted that the stroma or general supporting tissue of tumors that are transplanted on a foreign species are derived from the host. The transplanted cells on the other hand were believed to maintain the characteristics of their origin. The transplanted cells retain most of their microscopic characteristics and can readily and easily be transplanted back to the species of origin even though an increase in their numbers occurs. For the evaluation of tumor immunity and effects of such procedures as radiation on viability of transplants and grafts, a series of studies was begun on the characteristics of these cells which could be described immunologically rather than by the more usual staining and histological procedures.

Immunological procedures provide a mechanism whereby proteins can be characterized in terms of their species origin as rabbit protein, chicken protein or mouse protein. These procedures are of such a sensitivity that they will permit detection of very small quantities of protein and permit an investigation to circumvent the difficulties presented by the stroma as noted above when the transplanted tumor is used to provoke a serological response under the proper conditions. The experiment under discussion utilized a mouse mammary adenocarcinoma which had spontaneously arisen in a female Swiss mouse and which had been transplanted for several generations. This tumor could be grown on the chorioallantoic membrane of the chicken embryo but successive generations grown on this medium showed no marked adaptive response to the host change. The tumor readily "takes" when transplanted back to mice after eight passages in the chicken embryo. This is, in a measure, presumptive evidence of its mouse origin and character. After such a series of passages it appeared to be identical with the tumor remaining in mice. In this experiment advantage was taken of the fact that the originating species, i.e., mouse, will not produce antibodies to this tumor tissue whereas another species such as chicken or rabbit will. Thus it is possible to set up a test system using rabbits to test separately against both mouse and chicken tissue and chickens to test against mouse tissue.

If a tumor from a mouse growing in a chick embryo retains all the immunological characteristics of mouse it will react with rabbit anti-mouse sera but not with rabbit anti-chicken sera. Likewise, the chicken will produce an anti-mouse antibody which will react against mouse protein but not chicken protein. The animals in each instance were immunized, in one instance with chick-embryo-propagated mouse carcinoma and in the other with mouse-propagated mouse carcinoma. When the tumor transplant was tested with the sera of properly immunized animals, it was found that in each instance it gave the reaction of the host in which it was currently growing and not the reaction of the species in which it had originated. These results would indicate that there is little if any mouse specific or neoplastic specific antigen in the mouse carcinoma that has been propagated two or more generations on the chick embryo. This conclusion was tested immunologically by utilizing guinea pigs sensitized to the respectively grown tumors and then reinjected to produce anaphylactic shock. This is an exceedingly delicate test for the sensitizing material. The results indicate again that the tumor constituents immunologically were similar to the host in which the tumor was currently growing and not its species origin. Preliminary experiments with normal tissue transplants similarly handled have yielded results identical with those obtained using the tumor.

These rather startling results suggest that it is extremely unlikely that a specific anti-tumor antibody can be developed and suggest that tumor in normal tissue transplanted to a foreign species becomes identified with that species in that it uses the host's substances for construction of a cell but retains potentially all the characteristics of the originating species. Further experiments to reveal additional facts regarding the components of such tissue transplants are under way.

These results suggest some speculative comment. Although no evidence is at hand and no experiments at this time are actually under way, we cannot help suggesting an analogy between this behavior and the ability of tumor cells to propagate themselves as metastases in areas of the body where the originating tissues are not normally found and to develop histologically in a similar fashion to the originating tissue but only occasionally to retain a small fraction of the function of the originating tissue. The importance of the facts uncovered in this study and their significance cannot fail to stimulate a host of productive studies along channels that have seldom if ever previously been pursued. The relationship between radiation effects and the ability of transplants to maintain themselves in strange or completely foreign environments must be thoroughly investigated. Experiments along these lines with therapeutic implications are still too preliminary to be discussed but they suggest the possibility of perhaps further elucidating some of the mechanisms whereby invasions may maintain themselves or be eliminated by processes not yet even described.

The nutritional implications of these observations have been pointed out and in themselves are of great interest. The data strongly suggest that synthetic mechanisms may operate in two fashions: in one, primary substances of proteins, namely the amino acids, are combined by cell enzymes into the characteristic cell proteins which then are formed into functional unity of the cell. In another, the same or other enzyme systems may use preformed intact proteins to manufacture the necessary functional units of the cell and the latter utilization may be dependent upon the functional characters of the protein presented and not its fundamental species structure. To those readers who are interested in the more technical description of this study, the details can be found in the quarterly scientific report of the Laboratory for June 30, 1951 (BNL 117 (S-10)).

The great usefulness of the 72-curie cobalt source which was installed early in the year, and which after some use was modified to eliminate technical breakdowns, has become apparent in the large number of significant radiation experiments that were done after the source was calibrated biologically. In future plans it is desirable that this or a similar source be available within the facility for the Division to eliminate the difficulties and delays inherent in having the source some two miles from the main Division laboratory.

Division of Biochemistry

As of June 30, 1951, the Division of Biochemistry had five scientists working in its laboratories. A technical staff of six persons filled out the personnel; a secretary was engaged but was awaiting clearance before reporting for duty.

On February 14, 1951, the remodeled building serving as the laboratory for the Division was first occupied; six month's use of these quarters has proved their utility. Work is now proceeding at a satisfactory rate and many problems are being developed.

The work of the Division may be grouped under a few headings: (1) amino acid and protein metabolism; (2) hormonal influence on protein metabolism; (3) miscellaneous projects and (4) defense projects.

In the study of amino acid and protein metabolism knowledge is being sought of the role various amino acids may play in the nitrogen economy of the organism. The uptake of free amino acids by the intact animal and subsequent incorporation into tissue proteins is being studied using C^{14}-labeled alanine. In this series of experiments the labeled compound was injected into rats which were then sacrificed at convenient intervals. The amount of material metabolized in the interim was approximated by collecting expired air and determining $C^{14}O_2$ therein. After sacrifice samples of liver, muscle and plasma were taken for analysis. The results thus far obtained are consistent with the concept of alanine as a typical "non-essential" amino acid occupying a key position in intermediary metabolism where it is continually being utilized and regenerated. Similar studies are planned for other amino acids at the proper time. The specific processes whereby free amino acids are taken up by tissues is under study in another project. When amino acids are infused into the circulation of an animal, they are taken up, without apparent chemical change or combination, by the tissues where they may reach concentrations several times greater than that in the circulating blood plasma. The attainment of such tissue concentrations is not explainable by physical diffusion, but appears to be a process involving energy output by the cells. The study of this process is being undertaken using C^{14}-labeled amino acids with the nucleated red blood cells of a fowl as a form of metabolizing tissue that can be studied by serial analyses and change of medium.

In children with the type of kidney disease frequently called "nephrosis" or the nephrotic syndrome, one of the features is protein malnutrition. Previously it has been noted that these patients frequently exhibit lower than usual concentrations of free amino acids in the blood plasma and on occasion, in periods of acute crisis, show sudden decreases in their concentration to values even below one-fourth of normal. Studies are under way using two-dimensional paper chromatography supplemented by other chemical methods to determine whether the deficit involves to especial extent any individual amino acid or group of amino acids. The results thus far accumulated are not sufficient to yield definite conclusions.

In a study of one hormonal factor affecting the incorporation of amino acids into tissue proteins, the effect of insulin has been observed on the metabolism of C^{14}-labeled alanine by isolated rat diaphragm. It has been observed that, besides its well-known effect in increasing the utilization of glucose, insulin also has a direct effect on the metabolism of amino acids and proteins and that these two effects can influence each other.

The various miscellaneous projects have a bearing on work done in the Division and the Department but are of such a nature that specific studies can be completed within a short period of time and are not planned to continue unless the results unexpectedly warrant a more extensive investigation.

Figure 3. One of the nephrotic children, a probationary recovery, ready to go home.

In the literature, experiments with brain tissue have indicated that the brain may be able to derive its energy from combustion of either glucose or lactate. Yet while insulin shock, caused by lack of glucose for the brain to oxidize, can be cured by glucose administration, lactate administration does not appear to have the same curative effect. A present study is planned first to develop methods and then to ascertain by *in vivo* animal experiments to what extent the brain can supply its energy from oxidation of lactate. Lactate labeled with C^{14} provides a suitable tracer material for this study. Results to date have shown some unexpected technical difficulties which it is hoped may be overcome by further work.

In conjunction with the Biology Department a study is being made of the phosphate metabolism of intact muscle tissue in the form of isolated rat diaphragm. Radioactive phosphorus is used as a tracer and the utilization of this compound under varying conditions has been studied. In this project, methods were developed for determining the effect of 2-4-dinitrophenol on phosphate metabolism and these are now applicable for study of the effects of insulin on this system.

Tracer quantities of phosphorus have been used to test and develop methods needed for the determination of phospholipids in the serum. It was found, surprisingly, that a relatively simple method now available was more accurate than a more elaborate method which was specially devised to assure a lipid solution free of inorganic phosphate. Some alternative procedures are also being tested to determine their usefulness.

In the study done during the past year on thyroid function in nephrotic children, it was found that the thyroid glands of these children have a considerable ability to take up radioiodine. To determine whether or not iodine collected by the gland is actually synthesized into hormonal products requires a method for determining protein-bound iodine in serum or plasma. The blood of patients with the nephrotic syndrome is notorious for causing difficulties in the application of many analytical methods and that for protein-bound iodine is no exception. Considerable work has been done and is being continued to develop in available methods the requisite accuracy for this study.

The defense projects which have been under way have been concerned with the study of additional blood substitutes. Two compounds have been investigated to varying extents. One of these, polyvinyl pyrrolidone or Periston, which was used in

Germany during World War II, has been studied with C^{14}-labeled material for undesirable prolonged body retention. The work was carried out in conjunction with the Biology Department and indicates that in animals about one-third to one-fourth of the injected material may remain in the body for rather long periods of time.

The other compound is a polymerized glucose not previously available which is under development by the duPont Co. From theoretical considerations it would appear this compound might have characteristics that would make it desirable as a blood substitute. Methods have been developed for analyzing it in mixtures of biological fluids and in tissues. The material has been studied as to its susceptibility to breakdown by body enzymes, and experiments have been carried out to determine its rate of loss from the vascular system and from the body. The results obtained suggest that it may be suitable for the purpose contemplated if a larger and uniform-size product can be manufactured. Further tests with this compound will be made as the product reaches the desired specifications. If preliminary tests are satisfactory, it is planned to make a C^{14}-labeled product which then can be readily studied for distribution and retention in the same manner as was done with Periston.

Division of Physiology

The Division of Physiology was formally activated on October 1, 1950. The strength of the Division June 30, 1951, totaled 10, of whom six were scientists and four were technical staff. Beginning the first of July, plans were completed to augment the staff in both categories and to employ a secretary for the Division. Originally this Division and the Division of Biochemistry shared space in Building T-333 but with the opening of the Biochemistry laboratories the space was left entirely for Physiology. On July 1, 1951, the division planned to move to Building T-354 which with relatively minor changes will provide suitable laboratory space for much of its activities. At the present time the Division consists of essentially three sections, the Section on Biophysics under Dr. J.S. Robertson which has responsibilities to the Department as a whole as well as the Division, the Section on Animal Physiology, and the Section in Clinical Physiology. On June 1, 1951, Dr. R.N. Watman joined the staff and assumed his duties as head of the Section on Animal Physiology. The Section on Clinical Physiology is concerned primarily with studies on patients.

The past year has seen the organization of the Section on Biophysics in the Division of Physiology. This Section provides consultation on biophysics problems to all Divisions of the Department, provides counting facilities for all work in the Department and has cognizance of all biophysical equipment in the Department. During the coming year the counting laboratory service for all Divisions will come into operation, which will give better and more accurate counting service than has always heretofore been available. In addition it is planned to organize a training laboratory for indoctrination of new scientific staff and technical staff members in counting procedures and their limitations.

During the year the number of radioactive isotopes in use by the Department has increased from three to eight. The counting facilities have been increased to meet the demands for greater variety and volume of counting. As previously mentioned in the discussion of the hospital, on July 3, 1950, the hospital patient counting room was opened. All equipment in this room and its technical operation is under the Section on

Biophysics. Experience during the year has shown the usefulness of this organization procedure.

Biophysics dequipment has been added to each unit as found necessary. The Electronics Division designed and built two scintillation counters, one for in vivo counting and the other for counting radioactive iodine in small blood samples. A very sensitive G-M tube for low-level iodine counting was donated by the Texas Co., and has been in use for 6 months. In the laboratory of the Division another shelf counter and a floor counter have been added.

Equipment for electro-deposition of iron has been designed and is being built by the Electronics Division. It is planned this summer to develop a tritium counting method suitable for proposed clinical studies. The Biophysics Section works very closely with Electronics in the instrumentation problems developing out of the brain tumor study and it is hoped that suitable instruments will be available shortly.

Work is already under way by the Animal Physiology Section in which studies are being started on an experimental splenic anemia. Animal preparations are being made and base line hematological studies on the experimental animals are being carried on.

During the year under review, most of the work of the Division has centered on clinical physiology. There has long been a question as to whether or not thyroid function is normal in children with the nephrotic syndrome. In a study carried out on eight such patients, data were obtained which indicate clearly that in these patients there is no failure of the thyroid gland to take up iodine from the blood. An unexpected uniformity of results was obtained in this instance. To establish definitely the normality of thyroid function, it is necessary to follow the fate of such thyroid iodine and to be certain it is incorporated in the thyroid hormone. Because of lack of suitable chemical methods which are now under development in the Division of Biochemistry this study has not yet been completed.

In an endeavor to obtain better information regarding the capacity of the kidney to perform specific tasks in these patients and further to clarify the nature of the disorder, studies have been begun on the relation between urea, inulin, para-aminohippurate clearances and the para-aminohippurate maximum tubular excretory capacity in these children. These studies are not completed sufficiently to warrant any discussion other than to state the results to date are of considerable interest.

Rather extensive studies on the extent of extracellular fluid accumulations in these children have been carried out using the dilution of infused sucrose as a measure of extracellular fluid and of infused antiphyrine as a measure of total body water. The purpose of this investigation is to clarify the changes in intracellular sodium concentration which appear to occur under certain conditions and which at this time seem to be of real clinical significance. Sodium-24 is used to estimate the quantity of total body sodium. As a consequence of this investigation, it is believed that already a more effective control has been achieved of some episodes of severe acidosis accompanied with profound and extremely serious depressions in kidney function. In studies now under way it is hoped that it will be possible to establish the role of sodium in this syndrome and more clearly to define the critical concentrations of this element within the cells which will prevent the complication of low sodium diets. Part of this study during the past year has been concerned with the equilibrium rates of sodium-24 in body fluids and the measurement of total red cell mass with phosphorus-32 to determine whether changes in blood volume are concomitant with occasionally observed rapid changes in hemoglobin concentration.

In patients with thyroid carcinoma receiving doses of I-131 which are large and repeated as often as possible, studies have been under way to determine whether any renal damage may be expected as a cumulative effect of the therapy. To date there fortunately have been no indications of any such danger but the study is being carried on together with careful observations on the effects of such repeated administration of radioactive isotopes on the production of blood cells. Doses of iodine-131 are now calculated on the basis of desirable dose modified by calculation of expected total blood radiation predicted by tracer doses. A wide variability exists among individuals in the rapidity with which the blood is cleared of radioactive iodine by renal mechanisms and tumor uptake. The distribution can be observed following administration of tracer doses and the results applied to circumstances obtaining when large therapeutic doses are given.

Studies have also been carried out on the effects of large doses of radioactive iodine administration on the body nitrogen economy, but to date the data are insufficient to warrant the drawing of any conclusions. It is likely that the effects noted in this sphere of body activity may be related to the total blood radiation and the studies are being modified to determine, if possible, whether such an association exists.

During the past year one of the major efforts, not only of the Division, but of the Department as a whole, was the start of work on the effects of thermal neutron radiation on brain tumor. During the summer of 1950, work on this problem was started and was centered at that time in the Division of Bacteriology. The work began as a search for a carrier for a suitable isotope which would selectively enter brain tumor tissue. Because of work that previously had been done along these lines; it was believed that a re-evaluation of dye penetration into tumors might yield information of value. Some 15 dyes were screened in this fashion -- with no encouraging results. The screening process consisted of injection of dye into tumor-bearing mice and then examination for dye content of the tumor together with nearby normal tissue. The work with radioactive diodofluorescein previously reported in the literature by several authors led to a careful examination of this compound. When its distribution was compared with that of radioactive sodium throughout tumor-bearing areas and normal tissues, the data strongly suggested that the diodofluorescein was distributed only in the extracellular fluid compartment of the body and that the retention of dye by the tumor was passive, probably resulting from vascular changes within the tumor mass. Further it appeared that diodofluorescein was not accumulated in sufficient quantities within the tumor area to make it a suitable carrier for boron which could then be rendered radioactive by thermal neutrons.

While data were changing the thinking in regard to the scientific approach to brain tumor problems, preliminary discussions were under way with a neurological clinic regarding possible collaboration on this problem, as it was believed that sufficient work could be done with patients on certain problems of localization to warrant their admission while methods of boron administration were worked out. This belief was strengthened by the results of calculations regarding the concentration of stable isotopes required for thermal neutron activation. Just at this juncture, it was noted that work on distribution of boron in brain tumors was under way at the

Figure 4. The boron injection is being given to a patient with a brain tumor, and within precisely ten minutes, the tumor will be the target of a neutron beam from the nuclear reactor.

Massachusetts General Hospital. Within a short period a conference with Dr. William H. Sweet and his colleagues was arranged to discuss the mutual interests. At this meeting both groups of investigators found that each believed this problem to have great urgency because of the present hopeless future for patients with glioblastoma multiforms; a preliminary agreement was entered into to collaborate in the problem.

Patients were to be selected at the Massachusetts General Hospital for this study. At the time of operation, necessary chemical studies on the distribution of boron between tumor and normal brain tissue in patients were to be done by the Boston group and those patients deemed suitable for treatment were to be considered for admission to Brookhaven. It was agreed that Brookhaven should concentrate on the radiological aspect of the problem and should arrange for obtaining the most suitable boron isotope and its synthesis into the desired compound. The cooperation of the Chemistry Department was secured for this enterprise. The Department of Instrumentation and Health Physics generously assumed the responsibility for developing the difficult and vexing instrumentation problems which at the time of beginning collaboration were shared in part with the Biophysics Group at the Massachusetts General Hospital from the Massachusetts Institute of Technology. Later it was agreed that this development work be carried on entirely at Brookhaven. The Department of Reactor Science and Engineering cooperated in the development of suitable facilities at the nuclear reactor for the work being planned on patients.

Progress was unexpectedly rapid and by January 1, 1951, it was evident that soon the first therapeutic trial could be made. Preliminary runs with phantoms and animals had given information regarding the necessary margin of safety so that on February 15, 1951, the first patient was treated. The time limits of exposure to the thermal neutron column had been estimated from calculation and this was to be checked by direct instrumentation during the actual run. This new treatment was carried out without incident and according to plan.

Subsequently four additional patients have been so treated. The staff is quite confident now that the thermal neutron radiation can be controlled within safe limits and constitutes no unusual hazard for these patients. Although three of the patients have subsequently died, their course following this therapeutic procedure was such that further efforts are encouraged. The evaluation of these first steps awaits further complete histological studies, which are now under.way. However, even without the histological data, a great deal has been learned, and during the months of May and June 1951, a new series of exploratory experiments and observations were begun, better to establish the precise conditions under which this therapy may be expected to be of benefit.

A complete revision of instrumentation was found to be necessary and the Instrumentation Division is making headway in this problem. The Chemistry Department is carefully exploring some new synthetic compounds which may distribute themselves to better advantage in the affected tumor areas; means are being developed to test these compounds more effectively prior to use. It is the hope that during the ensuing months this study may be so developed that the present chemical screening techniques at operation may become unnecessary. More efficient radiation induction in situ can, it is believed, also be developed and work to this end is now being prosecuted.

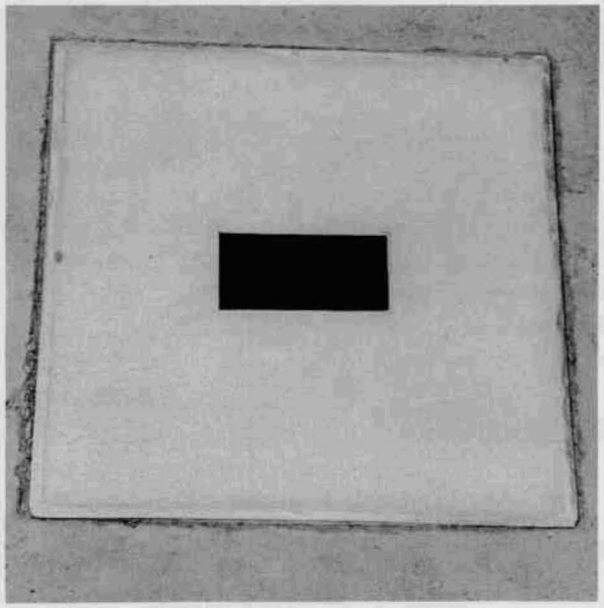


Figure 5. The radiation port through which the thermal neutron beam is emitted from the nuclear reactor. Over this port the head of the patient is placed, so positioned that the neutron beam is directed at the tumor area.

It is, of course, apparent that this study can accommodate only a very few patients, particularly during its developmental period. The mass of data and complexity of the procedure also are of such a magnitude that very considerable study and evaluation are necessary in each instance. The thanks of the Department are due the medical profession at large for their understanding of this problem and their realization that initially it is not possible for all clinics to participate in this study. It is the earnest hope that at an early date the data can be adequately digested for a preliminary report to the directly interested medical and scientific societies.

DIRECT SERVICES

The direct services of the Laboratory include those functions that contribute directly to the research programs of the various scientific departments as well as to the operation of the major research instruments and the development of new instruments and facilities. The services are of a technical nature and include: Technical Information and Research Library, Technical Photography and Duplicating Services, Mechanical Engineering and Central Machine Shops.

Technical Information

During this review period, the budgeted staff of the Technical Information Division was reduced from 36 to 21. This reduction was made possible in part by the transfer of the group (5 personnel) concerned with the reproduction of reports to the Technical Photography and Duplicating Division, and in part by the fact that the initial phase of building up the basic collection in the Research Library had been virtually completed.

In the Research Library, the Circulation and the Reference Sections, in particular, have felt the progress in the Laboratory's entire research program, by an increasing demand for their services. The Reference Section has been so occupied with routine reference work and some small literature searches that it has not been able to undertake the compilation of any extensive bibliographies.

The new acquisitions now consist almost entirely of current items, textbooks and periodicals, requested by the scientific staff. There has been a slow growth, during the past year, of departmental libraries. Such libraries, comprising basic reference texts and journals, are located in the department offices for the sake of convenience, although the Research Library has ordered and catalogued their holdings.

In cooperation with the Technical Information Service, AEC, the Library has conducted a test on the various techniques for preparing and using documents in microprint. Plans are underway in the Commission for issuing the older and less used report material in this form, and it is important to find which technique, microfilm on reels, microfilm on cards, or microcards, is the most practical, both from the scientist's and the librarian's viewpoint.

In late 1948, the Library started a collection of translated Russian scientific articles. The necessity for such a collection became evident when subscribers to the Guide to Russian Scientific Periodical Literature made inquiries concerning the availability of translations listed by title in the Guide. There are now over 500 translations on file, and requests for loans average 30 per month. The success of this service is attributed to the libraries throughout this country, Canada and Great Britain, which contribute 95% of the translations. In this cooperative effort, the Research Library maintains the collection and distributes the cumulative list of holdings, which is also published annually in the Guide.

The Classified Library, in addition to its routine functions in safeguarding and disseminating classified documents, has devoted much time and effort during the past year to an intensive destruction program. This has involved the disposal of surplus copies of classified correspondence, drawings, photographs and reports. By this means, two objectives have been served: a reduction in the amount of material to be inventoried and checked, and an increase in available vault space. A Laboratory-wide inventory of all secret research and development reports was recently concluded; over 14,000 individual documents were checked, without a single missing item.

The Division's Publication Group has edited and processed 38 major Laboratory reports, of which 13 are secret. Twelve issues of the Guide to Russian Scientific Periodical Literature have been prepared; in addition to translated titles and abstracts, 8 full-length papers in the field of nuclear science have been included.

The Division has processed over 200 technical manuscripts written by Laboratory staff members for publication in the professional journals. This procedure involves the reviewing of each paper for possible classified information, patent significance, or policy statements before it is released for publication.

The distribution lists for the Laboratory's unclassified reports have increased steadily. Under the existing Government ruling, Brookhaven is authorized to distribute its own reports only within the national atomic energy project, and cooperating Government agencies. However, every effort is being made to ensure that, within these restrictions, Laboratory publications receive the widest possible circulation. With the cooperation of the Trustees, a plan is now being developed to give maximum practical distribution of Progress Reports to interested individuals within the nine Associated Universities. All requests for Brookhaven reports from outside the project are referred to the Office of Technical Services, Department of Commerce, Washington 25, D.C., where copies may be purchased at a small cost.

Technical Photography and Duplicating

The staff of the Division numbers twenty-six and one additional summer visitor.

Room was acquired in the rear of the personnel building to accommodate the combined mimeograph and copy preparation section. Space is now generally adequate, although the fact that the Division is located in three different buildings remains a handicap.

No new major equipment has been acquired although some replacement is becoming necessary. Various accessory items for microphotography have been added to the photomicrographic apparatus.

A detailed study of film readability from the monitoring stations resulted in some changes of technique with consequent improvements. The photographic load has tended to increase in variety with a fairly uniform distribution among the research departments. The darkroom has continued to render processing service to the Laboratory at large.

Increased demand on the duplicating facilities of the Division, both for reports and general work, was met with greater flexibility of personnel and equipment resulting from the combination of offset, mimeo, copy-preparation, photostat, and photographic duplicating techniques. For reasons of economy laboratory forms have been redesigned, wherever practical, for internal production.

Improved methods of copy preparation and short run duplication are being investigated.

Production figures for the review period follow:

Photographic negatives	2,506
Photomicrographs	338
Prints	21,567
Lantern slides	1,919
Photostats	27,165
Offset impressions	1,804,308
Offset plates	1,893
Offset negatives	3,431
Sheets collated and bound	637,770

Approximately nine miles of 16-mm film were processed for the area monitoring stations and other users of motion picture cameras.

Mimeograph is currently running at the rate of 110,957 impressions per month.

Mechanical Engineering and Design

Late in the fiscal year the Laboratory established the Mechanical Engineering and Design Division, composed of a selected group of engineers previously assigned to various research and development activities, and the designers and draftsmen previously assigned to Central Drafting. At present, this Group is administratively included in the Accelerator Department. The change has permitted greater flexibility than before and has resulted in better and more effective coordination between engineering and design. Present staffing includes seven engineers, 25 designers and draftsmen and two clerical positions.

The effort of the Division has been expended approximately as follows:

Services to facilities	36%
Services for development of research equipment, instrumentation, etc.	64%

Services, the development of research equipment, instrumentation, etc., to the several research departments and supporting scientific and technical activities were widely spread as is evidenced by the following tabulation:

Physics	23 projects
Chemistry	12 projects
Biology	11 projects

Medicine	2 projects
Reactor Science and Engineering (including operations groups)	69 projects
Health Physics	5 projects
Central Shops	10 projects

Among the interesting and unique equipment designed for facilities and research were: fast neutron chopper for physics research at the reactor; closed dissolving system for experimental use at the hot laboratory; dry box, and dry box instrumentation for the target laboratory of the cyclotron; shield testing apparatus for the shielding experiments at the reactor; pill extractor in connection with the breeder studies at the reactor; neutron spectrometer and photo-tube scanner for Chemistry; gamma field source for Biology; special equipment for extractive distillation and reactor components testing experiments at the reactor.

In addition, the Division received 254 requests for illustrations and graphics in connection with publications and lectures.

Central Machine Shops

During the year activity in the shops showed a marked swing from services for facilities to services for development of research equipment and special instrumentation.

Services for facilities included: active participation in the modification and completion program of the reactor complex; manufacture of the dry box for the target laboratory of the cyclotron; development of the vacuum chamber assembly jig and platform as well as the manufacture of the welded steel truss for the Cosmotron. The shops are also participating in the modification of the research electrostatic generator designed to bring it up to required specifications.

In the field of services to the development of research equipment and special instrumentation some of the more important contributions include: work on the extractive distillation system, the closed dissolver system, a neutron irradiation cryostat, a cloud chamber magnet yoke and a neutron spectrometer.

The shops also cooperated with the several Laboratory activities in subcontracting machine shop jobs which could not be accommodated by the Laboratory's shop facilities. During the year 25 such subcontracts were completed by 16 separate firms. The maximum number of such subcontracts to a single firm was four.

Distribution, geographically, of these subcontractors shows that five were within 50 miles of the Laboratory, seven were within 50 to 75 miles, and four were more than 75 miles. Distribution of these subcontractors by size indicates that three would be rated as large and 13 as small.

The shops during the year took over the full responsibility for the management and control of the metals stock. In this period, book value of active stocks were reduced by \$112,000, or 27.0%. Book value of transfers to excess were \$95,250, and book value of disposals from excess amounted to \$55,500. This program of inventory adjustment will be carried forward for the next several years.

In staffing, the shops over the past several years have shown a continued trend toward increasing the productive man-hours available. The following data is based on June 30th employment from the Personnel Division records:

	Employment on June 30th			
	1948	1949	1950	1951
Superintendent	1	1	1	1
Clerical	6	6	4	3
Tool Cribs, Inventory, etc.	3	5	4	5
Foremen, Sub-Foremen and Others, Technical	3	4	7	8
Skilled	57	49	54	57
Semi-Skilled	29	20	16	13
Total	95	85	86	87

The Laboratory calculates its productive man-hours available and its man-hour costs in the shops on the basis of employment in the skilled category. The above table shows that although total shop employment has declined by 8.5% in the 4-year period, man-effort available in the skilled category has increased from 60% to 66% of total shop personnel.

ADMINISTRATION AND MAINTENANCE

Included in this section on Administration and Maintenance are reports on Personnel, Architectural Planning and Plant Maintenance, Budget, Office Services, Purchasing, Receiving Warehouse and Distribution, Inventory and Fiscal activities.

A considerable portion of the activities of the Architectural Planning and Plant Maintenance Department are in direct technical support of the research program either through the construction of equipment and facilities or the provision of special services. These activities are contained in the report of the entire Department and included in this section for convenience.

The Laboratory management has continued in its efforts to consolidate these activities and to effect a more efficient operation of its supporting administrative and service activities. The more extensive reorganization of June 1950 has been followed by others of minor character. The Housing Group has been abolished. Its activities are now carried out by the Laboratory Residence Services Section and the Employee Services Group, the latter handling the much reduced load of assistance to new employees in acquiring off-site housing. The Purchasing Group is no longer a part of the Technical Services Division and reports directly to the Business Manager. The Office Services Group has been made a part of the Technical Services Division for administrative purposes.

The relative increase in technical personnel has occurred partially by expansion and partially by reduction of service and administrative help. In June of 1949, 45.8% of the total Laboratory personnel were in the technical category (scientific or direct technical helpers). In June of 1951 this number had increased to 57.5%.

Scientific Staff

The growth of the scientific staff from January 1, 1947 is indirectly shown in Figure 1, on page 12. The actual number of scientists participating in the Laboratory program is plotted for each month. The "continuing staff" includes all regular employees on the Laboratory's scientific staff. "Salaried visitors" includes scientists and engineers on leave from their institutions, graduate students doing doctoral investigations on leave from their graduate schools and temporary appointees whose services are in some measure requested by the Laboratory. "Guests" include scientists and engineers who receive from the Laboratory no remuneration for services. The increase in the "Guest" category continues to reflect an expanding interest on the part of scientists to make use of the facilities that have recently become available at this Laboratory. The man-months of service rendered by scientists and engineers who hold consultant contracts is not included in this graph. During fiscal 1951, there were 15.4 man-months of services rendered by these consultants.

The changes in the scientific staff during fiscal 1951 are reflected in Tables 1a and 1b of this section. The continuing and on-leave staff increased from 229 to 241. The net change, however, does not reflect the magnitude of the change in individual personnel comprised of an influx of 49 new members, a departure of 42 members and a net internal transfer of +4. During the fiscal year, new appointments were offered to 81 scientists of which 67 have been accepted. Similarly for the temporary and guest appointees, the net increase of 21 does not reflect the actual flow of scientific personnel. During the year, 114 reported for work in these categories and 91 departed, most of the flux occurring during the summer season.

Glossary of Terms

Tenure Appointments are continuous appointments for Senior Scientists and Scientists whose research proves exceptionally significant to Brookhaven's program. These appointments are terminated only for adequate cause, through retirement for age or disability, or for financial exigency.

Term Appointments are limited appointments, normally for one or two years, renewable on the basis of merit and the status of Brookhaven's program but not expected to exceed a total of four years unless the appointee is advanced to Scientist or a tenure appointment.

Indefinite Appointments are appointments to positions supporting research projects normally made on the basis of merit after a one or two-year term appointment. These do not include tenure but are not limited to specific terms.

On-Leave Appointments are appointments generally made for one year, but for shorter or longer periods by mutual agreement between the individual, his home instituion and the Laboratory. During his stay at Brookhaven, the appointee is on leave from his regular employment. On-leave graduate students who undertake their doctoral investigations at Brookhaven are called Junior Research Associates.

Temporary Appointments are those not exceeding three months and usually for the summer months.

Guest Appointments are made for specific terms during which the appointee receives from the Laboratory no remuneration for services.

Continuing Staff of the Laboratory consists of those scientists with tenure, term and indefinite appointments.

Participation in the Laboratory Program by Other Institutions

The following statistics indicate the measure of participation in the Brookhaven program by scientists from other institutions during fiscal 1951.

Appointments of Staff Members from Other Educational Institutions

On Leave:	11 from 8 institutions for 80.6 man-months
Temporary:	47 from 30 institutions for 69.1 man-months
Guests:	13 from 13 institutions for 31.0 man-months

These appointments represent an affiliation with Brookhaven National Laboratory of 68 staff members from 36 different educational institutions for a total of 15.1 man-years

Table 1a

Total Scientific Staff Employed June 30, 1951 Compared with June 30, 1950
(By appointment categories, scientific classifications and academic degrees)

Scientific Classification	Appointment Category															
	Tenure		Term		Indefinite		On Leave		Sub-Total		Temporary		Guest		Grand Total	
	1950	1951	1950	1951	1950	1951	1950	1951	1950	1951	1950	1951	1950	1951	1950	1951
Senior Scientist	27	30	-	-	5	5	3	3	35	38	4	1	-	-	39	39
Scientist	2	2	12	12	6	6	1	2	21	22	3	5	-	2	24	29
Associate Scientist	-	-	79	93	20	16	3	3	102	112	13	10	1	4	116	126
Research Associate	-	-	1	4	-	-	-	-	1	4	-	-	1	3	2	7
Junior Scientist	-	-	26	30	29	23	-	-	55	53	4	2	-	-	59	55
Junior Research Associate	-	-	-	-	-	-	12	12	12	12	-	-	4	4	16	16
Research Assistant	-	-	3	-	-	-	-	-	3	-	19	26	5	19	27	45
Total Scientific Staff	29	32	121	139	60	50	19	20	229	241	43	44	11	32	283	317
By Academic Degree																
PhD or MD degree	28	31	73	92	6	6	5	5	112	134	20	16	2	9	134	159
Master's or equiv. degree	-	-	25	25	16	13	6	8	47	46	6	8	-	5	53	59
Bachelor's degree	1	1	23	21	32	28	8	7	64	57	15	18	9	18	88	93
No degree	-	-	-	1	6	3	-	-	6	4	2	2	-	-	8	6
Total	29	32	121	139	60	50	19	20	229	241	43	44	11	32	283	317

Table 1b

Consultants Services

Item	For Fiscal 1950	For Fiscal 1951
Total Contracts	149	124
No. of Consultants who rendered services as such	63	38
No. of man-days of service	780.5	338
or Man-years	3.0	1.3

on a 12 month per year basis. Among the Guests are included four who held AEC post-doctoral fellowships.

Appointments of Students from Universities

Jr. Research Associates:	20 from 11 institutions for 116.2 man-months
Temporary:	51 from 21 institutions for 70.8 man-months
Guest Fellows:	33 from 10 institutions for 40.7 man-months

Through these appointments, 102 students from 26 different universities worked here for a total of 19 man-years. Guest Fellows included four graduate students who held AEC pre-doctoral fellowships and were carrying on work directly related to their doctoral theses which required the facilities here; seven graduate students, who held either fellowships or assistantships at their universities and were also working on doctoral investigations; and, 22 AEC Radiological Physics Fellows, who came here for ten weeks of practical experience in the Health Physics Division. Eleven of the 31 graduate students completed their doctoral investigations during fiscal 1951.

Including both staff members and students, the total participation of representatives from educational institutions in the Laboratory program during fiscal 1951 amounts to 34.1 man-years by 170 individuals from 45 different institutions. Among these institutions are 30 from the northeastern region, 13 from outside the northeastern region and two foreign institutions.

Appointments of Staff Members from Other than Educational Institutions

On Leave:	5 from 3 industries for 26.4 man-months
Guest:	8 from 8 institutions for 22.6 man-months

These appointments represent participation by 12 additional individuals from 11 different organizations amounting to 49.0 man-months or 4.1 man-years.

Consultant Contracts with Staff Members of Other Institutions

There were 124 such contracts during fiscal 1951, 112 with staff members of educational institutions, and 12 with staff members of other organizations. Only 38 of these consultants rendered services, as such, during fiscal 1951, amounting to 15.4 man-months or 1.3 man-years.

For the summer of 1951, arrangements were made for 46 staff members from 25 universities and 5 other institutions to work at the Laboratory. Of these, 16 were Guests receiving no remuneration for services. There were 33 graduate students from 16 universities on temporary appointments of which two were in the Guest category. In addition, 17 AEC Radiological Physics Fellows received practical training in the Health Physics Division.

Personnel

Employment

The total number of employees on June 30, 1951 was 1373, representing a net increase of 48 staff members during the fiscal year 1951. The ratio of 1 scientist to

4.7 non-scientists on the staff on June 30, 1951 remains virtually unchanged from the comparable ratio at the close of the previous fiscal year. Pertinent personnel statistics are set forth in Table 2.

Table 2

Staff Data	Fiscal Year Ending					
	June 30, 1950			June 30, 1951		
Total number of employees	1325*			1373**		
Scientific staff	229			241		
Ratio: Scientists to non-scientists	1 to 4.8			1 to 4.7		
Turnover Data	Total Numbers	Annual Rate	Average Monthly Rate	Total Numbers	Annual Rate	Average Monthly Rate
Accessions	205	14.46%	1.21%	337	25.21%	2.10%
Separations (turnover)	291	20.63%	1.72%	289	21.64%	1.80%
Net Accessions	-86	-6.28%	-0.52%	48	3.54%	0.30%
Replacements (net turnover)	146	10.23%	0.85%	259	19.38%	1.62%

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

**Not including 44 temporary appointees and 4 employees of the AUI Public Education Office.

It may be noted that the average monthly turnover rate of 1.80% for the 12-month period ending June 30, 1951 is only slightly higher than the figure for the comparable preceding period. The annual net turnover figure, however, for the fiscal year 1951 was almost twice that of the preceding year. The lower net turnover rate in fiscal year 1950 resulted largely from an over-all reduction in (non-scientific) staff during this period, with the concomitant separation of personnel for whom no replacement was required. The higher net turnover rate in the fiscal year 1951 is considered more normal, and characteristic of a relatively stabilized situation in which replacements usually are required for terminating personnel. Nonetheless the higher net turnover rate, combined with the generally "tightening" labor market, complicated the problem of personnel recruitment. The Employment Office, however, by augmented recruiting activities, has been successful in obtaining necessary replacements without modifying employment standards.

With the publication of the Supervisor's Manual of Personnel Policies, a major objective of the Personnel Division has been achieved. The manual itself represents a complete codification of Laboratory personnel policy while the format facilitates its use as a working guide by line supervisory employees in dealing with their routine responsibilities of personnel administration. The Manual of Personnel Policies, together with two supplements -- viz., (1) The Wage and Salary Manual, and (2) the Collective

Bargaining Contract with FLU No. 24426, American Federation of Labor -- were submitted to the Atomic Energy Commission as a complete compilation of Laboratory Personnel Policy for which a single Reimbrusement Authorization was requested. The single Reimbursement Authorization, as subsequently issued, replaces the several such authorizations in effect at that time. Modifications or additions to this all-inclusive Reimbursement Authorization can be effected on a much simpler and more efficient basis than was possible heretofore.

In accordance with the provisions of the collective bargaining contract negotiated with Federal Labor Union No. 24426, AFL, on July 21, 1950, the first annual improvement factor and the first semi-annual cost-of-living adjustment were made effective for employees in the bargaining unit covered by this contract on July 2, 1951. The contract extends until June 30, 1955, without interim re-opening provisions. Indicative of the continuing mutual desire of both the Laboratory and the Union to work harmoniously in the interests of both the Laboratory and its employees, is the fact that only one grievance reached the fourth step of the five-step grievance procedure provided in the contract. No grievance required processing to the fifth step of the grievance procedure which provides for arbitration on a limited number of issues.

On the basis of the most recent periodic wage survey conducted by the Personnel Division in Nassau and Suffolk Counties, the wage schedule covering non-bargaining unit weekly employees was revised. The effective date of the modification was July 2, 1951. Each non-bargaining unit weekly employee, in accordance with established policy, on the basis of merit was placed at the appropriate level within the new range for his classifications during the semi-annual personnel review.

With the advent of national wage stabilization under the Defense Production Act of 1950, it became necessary for the Personnel Division to examine each personnel action in terms of regulations promulgated by the Wage Stabilization Board. Under the provisions of General Wage Stabilization Regulation No. 7 the Laboratory may adjust wages, salaries and other compensation of employees without prior approval of the Wage Stabilization Board although the Regulation indicates further that conformance with the national wage stabilization policy is expected. As a matter of policy the Laboratory is conforming with the National Wage Stabilization Program.

Safety Engineering

The disabling injury frequency and severity rates increased moderately -- but not significantly -- during the fiscal year 1951, as compared with fiscal 1950. With full realization that as accident rates approach a minimum, accident prevention activities must increase in disproportionate amounts to achieve further improvement, the safety objective is primarily to maintain the level of performance already obtained and which was recognized by the National Safety Council in 1949 by the presentation to the Laboratory of its Distinguished Service to Safety Award. Significant data are recorded in Table 3.

The Safety Group undertook a revision of the Basic Emergency Plan of the Laboratory which constitutes an integral portion of the Safety Manual. The Plan provides now for organized emergency planning on a broader basis than previously contemplated. A standard instruction on beryllium was prepared for inclusion in the Safety Manual as the first item in a hazardous chemical reference series. The proposed Biology

Table 3

Disabling Injuries

Rate	Fiscal Year Ending	
	June 30, 1950	June 30, 1951
Frequency*	2.63	3.14
Severity**	.03	.04

*Number of disabling injuries per million man-hours worked
**Days lost per thousand man-hours worked

laboratory (Phase II), and the new engineering laboratory required the largest amount of safety and fire protection engineering service which, as a matter of course, is provided on all proposed new constructions and on modifications to existing facilities.

Pending authorization for the replacement of several facilities which existed on the site prior to AUI management, operational requirements have necessitated continued use of these facilities irrespective of the sub-standard fire protection which has been provided for them. Nonetheless, the negligible fire loss ration of $0.00001 per hundred dollars invested established during the fiscal year 1950, was reduced to nil in the fiscal year 1951. Improved life safety from fire was achieved by the installation of an automatic rate-of-rise fire alarm system in the New Guest House, and discontinuation of the use of multi-story dormitory facilities that were not equipped with automatic sprinklers.

The Laboratory and the Mobilization Program

The national military mobilization program necessitated a review of Laboratory personnel who are members of the various reserve components of the Armed Forces. Each reservist was classified relative to the period of time required to train a replacement, in accordance with the AEC Categorization Program in which the Laboratory is participating. Both the Armed Forces and the Selective Service System have cooperated, respectively, in the matter of deferment of reservists and draftees so that -- to date -- no important Laboratory activity has been affected seriously as a result of the mobilization program.

Employee Benefit Programs

Employee participation in the various benefit programs continued at about the same relative levels, with approximately 85% of the staff enrolled in the group insurance program, 80% in the hospitalization program, and 45% in the retirement program.

Under the 1950 amendments to the Social Security Act, employees of the Laboratory became eligible for Federal Old Age and Survivors Insurance on January 1, 1951. During December of 1950 all employees were questioned to determine whether or not they desired this coverage. In the final tabulation, 89% or 1188 out of a total of 1335 employees expressed their desire to participate. Accordingly, deductions started for these employees on January 1, 1951 and under the provisions of the Act, participation has been required for all new employees hired since that time.

Employee Activities

During the past fiscal year 20 cultural, social, and physical activities functioned regularly under the supervision of the Brookhaven Employees' Recreation Association. Cultural activities included the Film Study, Theater, Model Railroad and Concert Groups, the Band and the Camera Club. Employees participated in eleven physical activities with regular annual tournaments held in softball, tennis, golf and bowling. Social activities included the annual dance, numerous square dances and a modern dance class held at frequent intervals. All of these activities continued to function without direct subsidy from the Laboratory with approximately 60% of the employees participating in at least one activity.

Other Employee Services

With a continued diminution of the number of new staff members who require assistance in securing residence, the provision of this service -- formerly a function of the Housing Group -- has become a part-time activity which is now assigned to the Employee Services Group. The other major activity of the Housing Group, the management of Laboratory-controlled apartment and dormitory rental facilities, has been assigned to a newly created operating unit designated as the Laboratory Residence Services Section. With the transfer of its two major functions, the Housing Group has been deactivated.

Table 4 indicates the assistance furnished to employees in securing a residence:

Table 4

Housing	Fiscal Year Ending	
	June 30, 1950	June 30, 1951
Assistance in:		
Sales and Mortgages	29	31
Rentals	93	67

Architectural Planning and Plant Maintenance

During the fiscal year 1951 the Architectural Planning and Plant Maintenance Department reduced its personnel by 14 from 289 to 275. This was part of the major reduction planned and, for the most part, carried out prior to June 30, 1950, as detailed in the last annual report. There have been no significant changes in the constitution of this work force.

The physical plant of the Laboratory is vast and complex; some idea of the magnitude and complexity of the task faced by the Department charged with its operation and maintenance can be gained by considering the following statistical information about the plant:

Electrical and power system consisting of 2 substations (25 kva capacity), 160 transformers, and 20 miles of overhead and underground distribution lines;

1200 electrical motors from 1500 hp down to fractional horsepower;

10 traveling cranes and 5 elevator and/or material hoists;

Water supply system (800,000 gal/day) consisting of 3 water wells and pumps, 300,000 gal storage tank, and more than 20 miles of water mains, fire hydrant and sprinkler supply mains;

Sewage disposal plant with more than 15 miles of sewers;

Incinerator plant and refuse dump for disposal of 75 to 100 tons of trash and garbage per month;

67 air compressors, 99 domestic-type refrigerators, 27 water coolers, 37 commercial-type refrigeration units, air-conditioning and dehumidifiers (totalling more than 1500 tons of refrigeration capacity);

Heating plant consisting of: (a) 2 high pressure and 2 low pressure boiler plants with 3 separate distribution systems totalling more than 5 miles of steam supply and condensate return mains of varying sizes; (b) 14 individual building steam plants; (c) 50 warm air furnaces and 50 domestic hot water systems; 10 to 12,000 tons of coal unloaded in the summer and distributed throughout the plant every year;

Grounds of more than 300 acres of grassed areas, 25 miles of paved roads, and 30 miles of dirt and cinder roadways, more than 20 miles of fire lanes, as well as the usual walks, curbs, sidewalks, parking areas, drainage ditches and storm sewers, catch basins, etc.;

52 sedans and station wagons, 117 trucks of all kinds (dump trucks, panels, pickups, buses, fire trucks, etc.), 18 gasoline stationary engines, 10 fork lifts;

88 buildings or groups of buildings, with 208 toilets and rest rooms, and an area of almost 600,000 sq ft cleaned daily;

About 150 garments laundered, ironed, and delivered daily by the Protective (radioactive) Clothing Service;

Maintenance warehouse services processing an average of more than 800 issues per month and issuing materials and supplies at the rate of $400.00 daily.

The services which the Architectural Planning and Plant Maintenance Department performs for the Laboratory can be grouped into four general categories: 1. architectural-engineering planning and design; 2. site operations, including repairs incidental to such operations; 3. maintenance, including preventive maintenance; 4. work for others and for facilities. Table 5, which has been developed from job analysis and salary and wage distribution records for the past year, indicates the way in which the 275 man-years available for the performance of these services are distributed between the four categories enumerated above.

Although the four categories of these services, basic to the existence of the Laboratory, are a logical division of the functions of the Department, they are somewhat difficult to define exactly inasmuch as they overlap in many areas and are best described by means of typical and broad examples, as follows:

Architectural Engineering Planning and Design provides services which include: 1. preliminary and developmental as well as final working drawings and specifications for construction and special installation requirements of equipments; 2. studies,

Table 5

Group or Service	Total No.	Archt'l Eng. Plan. & Des.	Site Operations	Maint.	Work for others and facilities
Administration, supervision and services:	20	3	9	4	4
Archt'l Eng. Group:	23	7	5	3	8
Maint. groups & shops: (Electricians, plumbers, sheetmetal, carpenters, cabinet and model makers, painters, laborers, grounds men, riggers, mechanics)	108	-	20	33	55
Heating, ventilating, air-conditioning, coal and ash removal:	73	-	63	10	-
Sanitation, water supply, sewerage:	8	-	8	-	-
Motor vehicles:	13	-	4	9	-
Janitors:	27	-	27	-	-
Protective clothing:	3	-	3	-	-
TOTALS (man-years)	275	10	139	59	67

estimates, reports for construction, special equipments, utilities services; 3. contract negotiation and field supervision of construction and utilities development contracts; 4. study and proposal of long-range site development plans.

Site Operations covers all of the work necessary to operate the essential services on the Laboratory site. This includes the operation of the heating plants, the air-conditioning systems, the refrigeration plants, the water supply systems; the electrical distribution system; the cleaning of streets and catch basins, snow removal, grass cutting, garbage collection, removal and incineration; operation of the sewage disposal plant; the furnishing of drivers for automobiles and buses; the furnishing of janitorial services; the operation of "hot" laundry facilities.

Maintenance includes preventive maintenance as well as repairs and replacement of worn or defective materials. Included in this category are such things as -- screen repairs, repairs of roof leaks, repair or replacement of steps, door checks, broken glass; the inspection and maintenance of electrical motors and repairs where necessary; inspection, maintenance and repairs of heating and air-conditioning equipment; replacement of belt drives; replacement of packings, valves and valve seats on all the steam, water, gas, and air piping systems; inspection and replacement of insulators, fuses, and pole hardware on the electrical overhead distribution system; the periodic inspection and greasing of all automotive equipment including replacement of defective parts and similarly greasing and repairs of all the heavy equipment used by the grounds group such as bull-dozers, fork lifts, mowers, rollers, etc.; the replacement of eroded ground areas, sodding of vegetative water ways, road patching, replacement of road signs, work performed for the Laboratory on-site housing facilities consisting of replacement of broken glass, broken screens, damaged or rotted hand rails and steps, and where necessary, refinishing floors and painting and papering of vacated apartments which have deteriorated through hard use.

A major program of painting (exterior) the buildings at the site has been underway since early spring of 1951; by the end of the summer more than 80 buildings and structures of various types and sizes will have been repainted. This work is being done by outside contractors and includes all necessary repairs to windows, screens and roofs; the total cost of the work thus undertaken during the past spring and present summer amounts to more than $80,000 of which about 60% was completed by June 30, 1951. It is expected that the painting program, initiated this year, will be a continuing part of the general maintenance plan of the Laboratory and it is hoped to include in it painting of the interior of the buildings.

An interesting feature of the painting program is the use of different color combinations, harmonizing and blending with the surrounding areas and structures, in an attempt to relieve the universal and dull monotone so characteristic of army installations. It is felt that this scheme and the selection of colors have been generally successful and the great majority of the comments on the renewed and different appearance of the buildings have been favorable.

Facilities and Work for Others includes such things as connecting services on Laboratory furniture in the reactor, roads and drainage improvements, installing fixtures and apparatus used in laboratories, manufacturing racks and holders for specific equipment, making boards on which to hang monitoring film badges, cocooning the Cosmotron magnet, moving equipment, fabricating a variety of boxes, cutting lumber to desired shapes and sizes, installing electrical service in a specific location of a laboratory for a particular use.

During the year ending June 30, 1951, more than 3,000 Intra-Laboratory Requisitions were processed by the Buildings and Grounds Division. These requisitions, originating outside the Department, cover all categories of work for site operations, maintenance, and work for departments (scientific, administrative, and service) and have resulted in more than 1,200 separate job orders, many of which require work to be done by more than one trade. In several instances, they represent protracted jobs, such as the installation of laboratory services in the pile laboratories, the improvement of the roads, walks and grading around the reactor building, hot laboratory, cyclotron and cosmotron buildings, as well as drainage along Cornell Avenue near the new engineering laboratory.

With the completion in the fall of 1950 of the installation of equipment for the "hot laundry," a new service -- Protective Clothing -- was initiated as a part of Architectural Planning and Plant Maintenance operations. This service takes care of the laundering, ironing, and delivery to all laboratory hot areas of the various types of garments -- laboratory coats, coveralls, shoe covers, gloves -- used in these areas and which cannot be sent to commercial laundries in the vicinity for fear of contaminating outside areas. This operation is in effect a decontamination of the protective clothing and is at all times subject to the close supervision of the Health Physics Division. This service is now handled by 3 employees (1 laundry man, 1 ironer, and 1 driver for pick-up and delivery) and processes about 150 pieces daily.

The Motor Vehicle Section reports no change in the average total monthly vehicle mileage. During the year the value of active inventory stock in the Motor Maintenance Warehouse has been reduced from more than $15,000 to approximately $7,000. This has been accomplished through eliminating items of small usage, eliminating duplications of similar items, and standardization on sizes and types; part of this was made possible by a reduction in kinds of vehicles and by the replacement of new vehicles of 30 Army-type vehicles, for which parts were no longer available, thereby making possible a substantial reduction in active inventory requirements.

The Maintenance Warehouse Service was taken over by the Architectural Planning and Plant Maintenance Department, July, 1950. A plan was initiated to establish stock balances on approximately 6500 items, to establish a re-order system to keep adequate supplies of stock, and to declare surplus those items that do not warrant being stocked. To date, the number of items has been reduced from 6500 to 4500 by eliminating items of very small usage, eliminating duplications of similar items and standardizing on sizes and types. Of the 4500 remaining items, approximately 90% have stock balances and re-order points assigned. Approximately $50,000 worth of excess material was declared surplus.

A complete inventory has been taken and nomenclatures have been corrected or changed on many items to agree with commercial practice; a catalog of all items stocked by the Maintenance Warehouse Service is being prepared. The records indicate that about 60% of the value of the issues is to the Architectural Planning and Plant Maintenance Department, with the balance going to other departments. Stock levels and items to be stocked have been worked out in close liaison with the using agencies.

The following information is of general interest and is concerned with the Laboratory as a whole and the development of its facilities:

A. Construction Completed by Outside Contractors

1. Facilities added:

   a. Chemistry laboratory, including electron-Van de Graaff machine installation, added to Chemistry complex, 2,300 sq ft
   b. Hot laundry, 3,500 sq ft
   c. Biochemistry laboratory for Medical Department, 4,100 sq ft
   d. 200-curie gamma field for Biology Department
   e. Space improvements at no increase in area in active use. Fifteen jobs, including small chemistry labs and offices, isotope dilution lab for Biology, target lab for cyclotron, laboratory for Electronics, dark rooms for reactor and cyclotron buildings, reactor security partitions providing two levels of security working areas.

2. Modification and extension of laboratory services (air conditioning, hoods, dehumidification, piping, electrical work) -- 36 jobs.

3. Other physical improvements to and maintenance of buildings (doors, platforms, floor gratings, protection, exterior painting and repairs, roof repairs and painting) -- 19 jobs.

4. Modification of site-wide facilities (subsurface steam, electric power, water, sewerage, grading and paving) -- 7 jobs.

B. Summary of Building Area in Active Laboratory Use

1. New construction (since 1947) -- 261,900 sq ft (less than 1% increase during the past year).

2. Modification of former Camp Upton buildings acquired in 1947 -- 476,000 sq ft (1 1/2% increase during the past year).

3. Existing buildings acquired in 1947, used without modification -- 356,800 sq ft (slight decrease of 3% during the past year due to reduction in space used for storage).

4. Total building area in active use by Laboratory -- 1,094,800 sq ft (virtually the same as a year ago). There are an additional 310,800 sq ft of buildings either vacant or not in active use by the Laboratory.

C. New Design and Planning Work Initiated (about 165 jobs, including most of the construction completed)

1. For new facilities to be added:

   a. Preliminary drawings and specifications for 25,000 sq ft extension of Biology laboratory as well as close collaboration with Architect-Engineer-firm under contract (AEC) for the detailed design and engineering.
   b. Repair or replacement of Upton Road Bridge over the Long Island Railroad.
   c. 200-curie experimental gamma field for Biology.
   d. Site entrance facilities and security controls.

2. Space improvement and modification of vacant buildings for new facilities; About 20 jobs, including summer apartments, occupational therapy rooms, toilets in gymnasium, physiology laboratory for Medical Department.

3. Modification or new installation of laboratory services; about 80 jobs, including electrical work, ventilation and air-conditioning, piping, hoods.

4. Miscellaneous other physical improvements to buildings; about 30 jobs.

5. Site work, including maps, engineering studies for utilities, design of modifications of steam, electric power, sewerage, and other systems; about 30 jobs.

Fiscal

During the fiscal year ended June 30, 1951 the Laboratory accounting was revised to provide for the distribution on the books of costs of supporting scientific activities and general and administrative costs to direct research accounts so that a better accumulation of costs by programs could be obtained. In this connection, provision was also made to accumulate by means of job orders, costs of fabricating equipment in Laboratory cost center, such as the machine shops, so that the costs of such equipment could be reflected properly in the capital equipment accounts.

The fiscal year also saw the introduction of a voluntary payroll deduction plan for employee purchase of the U.S. Savings Bonds and the coverage of BNL employees under the Federal Insurance Contributions Act.

The number of employees at June 30, 1951 was 58, the same as the June 30, 1950 employment level.

In fiscal year 1952, the Fiscal Division will assume the responsibility for maintaining inventory records.

Budget

During the year the budget planning of the Laboratory has become somewhat more complex. The Laboratory no longer has an Operations Budget including all direct costs and Capital Equipment and Facilities budgets representing only external expenditures. There now is an Organizational budget which, in turn, estimates the total effort and value directed toward Operations, Capital Equipment, and Facilities. The Capital Equipment and Facilities budgets, in turn, are the anticipated sums of the costs from organizational units plus the sums which are estimated will be expended for external buying.

During the year the Budget Office has cooperated with the Fiscal Division and several of the organization units in establishing standard hourly costs for several of the technical service groups. It is anticipated that this will help the management and the research departments in planning future development.

Forecasting anticipated costs two and three years in advance has become, and currently is, more uncertain than ever. Rapid changes in the economy make one day's estimates practically worthless by the next day.

Purchasing

During the period from July 1, 1950 until June 30, 1951, the Purchasing Group wrote 12,775 Purchase Orders including 1,442 Change Orders for a total amount of $2,419,000. Listed in Table 6 is a tabulation of activities for the past several fiscal years.

The Purchasing Group in the last year has had approximately 18 people on the job at all times and has made the processing of Purchase Orders much more efficient and more quickly handled. This streamlining of the activities of the Group has resulted in much quicker action on all requisitions and especially on the very considerable number of special requirements where almost immediate action is required in order that some research problem may be more quickly accomplished. Requests for material and services are as varied as they always have been and despite the completion of several of the major facilities, the number of Purchase Requisitions, Purchase Orders and dollar value of these orders remains fairly constant.

Table 6	FY 48	FY 49	FY 50	FY 51
No. Personnel (6/30)	23	23	17	18
No. Purchase Orders Issued	10,695	11,588	11,548	11,333
No. Change Orders Issued	1,998	1,963	1,499	1,442
Total Orders Issued	12,693	13,551	13,047	12,775
Total Dollar Values	$3,893,000	$4,177,000	$2,335,000	$2,419,000

It is found that deliveries in many cases are somewhat longer than in prior years but good cooperation is being received from the departments in anticipating requirements. Under the Controlled Materials Plan, allocations have been adequate. The problem has been to locate sources of supply which still have unallocated materials.

As in the past, the Catalog Library has been used considerably by the Laboratory personnel.

Receiving, Warehousing and Distribution

The number of personnel in the Receiving Warehousing and Distribution Group decreased during the report period from 43 to 37. As an indication of the volume of materials handled by this group of employees the following statistics are of interest:

21,000 receipts of materials comprising 52,000 pieces were received and processed;
25,000 issues from stores were distributed;
3,614 shipments of excess materials were made;
7 stockrooms and issuing centers and 12 warehouses were maintained;
Surplus materials to the value of over $400,000 were declared to the AEC during the year;
Over $500,000 worth of surplus was transferred or sold.

It should be pointed out that the major portion of this resulted from termination of major subcontracts, and in large part, comprised construction materials, tools, and equipment.

In the fiscal year, the Laboratory's program of reduction of active inventory resulted in lowering the dollar value carried by about $200,000. In addition the staff completed during the year the cataloging of all materials carried, identifying and assigning stock numbers to each item. Separate catalogs have been issued for the various categories of stores items such as electronics, laboratory supplies, glassware, tools, etc. Completion of this program has, through positive number identification, made the stores function more efficient and has made possible more effective inventory methods.

Inventory

For the past three years the Laboratory has been engaged in reducing its inventory levels. Prior to the close of fiscal 1950 all inventory was regarded as active. However, in order to present a clearer picture of the Laboratory's inventory, a program was undertaken late in fiscal 1950 to indicate as excess those items not required for Laboratory operation and/or surplus to its needs. It is from excess items that sales and transfers to others are made.

Table 7

Inventory Changes

Type of Inventory	Fiscal Year 1950	Fiscal Year 1951
Active Inventory		
Opening Active Inventory July 1	$1,218,947	$1,080,884
Net of Purchases, Stores Issues, Adjustments, Additions to Inventory*, Transfers to Excess	-138,063	-277,562
Closing Active Inventory June 30	1,080,884	803,322
Excess Inventory		
Opening Excess Inventory July 1	-	38,843
Net of Transfers from Active Inventory, Dispositions, and Adjustments	38,843	141,725
Closing Excess Inventory June 30	38,843	180,568
Total Inventory		
Opening Total Inventory July 1	1,218,947	1,119,727
Net of Purchases, Stores Issues, Adjustments, Transfers to Excess and Dispositions	99,220	135,837
Closing Total Inventory June 30	$1,119,727	$ 983,890

*In fiscal year 1950 the Laboratory transferred to inventory coal and fuel oil and automotive parts, in the amount of $147,742. Automotive parts, in the amount of $38,843, were declared excess.

The Laboratory inventory is composed chiefly of: (a) items stocked by the Laboratory, (b) items transferred to or acquired for the Laboratory by the Army and the AEC, (c) additions to inventory representing items which the Laboratory has decided to bring under inventory control (for example, coal and fuel oil). Transfers to excess so far in the program have been confined largely to inventory acquired from the Army and AEC (metals, glassware, maintenance, and automotive parts).

The process of weeding out excess from total inventory has moved somewhat slower than originally estimated by the Laboratory and dispositions of excess even more slowly. Reduction of active inventory, however, has progressed at a somewhat faster rate than anticipated and has served to compensate to a degree the slower pace of the excess phase of the inventory problem.

Table 7 will provide some measure of the progress that has been made.

Office Services

The present personnel for Office Services is 21 employees including nine telephone switchboard operators. Since the last report, the Stenographic Pool has been discontinued and the one remaining employee terminated. An additional operator has been added to the Telephone Section. The former Group Leader of Office Services has been transferred to the Budget Staff of the Director's Office. His position was filled from within Office Services without increasing the staff.

The Mail and Messenger Section has continued to provide an important service function and also to be valuable in training new employees in the basic rules and regulations of the Laboratory operations and general organization. A high promotional standard of these employees to more responsible positions throughout the various departments of the Laboratory has continued to be maintained.

In the Telephone Section the increase in the switchboard traffic and occasional special 24-hour coverage of the Medical switchboard has necessitated one additional operator. This new operator is a very successful transfer to one of the messengers. In addition to the other duties performed, a monthly report, by Departments, of the official toll calls has been instituted and is sent to the various department heads for their information and review. Close supervision is maintained on all calls and services.

The Archives or Records program is progressing steadily with a marked increase in transfile receipts and reference calls. The several departments of the Laboratory are realizing that the deposited records are readily accessible whenever needed. The disposal problem is being studied with the immediate result that a more detailed analysis will be made by the different offices of records to be deposited. This should eliminate much unnecessary material clearing through the records center. A disposal program is being developed with careful study of the references, needs and requirements of the Laboratory and in conjunction with AEC policy. The Records Manager of AEC's New York Office has been very cooperative and helpful with the records program and also with the microfilming of vital records under the Commission's security program.

The Office Machine Repair Section has an important part in the office machine program as set forth in the government cost and replacement schedules followed by the Laboratory. Inspection schedules have been established in order better to maintain the numerous office machines in working condition. A complete record of each machine is being set up as to make, model, age, condition and cost of maintenance and maintained for ready reference in analyzing Laboratory requirements according to government replacement schedules.

Security and Plant Protection

Results of the consolidation of the Security, Police and Fire Groups effected late in the previous fiscal year have largely accomplished the hoped-for savings as evidenced by the following comparisons:

Employment at June 30

1948	1949	1950	1951
160	161	130	114

The Police Group has had a larger than usual turnover in personnel because of military recalls and resignations to accept more lucrative positions in defense plants. Replacements have been obtained and their training has assumed greater importance and has consumed greater time.

The work load of the Police Group has increased to the extent that two new exclusion areas have been established, one in a section of the hot laboratory and another encompassing the entire engineering laboratory. As the Laboratory undertakes further special projects of importance to the defense program the demands on the Police Group will continue to require additional staffing of the Security and Plant Protection Division.

The Fire Group continues to maintain an excellent record in its fire fighting activities and in its inspection and fire prevention programs. There have been no serious fires within the Laboratory site. During the spring and early summer, however, a number of very serious forest fires, two of which directly threatened the Laboratory Site, occurred in the surrounding countryside. The Fire Group and their auxiliaries from the Police Group worked in cooperation with neighboring fire companies under their mutual aid agreements, to bring these fires under control.

The over-all plan for meeting Laboratory emergencies developed into the organization and training of 135 employee volunteers prepared to meet whatever emergency situations may arise. These volunteers have completed training in First Aid, Auxiliary Police, Auxiliary Fire, Rescue and Special Detail squad work. Further training is contemplated when the necessary area alarm system has been completed. All of the work of these volunteers is geared toward a civilian defense program specifically adapted to the needs of the Laboratory.

APPENDIX

A. UNCLASSIFIED PUBLICATIONS, JULY 1, 1950 - JUNE 30, 1951

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

Annual Report, July 1, 1949 - June 30, 1950 (BNL 74 (AS-4))

Quarterly Progress Report, July 1 - September 30, 1950 (BNL 82 (S-7))

Quarterly Progress Report, October 1 - December 31, 1950 (BNL 93 (S-8))

Quarterly Progress Report, January 1 - March 31, 1951 (BNL 103 (S-9))

Quarterly Progress Report, April 1 - June 30, 1951 (BNL 117 (S-10))

Conference Reports:
- Waste Processing I. Brookhaven National Laboratory Waste Problems (BNL 58 (C-11))
- Waste Processing II. Evaporation (BNL 59 (C-12))*
- CO_2 Assimilation Reactions in Biological Systems (BNL 70 (C-13))

Guide to Russian Scientific Periodical Literature 3, #7-12 (BNL-L-76 to 81)
4, #1-6 (BNL-L-82 to 87)

Weekly Bulletin 3, #49-52; 4, #1-48

Weekly Selected Reading List 3, #17-52; 4, #1-16

STAFF PUBLICATIONS AND ABSTRACTS

Accelerator Project

Blachman, N.M.
Forced betatron oscillation in a synchrotron with straight sections
Rev. Sci. Instruments 22, 569-71 (1951)

Blachman, N.M.
Synchrotron-oscillation resonance
Rev. Sci. Instruments 21, 908-11 (1950)

Blewett, J.P.
Electron loading in ion accelerating tubes II (A)
Phys. Rev. 81, 305 (1951)

Blewett, J.P., Plotkin, M. and Blewett, M.H.
Ferromagnetic ferrites
Proc. I.R.E. (In press.)

*For official use only.

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

Blewett, M.H. (See Blewett, J.P.)

Courant, E.D.
Direct photoelectric effects in nuclei
Phys. Rev. 82, 703-9 (1951)

Golian, S.E. and Reilly, E.G.
A magnetic orientation device
Rev. Sci. Instruments (In press.)

Kelly, J.M.
Magnetic field measurements with peaking strips
Rev. Sci. Instruments 22, 256-8 (1951)

Plotkin, M. (See Blewett, J.P.)

Pressman, A.I. and Blewett, J.P.
A 300- to 4000-kc electrically-tuned oscillator
Proc. I.R.E. 39, 74-7 (1951)

Turner, C.M.
Electron loading in ion accelerating tubes. I (A)
Phys. Rev. 81, 305 (1951)

Yuan, L.C.L. and Poss, H.L.
Particle localization by means of a scintillation detector (A)
Phys. Rev. 81, 323 (1951)

Yuan, L.C.L. (See Falk, C.E., Physics)

Architectural Planning and Plant Maintenance

Ruddy, J.M.
Gamma-ray shielding
Am. Soc. Civil Engrs. (In press.)

Biology Department

Bowen, V.T. and Sutton, D.
Comparative studies of mineral constituents of marine sponges. I. The genera *dysidea*, *chondrilla*, *terpios*
J. Marine Research (In press.)

Bowen, V.T. (See German, F.)

Bowen, V.T. and Rubinson, A.C.
The uptake of lanthanum by a yeast (L)
Nature 167, 1032 (1951)

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

Cochrane, V.W. and Gibbs, M.
The metabolism of species of streptomyces. IV. The effect of substrate on the endogenous respiration of *S. coelicolor*
J. Bact. 61, 305 (1951)

Culbreth, G.G. (See Sacks, J.)

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

DeMoss, R.D. (See Gibbs, M.)

DuBow, R. (See Moses, M.J.)

Edelmann, A. (See Katsh, S.)

Edelmann, A.
Adrenal shielding and survival of rats after X-irradiation
Am. J. Physiol. 165, 57-60 (1951)

Edelmann, A. and Eversole, W.J.
Changes in antidiuretic activity of rat serum after X-irradiation
Am. J. Physiol. 163, 709 (1950)

Edelmann, A. and Katsh, S.
The survival of rats adrenalectomized after X-irradiation (A)
Federation Proc. 10, 38 (1951)

Eversole, W.J. (See Edelmann, A.)

Forro, F., Jr. (See Pollard, E.)

Gastel, R. and Gibbs, M.
On the mechanism of lactic acid synthesis by the fungus Rhizopus oryzae studied with C^{14} (A)
Am. J. Botany 37, 668 (1950)

German, F. and Bowen, V.T.
A technique for growing plants under sterile conditions
Plant Physiol. (In press.)

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

Gibbs, M. (See Cochrane, V.W.)

Gibbs, M. and DeMoss, R.D.
A new mechanism of ethanol formation in the heterolactic fermentation (A)
Federation Proc. 10, 189 (1951)

Gibbs, M. (See Gastel, R.)

Gibbs, M.
The position of C^{14} in sunflower leaf metabolites after exposure of leaves to short period photosynthesis and darkness in an atmosphere of $C^{14}O_2$
Plant Physiol. 26, 549-56 (1951)

Katsh, S. and Edelmann, A.
The adrenal cortical requirements of adrenalectomized, X-irradiated rats (A)
Federation Proc. 10, 73 (1951)

Katsh, S. (See Edelmann, A.)

Koester, M.L.
The effect of continuous gamma radiation upon starch formation in Zea mays pollen (A)
Genetics Society Meetings, Minneapolis, September, 1951

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

Matthews, S.A.
The effect of thiouracil on the uptake of radioactive iodine by the thyroid gland of summer frogs (Rana pipiens)
Am. J. Physiol. 162, 590-7 (1950)

Moses, M.J.
Absorption spectrum of the feulgen-nucleal complex in vitro and in situ (A)
Histochemical Society Meetings, Detroit, March 19-20, 1951

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

Moses, M.J., Dubow, R. and Sparrow, A.H.
The effects of X-rays on desoxypentose nucleic acid in situ. Quantitative cytochemical studies in Trillium (A)
Histochemical Society Meetings, Detroit, March 19-20, 1951

Nims, L.F. (See Scheraga, H.A.)

Nims, L.F.
Protection of biological systems from the effects of ionizing radiation (A)
J. Chim. Phys. 48, 280-3 (1951)

Perry, M.F.C. (See Rubin, B.A.)

Pollard, E., Buzzell, A., Jeffreys, C. and Forro, F., Jr.
Inactivation of pepsin and trypsin by deuteron and electron bombardment
Arch. Biochem. and Biophys. 33, 9-21 (1951)

Rubin, B.A. (See Sparrow, A.H.)

Rubin, B.A. and Steinglass, P.
The recovery of streptomycin from cultures of streptomycin requiring mutants of Escherichia coli (A)
Proc. Soc. Am. Bacteriologists, 1951, pg. 33

Rubin, B.A., Perry, M.F.C. and Thanassi, F.Z.
The relation of the mechanism of antibiotic action to studies of the genetics of streptomycin resistance (A)
Proc. Soc. Am. Bacteriologists, 1951, pg. 54

Rubin, B.A.
The relation of nucleic acid metabolism to the genetic effect of radiation in bacteria (A)
Genetics Society Meetings, Minneapolis, September, 1951

Rubinson, A.C. (See Bowen, V.T.)

Sacks, J. and Culbreth, G.G.
The absorption of phosphate from the subarachnoid space (A)
Am. J. Physiol. 163, 746-7 (1950)

Sacks, J. and Culbreth, G.G.
Phosphate transport and turnover in the brain
Am. J. Physiol. 165, 251-6 (1951)

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Phosphate transport and turnover in the liver
Arch. Biochem 30, 423 (1951)

Scheraga, H.A. and Nims, L.F.
The action of X-rays on fibrinogen
Arch. Biochem. and Biophys. (In press.)

Sharpe, L.M., Culbreth, G.G. and Klein, J.R.
The blood and packed cell volume of the adult rat as measured by tagged cells
Proc. Soc. Exp. Biol. 74, 681-5 (1950)

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The influence of blood incompatibilities on the measurement of blood volume by cell-tagging methods
Proc. Soc. Exp. Biol. and Med. 75, 61-2 (1950)

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Anat. Record 105, 575 (1949)

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J. Biol. Chem. (In press.)

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Effect of continuous gamma radiation of mutation rate in maize (A)
Genetics Soc. Meeting. Minneapolis, September 11, 1951

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Effect of continuous gamma radiation on corn
Agronomy Soc. Meeting, Pennsylvania State College, August 29, 1951

Singleton, W.R.
Inheritance of corn grass a macromutation in maize, and its possible significance as an ancestral type
Am. Naturalist 85, 81-96 (1951)

Sparrow, A.H.
Consideration of the relationship between chromosome breakage and mitotic inhibition induced by ionizing radiation (A)
5th Intl. Congress of Cancer, Paris, July, 1950, pg. 132

Sparrow, A.H., Moses, M.J. and Steel, R.
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Brit. J. Radiology (In press.)

Sparrow, A.H. and Maldawer, M.
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Proc. Nat. Acad. Sci. U.S. 36, 636-43 (1950)

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BNL 97 (T-22)

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Non-random distribution of chromosome fragmentation in unirradiated Trillium (A)
Genetics 35, 135 (1950)

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

Sparrow, A.H.
Tolerance of Tradescantia to continuous exposures to gamma radiation from cobalt^{60} (A)
Genetics 35, 135 (1950)

Sparrow, R.C. and Sparrow, A.H.
Spontaneous chromosome fragmentation in Trillium erectum L.
Am. Naturalist 84, 477-88 (1950)

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

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Federation Proc. 10, 251 (1951)

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

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Chemistry Department

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The preparation of radioactive vitamin B_{12} by direct neutron irradiation (L)
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Bigeleisen, J. and Allen, T.L.
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J. Chem. Phys. 19, 760-4 (1951)

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The infrared spectra of $N^{15}N^{14}O^{16}$ and $N^{14}N^{15}O^{16}$. Some thermodynamic properties of the isotopic N_2O molecules
J. Chem. Phys. 18, 1656-9 (1950)

Bigeleisen, J. (See Friedman, L.)

Bonner, F. and Weinstein, A.
A geiger counter mounting for continuous counting of gas-phase radioactivity (N)
Rev. Sci. Instruments 21, 934 (1950)

Bonner, F. and Turkevich, J.
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J. Am. Chem. Soc. 73, 561 (1951)

Bothner-By, A.A. and Gibbs, M.
The epimerization of glucose-1-C^{14} (N)
J. Am. Chem. Soc. 72, 4805 (1950)

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J. Chem. Phys. 19, 755-9 (1951)

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An N^{15} tracer study of organic azide reactions. I. The curtius rearrangement of 3,5-dinitrobenzazide-N^{15}
J. Am. Chem. Soc. (In press.)

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Quinone-hydroquinone exchange reactions. I. Non-exchange in duroquinhydrone
J. Am. Chem. Soc. 73, 4228 (1951)

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Simple preparation of optically active secondary alcohols (N)
J. Am. Chem. Soc. 73, 846 (1951)

Bothner-By, A.A., Gibbs, M. and Anderson, R.C.
The synthesis of L-ascorbic acid uniformly labeled with C^{14}
Science 112, 363 (1950)

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Studies on the mechanism of the Willgerodt reaction. I. The over-all mechanism
J. Am. Chem. Soc. 73, 3735-8 (1951)

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Paramagnetic susceptibilities of solid solutions of MnF_2 and ZnF_2
J. Chem. Phys. 18, 1256-7 (1950)

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Cross, J.M. (See Pinajian, J.J.)

Delabarre, Y. (See Corliss, L.)

Delabarre, Y. (See Anderson, R.C.)

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

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Dodson, R.W.
Research at Brookhaven National Laboratory
The Johns Hopkins Magazine 11, 4-9 (1950)

Elliott, N. (See Stoenner, R.)

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Absorption spectra of chlorophylls in solutions at low temperatures. Equilibria between isomers
Science 114, 275-6 (1951)

Friedlander, G. (See Alburger, D.E., Physics)

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Phys. Rev. 80, 30-3 (1950)

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J. Chem. Phys. 18, 1325-31 (1950)

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J. Am. Chem. Soc. (In press.)

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The kinetics of the exchange reaction between the two oxidation states of cerium in acid solution
J. Am. Chem. Soc. 73, 2890 (1951)

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The exchange reaction between the two oxidation states of thallium in solution
J. Am. Chem. Soc. 73, 2442-7 (1951)

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Phys. Rev. 83, 223 (1951)

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J. Acoust. Soc. Am. 23, 463-71 (1951)

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J. Chem. Phys. (In press.)

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Phys. Rev. 82, 688-90 (1951)

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J. Chem. Phys. 19, 224-7 (1951)

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J. Am. Chem. Soc. (In press.)

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J. Am. Chem. Soc. (In press.)

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J. Am. Chem. Soc. 73, 537 (1951)

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Spectrophotometric determination of cerium (IV)
Anal. Chem. 23, 453 (1951)

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Anal. Chem. (In press.)

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Use of a modified syringe for extraction with solvents of low density (N)
Anal. Chem. 23, 545 (1951)

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Perlman, M.L. and Friedlander, G.
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Phys. Rev. 82, 449-50 (1951)

Pinajian, J.J. and Cross, J.M.
Use of sintered glass disc in the preparation of radioactive precipitates
Anal. Chem. 23, 1056 (1951)

Rubinson, W. and Bernstein, W.
The emission of Pb X-rays from Po^{210} sources (A)
Phys. Rev. 82, 334 (1951)

Sancier, K.M. (See Freed, S.)

Schaeffer, O.A.
The effect of isotopic substitution on mass spectra of molecules
J. Chem. Phys. 18, 1101-4 (1950)

Schaeffer, O.A.
The effect of mass discrimination on isotope abundance measurements. Relative abundances of krypton isotopes (L)
J. Chem. Phys. 18, 1681 (1950)

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Schaeffer, O.A.
On the relative efficiencies for the collection of positive ions by a 60° sector mass spectrometer
Phys. Rev. (In press.)

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The magnetic susceptibility of uranium tetrachloride
J. Chem. Phys. 19, 950-1 (1951)

Stoenner, R.W. (See Medalia, A.I.)

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Thompson, S.O., Turkevich, J. and Schissler, D.O.
Behavior of paraffin hydrocarbons on electron impact. Synthesis and mass spectra of some deuterated paraffin hydrocarbons
Trans. Faraday Soc. (In press.)

Thompson, S.O., Turkevich, J. and Irsa, A.P.
Reaction of deuterium with hydrocarbons over a cobalt-thoria Fischer-Tropsch catalyst
J. Am. Chem. Soc. (In press.)

Thompson, S.O., Turkevich, J. and Irsa, A.P.
Study of the Fischer Tropsch reaction using deuterium gas
J. Phys. & Colloid Chem. (In press.)

Turkevich, J. (See Thompson, S.O.)

Turkevich, J. (See Bonner, F.)

Turkevich, J., Schissler, D.O. and Irsa, A.P.
A study of the interaction of ethylene and deuterium
J. Phys. & Colloid Chem. 55, 1078-84 (1951)

Weinstein, A. (See Bonner, F.)

Wilson, E. (See Mihelich, J.W., Physics)

Electronics and Instrumentation Division

Bernstein, W. (See Rubinson, W., Chemistry)

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Resolution of the scintillation spectrometer (L)
Rev. Sci. Instruments (In press.)

Burditt, W.F. (Se McMahon, A.J., Physics)

Chase, R.L. (See Higinbotham, W.A.)

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Rev. Sci. Instruments 22, 688-90 (1951)

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Rev. Sci. Instruments (In press.)

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Precision regulated high voltage supplies (N)
Rev. Sci. Instruments 22, 429-31 (1951)

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Kuper, J.B.H.
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Bull. Atomic Scientists (In press.)

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Health Physics Division

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Nucleonics 7, 39-45 (1950)

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Nucleonics 8, 51-4 (1951)

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Harris, S.J.
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RA-DET 3, 14 (1950)

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Beta calibration rack using uranium oxide (N)
Nucleonics 7, 73 (1950)

Keene, B.E. (See Reinig, W.C.)

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Nucleonics 8, 84 (1951)

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Federation Proc. 10, 264 (1951)

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J. Biol. Chem. 191, 299-304 (1951)

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Phys. Rev. 83, 223 (1951)

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Phys. Rev. 82, 115-6 (1951)

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Phys. Rev. 83, 468-9 (1951)

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Phys. Rev. 83, 176-7 (1951)

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Phys. Rev. 82, 98-9 (1951)

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Robert A. Patterson, Assistant Director, University Liaison

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J.B.H. Kuper, Chairman, Instrumentation and Health Physics Department
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Thomas H. Johnson, Chairman, Physics Department
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J. Georges Peter, Manager, Architectural Planning & Plant Maintenance Department
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Lawrence R. Swart, Personnel Officer
Frederick H. Williams, Security Officer

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Donald F. Howard†
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Joseph A. Kosh†
Calman Lasky
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(transferred to Director's Office)
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William H. Moore, Jr.
Martin Plotkin
Irving J. Polk
Abraham I. Pressman†
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Fred J. Seufert, Jr.†
Edward E. Shelton
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(transferred from R. S. & E. Dept.)
Lyle W. Smith
Lincoln D. Stoughton
J. Curry Street
(on leave from Harvard U. to 12/15/50)
Clarence M. Turner
Richard H. Van Haagen†
James L. Walsh
Abraham N. Wise†
Luke Chia-Liu Yuan

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Howard J. Curtis, Chairman
Vaughan T. Bowen
Margaret R. Bubeck†
Elwood J. Dollinger
Rosalind J. DuBow
Abraham Edelmann

*To be appointed Guest Scientist, July 1, 1951.
†Terminated before June 30, 1951.

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Mary Frances Perry
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Max M. Weiss

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James L. Gamble
Horace T. Gardner†
William M. Hale
Lawrence V. Hankes
Sidney C. Madden
Mortimer L. Mendelsohn
(on leave from Memorial Hospital since 1/1/51)
Wade N. Miller†

†Terminated before June 30, 1951.

Robert A. Love
Leo Lutwak
John H. Prodell, Jr.†
Alma W. Richards
(transferred to non-scientific staff)
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Wilma C. Sacks
F. Marrott Sinex
Richard D. Stoner
Donald D. Van Slyke
Robert N. Watman
Louis J. Zeldis
(on leave of absence)

Physics Department

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David Alburger
Charles P. Baker
(on leave from Cornell U.)
Ira B. Bernstein†
Marietta E. Blau
Eugene L. Church
Rodney L. Cool
Thomas Coor
Victor W. Cohen
Noel R. Corngold
Nancy W. Curtis
Charles C. Damm
Theresa Danielson
Edward der Mateosian
Charles E. Falk
Charles B. Fisk†
Earl C. Fowler
William B. Fowler
Gertrude Goldhaber
Maurice Goldhaber
Samuel A. Goudsmit
Everett M. Hafner
(on leave from U. of Rochester)
John A. Harvey
Norval J. Hawkins
Earl E. Hays
John Hornbostel
William F. Hornyak
Donald J. Hughes
Alfred C. Hunting†
John E. Iversen
Allen L. Johnson
Gerald W. Johnson
Edward J. Kelly
Vincent P. Kenny
David A. Kleinman
Jack J. Kraushaar
Seymour J. Lindenbaum
Herbert G. Lipson†
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Allen J. McMahon†
Andrew W. McReynolds
John W. Mihelich
Donald H. Miller†
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Frederick G.P. Seidl
Ralph P. Shutt
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George A. Snow
Hartland D. Snyder
Andrew W. Sunyar
Alan Thorndike
William A. Thornton
Ernest Wantuch†
Tunis Wentink, Jr.†
William L. Whittemore
A. William Wotring†

Reactor Science and Engineering Department

Lyle B. Borst, Chairman*
James E. Atherton, Jr.
Hampton O. Banks, Jr.
David S. Ballentine
David W. Bareis
George A. Bennett†
John E. Binns
Randolph H. Bretton
(on leave from Yale U. to 8/31/50)
Gloria D. Brown
(transferred to non-scientific staff)
William F. Charlesworth†
Jack Chernick
Melville Clark, Jr.
Harry C. Cook†
Shirley N. Connor
Marcel A. Cordovi
(on leave from Babcock & Wilcox since 1/8/51)
David K. Davies
(on leave from Babcock & Wilcox 12/29/50 to 3/29/51)
Dietrich H. Edel, Jr.

†Terminated before June 30, 1951.

*Will terminate August 1st. As of that date, Marvin Fox, Assistant Chairman, will have the responsibility for Reactor and Hot Lab operations and Clarke Williams, Assistant Chairman, will have the responsibility of the research program of the Department.

Howard N. Fairchild
(on leave from Cornell U. to 1/18/51)
Edward L. Fireman
John J. Floyd
Marvin Fox
Herbert M. Fried
William S. Ginell
Lionel S. Goldring
David H. Gurinsky
Loranus P. Hatch
Franklin A. Heasley
Raymond J. Heus
Robert V. Horrigan
Sheldon E. Isakoff†
Otto F. Kammerer
Irving Kaplan
Justin Karp
Carl J. Klamut
Herbert J.C. Kouts
John W. Kunstadter †
Paul H. Lee†
Walter Lones
Philip H. Lowry
Bernard Manowitz
Daniel A. Mazzarella
Lowell McLean
Francis T. Miles
J. Barry Oakes†
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Jack E. Phillips
Robert W. Powell
William W. Pratt
Alonzo C. Rand
Chad J. Raseman
Melvin Reier
Vance L. Sailor
Earl E. Schoessow
(on leave from Babcock & Wilcox 9/5/50 to 1/5/51)
Robert J. Schomer
(on leave from Gibbs & Cox since 5/7/51)
William F. Scully
Gerald J. Selvin
Thomas V. Sheehan
(on leave from Standard Oil Co. of Indiana)
Maynard E. Smith
Louis G. Stang
Gerald Strickland
Herbert Susskind
Robert J. Teitel
Walter D. Tucker
Robert L. Turner
Edward J. Vanderman
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†Terminated before June 30, 1951.