BROOKHAVEN NATIONAL LABORATORY*Annual Report*
July 1, 1952 **Associated Universities, Inc.**

under contract with the

United States Atomic Energy Commission

Annual Report
July 1, 1952

BROOKHAVEN NATIONAL LABORATORY

Associated Universities, Inc.

Upton, New York

ASSOCIATED UNIVERSITIES, INC.

Associated Universities, Inc., which operates Brookhaven National Laboratory under contract with the United States Atomic Energy Commission, is a private, nonprofit corporation organized under the educational laws of the State of New York. It is governed by a Board of Trustees representing nine sponsoring universities: Columbia, Cornell, Harvard, Johns Hopkins, Massachusetts Institute of Technology, Pennsylvania, Princeton, Rochester, and Yale. There are two Trustees from each institution, one of whom is a principal administrative or corporate officer and the other usually a senior scientist from its faculty. The purpose of Associated Universities, Inc. is to supplement the effort of the colleges and universities of the northeast area by initiation and management of operations that can be mutually helpful to all and that can substantially aid in the achievement of American objectives where this requires mobilization of academic effort, particularly in the field of research. The only corporate activities here reported are those related to the management of Brookhaven.

The Board of Trustees is the primary policy-making body of the corporation in all its activities. This function is not discharged by minute supervision and participation in day-to-day decisions. Rather it is met by the selection of a competent staff and by the establishment for that staff of general operating policies tested by sound experience. In addition, the Board appraises the performance of the Laboratory and above all serves as a channel through which the experience and resources of the nine sponsoring institutions can be mobilized.

With respect to Brookhaven, the corporation is at all times aware of its responsibility to the Atomic Energy Commission and through it to the country as a whole. The close association of AUI with scientific progress, both at Brookhaven and at the universities, provides the Commission with an important channel of access to scientific development which might not be otherwise so readily available to it and which is of great value in the development of progressive national policies in the field of nuclear energy.

This report is submitted under the terms of Contract #AT-30-2-GEN-16 between Associated Universities, Inc. and the Atomic Energy Commission. It is the third in a series of unclassified Annual Reports; the first two are

BNL 74 (AS-4) July 1, 1950
BNL 131 (AS-5) July 1, 1951.

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

September, 1952

1700 copies

CONTENTS

Part I - Report of Associated Universities, Inc. - - - - -	1
Part II - Report of Brookhaven National Laboratory	
Introduction - - - - -	7
Physical Sciences and Engineering	
Physics - - - - -	19
Instrumentation and health physics - - - - -	34
Accelerator - - - - -	42
Chemistry - - - - -	51
Reactor science and engineering - - - - -	66
Life Sciences	
Biology - - - - -	87
Medicine - - - - -	95
Direct Services - - - - -	108
Administration and Maintenance - - - - -	113
Appendix - A. Unclassified Publications, July 1, 1951 - June 30, 1952 - - - - -	129
B. Officers and Scientific Staff - - - - -	144

Bev. Day - Cosmotron Staff grouped around control room oscilloscope on the afternoon of June 20, 1952.

PART ONE
ASSOCIATED UNIVERSITIES, INC.

Management

1. General

Brookhaven National Laboratory is managed by Associated Universities, Inc. under contract with the U.S. Atomic Energy Commission and the work under that contract was the principal activity of the corporation during the fiscal year ended June 30, 1952. The corporate organization and management methods are, as is appropriate, of a university type and the organization chart appearing on page 6 is designed to show the relationship of the corporate structure to the Laboratory organization which is headed by the Director. The latter is charged by the corporation with full responsibility for the operation of Brookhaven. Also on page 2 appear the names and university connections of the members of the Board of Trustees and the names of the corporate officers, all as of June 30, 1952.

During the past fiscal year the Board of Trustees held four meetings, and the Executive Committee, nine. These meetings served to provide the contact between the Laboratory and the Board necessary to permit the latter to discharge its responsibility as the governing body of the corporation. The President provides the corporation with continuity of operation and implements its policies through his day-to-day decisions. Individual Trustees also, as dictated by circumstances, participate on an informal basis in the solution of particular problems of a technical or administrative character.

To strengthen the connection between the Laboratory and the Trustees, the latter at their meeting in January, 1952, pursuant to recommendation of the President, created a Committee on the Brookhaven National Laboratory. The purpose of the President's recommendation was to generate a group among the Trustees intimately familiar with the operating details of the Laboratory to an extent that would not be practical for the full Board. The Committee maintains close contact with the Director and members of his staff and serves him as an advisory group on matters of general policy and more particularly on planning the future of the institution. The Committee is made up of five Trustees, namely Messrs. Elgin, Hartline, Rabi, and Ramsey and Mr. Wright as Chairman.

The Visiting Committees, a familiar university concept, continued to prove their usefulness during the period covered by this report. Each committee met at Brookhaven at least once during the year and rendered a full report to the Trustees appraising the staff of the department in question, its plans and development, and the programs with which it is concerned. In addition to providing the Trustees with an independent means of evaluating the work of the Laboratory, the committee members are available to the Director for consultation and to the chairmen and staffs of the departments for informal advice and guidance.

ASSOCIATED UNIVERSITIES, INC.

Trustees

Chairman of the Board

George A. Brakeley*

President

Lloyd V. Berkner

Columbia University

George B. Pegram
I.I. Rabi**

Cornell University

Franklin A. Long
Theodore P. Wright**

Harvard University

Norman F. Ramsey
Edward Reynolds**

Massachusetts Institute of Technology

Thomas K. Sherwood
Jerrold R. Zacharias**

University of Pennsylvania

William H. DuBarry**
Foster C. Nix

Johns Hopkins University

H. Keffer Hartline**
P. Stewart Macaulay

Princeton University

George A. Brakeley
Joseph C. Elgin

University of Rochester

William S. McCann
LaRoy B. Thompson

Yale University

C. Hamilton Sanford, Jr.
William W. WatsonOfficers

George A. Brakeley, Chairman of the Board* Lloyd V. Berkner, President*

James S. Alexander, Treasurer
(Guaranty Trust Company of N.Y.) Leland J. Haworth, Vice PresidentJoseph F. Lord, Assistant Treasurer
(Guaranty Trust Company of N.Y.) Charles F. Dunbar, Secretary

Lewis R. Burchill, Controller

John D. Jameson, Assistant Treasurer
and Assistant Secretary***

*Ex officio member of Executive Committee.

**Member of the Executive Committee until October 1952.

***Resignation effective July 1, 1952.

As of June 30, 1952 the five visiting committees and the names and affiliations of their members were as follows:

For the Biology Department:

Chairman: H. Bentley Glass - Johns Hopkins University
 Richard Bradfield - Cornell University
 Arthur K. Parpart - Princeton University
 J. Walter Wilson - Brown University
 Harland G. Wood - Western Reserve University

For the Chemistry Department:

Chairman: Louis P. Hammett - Columbia University
 Ralph Connor - Rohm & Haas Company
 David Harker - Polytechnic Institute of Brooklyn
 Joseph W. Kennedy - Washington University
 George B. Kistiakowsky - Harvard University

For the Medical Department:

Chairman: J. Harold Austin* - College of Physicians of Philadelphia
 Herrman L. Blumgart - Harvard University
 G. Failla - Columbia University
 W.O. Fenn - University of Rochester
 Colin MacLeod - New York University

For the Physics Department:

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

For the Reactor Science and Engineering Department

Chairman: Thomas B. Drew - Columbia University
 Manson Benedict - Massachusetts Institute of Technology
 Harvey Brooks - Harvard University
 John Chipman - Massachusetts Institute of Technology
 Isaac Harter - The Babcock & Wilcox Tube Company
 Augustus B. Kinzel - Union Carbide & Carbon Research Laboratories, Inc.

Appointments to the committees are for three-year terms on a staggered basis so that one-third of the memberships expire each year. Since the reports for the year

*Deceased

have not yet been submitted, a summary of them will appear in the President's Annual Report to the Board of Trustees.

2. Contract and Organizational Changes

During the year the contract with the Atomic Energy Commission for the management of Brookhaven was amended four times. Two of these amendments were for the sole purpose of providing additional funds. Of the other two, one was to permit, by agreement between the Commission and the corporation, the carrying out of non-AEC activities involving the use of equipment, facilities or personnel of the Laboratory. This amendment has been used in connection with a short-term study contract made with the Department of the Army in June 1951. The remaining amendment, and the most important, drastically changed the method by which general corporate expenses are financed. The contract as originally written provided an overhead allowance to meet costs and expenses arising out of or connected with the work, but which were not directly reimbursable under some other provision of the contract. Expenditures from this allowance were subject to audit and to other controls the Commission deemed necessary, which, however, seemed to the corporation to deprive it of the discretion needed for the effective management of the Laboratory in the public interest. Accordingly, the contract has been amended to substitute for the overhead allowance a management allowance entirely free from audit or other outside controls. The amount of the allowance is subject to annual renegotiation. By a collateral agreement the parties have arrived at an understanding with respect to the types of expenses which will no longer be treated as directly reimbursable and will be met out of the management allowance along with other corporate expenses authorized by the Trustees. The amendment also extended the term of the contract to June 30, 1954.

During the past year some organizational changes designed to improve the efficiency of the operation of the corporation were made. These changes generally complete the organizational steps recommended in the Wallace-Clark report of July 1950.

At the annual meeting in October 1951, Leland J. Haworth, Director of Brookhaven National Laboratory, was elected a Vice President. At the same meeting, the Controller was made a corporate officer.

During the formative period of the Laboratory organization, press relations were treated as a responsibility of the general corporate management. Early in 1952 it was decided that since the vast bulk of the work of the Press Relations Officer has come to be directly concerned with Laboratory operations, it should be transferred to the office of the Laboratory Director, and so supervised by the Director.

Effective June 30, 1952, Mr. John D. Jameson, Assistant Treasurer, terminated his connection with the corporation. Mr. Jameson joined the staff in September 1947 and has played an active part in the work of the Laboratory since that time. Appropriate recognition of his services was made by the Trustees at their meeting in July 1952, and his departure is a signal loss.

3. Fiscal

In October, Haskins & Sells, the corporation's auditors, reported the results of their audit of the corporation's books for the year ended June 30, 1951, accompanied

by an unqualified certificate. From its inception through the fiscal year to end June 30, 1953, AUI has been authorized by the AEC to undertake activities under the contract for the construction, maintenance and operation of Brookhaven National Laboratory, the total cost of which will amount to over \$78,000,000. At Brookhaven AUI is presently responsible under that contract for property, title to which lies in the Government of the United States, which is carried on its books at an amount, less depreciation, of over \$39,000,000.

ASSOCIATED UNIVERSITIES, INC.

ORGANIZATION CHART
August, 1952

PART TWO

REPORT OF BROOKHAVEN NATIONAL LABORATORY

INTRODUCTION

This annual report of Brookhaven National Laboratory describes the program and activities for the fiscal year 1952. 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 quarterly scientific progress reports, in special reports, and in scientific and technical periodicals. (For the Laboratory's output in publications since 1946, see Figure 2.) Hence, they are treated in this report primarily in summary form, whereas the activities of the service organizations are treated more fully.

The fiscal year 1952 witnessed an active and sound research program in progress at the Laboratory with research activities at the nuclear reactor exceeding all expectations. As noted last year, the one remaining large facility yet to be completed was the proton-synchrotron, or Cosmotron. The construction program for the Cosmotron drew toward its conclusion in the early spring, and operational tests involving start-up of the machine were inaugurated soon thereafter. Early experiments were rapidly successful in bringing the beam to an energy of about 50 Mev. Then in a series of rapid steps, which involved a correction of the radio-frequency accelerating voltage, the beam energy was increased to 1.3 Bev on May 20, the first time that 1 Bev was exceeded in the laboratory, and on June 10, the full beam energy of 2.3 Bev was obtained. This is the maximum energy expected from design considerations without the application of corrections for saturation of the magnet. Soon after attainment of the 2.3-Bev beam, operations were suspended while those parts of the machine that were found to be wanting in the early experiments were modified and completed. In addition, a shielding wall was to be placed around that half of the machine where experiments will be undertaken. It is expected that the Cosmotron will be ready for full operation in the fall as part of the Laboratory's high-energy research program.

During the completion of the Cosmotron construction and start-up, considerable effort has been expended in the design, construction and testing of equipment suitable for research use with the neutron beams, meson beams and gamma rays to be produced with the Cosmotron. Efforts toward this end have been made by the Accelerator Group itself and in the Physics Department, where photographic emulsion, cloud chamber, and electronic techniques are all being used in the design of experiments. During the past several years, physicists have been using similar techniques to keep abreast of experiments in high-energy physics. Research with cosmic rays at high altitudes, involving balloon flights, aircraft flights, and mountain-top experiments, has

Figure 1.

been reported in past annual reports. These activities are drawing to a conclusion with the availability of the Cosmotron. Machine experience with high-energy particles has been obtained through cooperative use of the Nevis cyclotron.

The nuclear reactor continues to play a vital part in the Brookhaven program, and the volume of research carried out with this facility during the past year has far exceeded original expectations. The rapidity with which experiments have been introduced at the reactor is extremely noteworthy. Over 30 separate experimental equipment arrays are set up at various positions on the reactor faces, and all fields of endeavor at the Laboratory are represented. During the year several special facilities have been incorporated to provide such specialized services as irradiation at room temperatures, irradiations of very thin sample foils, air-cooled holes where the temperature remains below 50° C, and a vacuum system for irradiation of gases. The top of the reactor, which has been reserved for thermal columns and for experiments with very large equipment, now has a thermal column for biological measurements, a thermal column used in connection with lattice experiments, a water tank assembly for shielding measurements, a fission plate installation for fast neutron measurements, and a thermal neutron hole for special treatment of patients. With the increased use of the reactor, it has been necessary to expand the balcony areas to provide adequate floor space for equipment. The reactor itself has operated without undue incident and during the course of the year accumulated a total of 6,371-megawatt days. A maximum power level of 31 megawatts was achieved during the colder winter months. The operating schedule maintained is a compromise between the demand for the maximum number of neutrons and the cost of operating the reactor: maximum flux is provided during the normal daytime hours, and reduced levels prevail at night and over week-ends.

Figure 2.

A high current, low voltage cyclotron was constructed during the year to provide a high-flux source of neutrons for special experiments in connection with the neutron cross sections program. The machine, an 18-inch cyclotron capable of producing 2-Mev protons and 3-Mev deuterons, is set up in a temporary location, pending results of operational tests, during which the beam currents are being built up and a survey of the radiation surrounding the machine will be made. A proper permanent location, providing both biological safety and low radiation levels for experiments, will then be selected. It is hoped that the circulating ion current from this machine can be as high as 1 ma of charged particles on a neutron-producing target.

The 60-inch cyclotron has passed through a troubled year during which good operating beams have been obtained but steady operating conditions have not prevailed over extended periods of time. As a result, continued engineering and modification have gone into the machine, and only occasional spot time has been available for research purposes.

The 2-Mev electrostatic accelerator has been used exclusively for research purposes during the year while procurement and fabrication of parts intended for its modification have proceeded. It is now expected that the modification of the machine to extend its energy to perhaps 3 Mev will be undertaken late in the fall of 1952 after completion of research activities now in progress.

In addition to the completion of the Cosmotron, progress was made on other projects of the facilities program. A former gymnasium building, modeled into the Metallurgical Laboratory, was occupied by the Metallurgical Division of the Reactor Science and Engineering Department in September, 1951. This was the first construction project contracted for directly by the Atomic Energy Commission under the new relationship between the Laboratory and the Commission inaugurated in fiscal year 1951. The second major contract undertaken by the Commission for the Laboratory consisted of the design and construction of the Biology Laboratory - Phase II. Design of this building was completed during the spring of 1951, and the construction contract was placed during that summer. Construction has proceeded essentially on schedule throughout this fiscal year but the building will not be occupied until late fall 1952. The engineering studies for a waste concentration plant were undertaken on subcontract between the Commission and Sanderson & Porter with the close collaboration of Laboratory engineers. The design studies were completed, and in the spring of 1952 a contract was let for the construction, which will start in July 1952. The plant is expected to be in operation in the spring of 1953. Projects that were carried out on subcontract with the Corporation consisted of reconstruction of the bridge over the railroad on the south access road and of the approaches to this bridge, and numerous small jobs relating to the modification of buildings, facilities and structures on the site.

Laboratory operations in the temporary wooden structures taken over from the Army in 1947 have reached the point at which major decisions must now be made concerning future quarters. Any consideration of the long-range development of the Laboratory plant requires detailed study of its programs, its aims, and the ultimate size of its various activities. In a combined program of study between the Laboratory and the Atomic Energy Commission initiated during the year, the Laboratory postulated an equilibrium staff size on which discussion of future activities and facilities could be based. A firm of architects was retained by the Commission to study the requirements, specifications and proposals set forth by the Laboratory. The sum of these

ORGANIZATIONAL EXPENDITURES - FISCAL 1951 & 1952												
(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 (Net)	Total Organizational Costs	% of Total	Capital Equipment External Costs Only
Physical Sciences	1952	1,111,460	52,389	73,191	48,752	268,419	(12)	22,655	(243)	1,576,611	17.1	80,666
	1951	1,156,135	54,400	59,594	47,611	325,993	1,393	37,778	14,511	1,697,415	21.2	65,536
Life Sciences	1952	702,077	15,713	45,417	26,888	211,359	-	-	(8,483)	992,971	10.8	37,645
	1951	526,747	10,310	27,026	16,973	172,806	7,225	-	9,883	770,970	9.7	67,718
Applied Research	1952	540,047	21,472	33,931	24,542	304,225	24,970	-	(10,366)	938,821	10.1	91,277
	1951	245,056	10,692	12,056	11,748	102,149	27,526	-	23,250	432,477	5.4	63,693
Radiation Protection	1952	223,659	2,244	14,344	5,362	26,665	18,300	3,478	-	294,052	3.2	7,622
	1951	181,563	738	9,450	3,696	35,101	16,840	4,306	4,748	256,442	3.2	6,009
Supporting Scientific & Technical Services	1952	1,293,794	2,608	82,496	5,915	201,288	-	439,825	(53,914)	1,972,012	21.4	57,977
	1951	1,136,806	1,452	58,643	9,042	264,926	-	237,947	4,336	1,713,152	21.4	42,201
Security, Police and Fire Protection	1952	491,883	-	31,355	32	13,155	-	-	-	536,425	5.8	50
	1951	438,184	-	22,899	186	9,403	-	-	-	470,672	5.9	-
Miscellaneous (net of income)	1952	-	-	-	32	17,681	-	-	181,525	199,238	2.2	3,209
	1951	-	-	-	276	64,049	-	-	180,080	244,405	3.1	7,720
General & Administrative	1952	1,978,153	672	125,957	14,426	444,940	-	-	(95,778)	2,468,370	26.7	44,902
	1951	1,838,159	1,556	94,913	14,624	422,841	-	-	(106,004)	2,266,089	28.4	89,024
Laboratory Total	1952	6,341,073	95,098	406,691	125,949	1,487,732	43,258	465,958	12,741	8,978,500	97.3	323,348
	1951	5,522,650	79,148	284,581	104,156	1,397,268	52,984	280,031	130,804	7,851,622	98.3	341,901
AUI Administration and Public Education	1952	12,420	-	792	1,047	3,402	-	-	152,218	169,879	1.8	-
	1951	20,759	-	1,076	1,534	5,346	-	-	96,000	124,715	1.5	-
Total: AUI and BNL	1952	6,353,493	95,098	407,483	126,996	1,491,134	43,258	465,958	164,959	9,148,379	99.1	323,348
	1951	5,543,409	79,148	285,657	105,690	1,402,614	52,984	280,031	226,804	7,976,337	99.8	341,901
Work for Others, Direct Costs Only	1952	40,838	6,319	2,665	12,123	23,885	-	-	-	85,830	0.9	-
	1951	3,903	-	(59)	143	7,944	-	-	7,616	19,547	0.2	-
Grand Total	1952	6,394,331	101,417	410,148	139,119	1,515,019	43,258	465,958	164,959	9,234,209	100.0	323,348
	1951	5,547,312	79,148	285,598	105,833	1,410,558	52,984	280,031	234,420	7,995,884	100.0	341,901

Figure 3.

considerations will constitute a long-range plan with which the Commission will establish a pattern for the future operation of the Laboratory. Although the plan will be centered primarily on the problem of gradually replacing the temporary structures with permanent housing for laboratories, technical services, administrative services and operational service areas, consideration will also be given to possible future requirements for higher energy accelerators and reactors to meet specialized needs. The next fiscal year should see considerable progress in the formulation of this long-range plan and constructive action in the way of budget requests for its implementation.

There is increased use of Brookhaven's own facilities in the research activities of the Laboratory. The relative emphasis between classified and unclassified work has remained essentially unchanged from last year. There has been an increase in applied work which is evidenced by the expanding neutron cross sections program and by greater activity in the field of development, design, and testing of reactor components. Some diversion of effort from fundamental unclassified work was still necessary owing to the world situation and the needs of national defense. This diversion was felt most strongly in chemistry and physics. The results of programmatic studies in these areas and of much of the classified applied work are found in the classified reports of the Laboratory.

The research of the Laboratory is carried out within the framework of seven departments. Basic studies in the physical sciences are made primarily in the Physics, Chemistry and Accelerator Departments, and research in the life sciences is conducted in the Biology and Medical Departments. Although the major portion of applied research goes on in the Reactor Science and Engineering Department, some applied projects are found in each of the other departments. The Instrumentation and Health Physics Department participates in research in both the physical and life sciences and in general supports the research activities of the entire Laboratory.

Although the research program of each department is representative of its own interests, the particular facilities and equipment available to it and the capabilities of its staff, the entire program of the Laboratory may be said to fall into four categories. These are:

1. Fundamental studies of atomic nuclei, the particles which constitute them, and the forces involved in their structure;
2. The physical, chemical and biological effects of radiation;
3. The use of nuclear tools, such as neutrons, charged particles, gamma rays, and isotopic tracers, in all branches of scientific research;
4. Research and development, not necessarily itself of a nuclear nature, directed at the specific problems of atomic energy development.

The status of the research activities and the significant developments of the year for each department of the Laboratory can be found in the separate departmental sections of this report. A few samples of significant advances made in the above categories will be noted here.

The Physics Department and Accelerator Department carry on the major portion of the studies of atomic nuclei, nuclear particles and nuclear forces. Specific advances have occurred in high-energy physics, in neutron physics and in the systematics of nuclear isomers. The efforts of all the high-energy research staff were directed primarily at modifying old equipment and constructing new equipment - cloud

COST DISTRIBUTION BY PROGRAMS

	PHYSICAL SCIENCES	REACTOR DEVELOPMENT	LIFE SCIENCES	OTHER
1951	62.9 %	6.4 %	22.4 %	8.3 %
1952	57.8 %	12.3 %	24.0 %	5.9 %
BUDGET 1953	56.9 %	17.2 %	23.6 %	2.3 %

MAJOR CATEGORIES OF EXPENDITURES

	LABORATORY SALARIES AND WAGES	MATERIALS AND SUPPLIES	SPECIAL POWER	ALL OTHERS
1951	73.6 %	18.2 %	3.5 %	4.7 %
1952	74.1 %	17.9 %	5.1 %	2.9 %

Figure 4.

chambers, counters, photographic emulsion cameras - for use with the Cosmotron. Continuing analysis of photographic emulsions exposed in previous years at high altitudes has resulted in the discovery of a new phenomenon, most likely due to a new particle. A charged particle apparently stops in the emulsion and two very fast charged particles emerge from the point where it comes to rest. Ten such events, described as T-tracks, have thus far been observed.

Neutron physics studies ranged from conventional cross section measurements to the measurement of the neutron-electron interaction. The cross section work is in a continuing process of expansion. Brookhaven played an active role in the completion and publication of the "Neutron Cross Section Compilation" under the sponsorship of the AEC Cross Section Committee. The publication brings together in graphical form a critical evaluation of the existing information as of March, 1952. The "fast chopper" completed successful initial trials, and results are already being obtained up to 1000 ev at greater precisions than ever before achieved. Increased rotor speeds for the chopper are still possible, and the range of energy measurement will be increased.

The systematics of atomic nuclei, especially isomers, and their description by shell theory is progressing through painstaking, precise, measurements of their half-lives, energies of their beta and gamma radiations, directional correlations of their radiations and their interaction with orbital electrons. Brookhaven results confirm the shell structure model and have led to refinement of the theory.

Radiation can be used to study the effects of the radiation itself on materials and organisms or to induce effects in specimens to permit their study under conditions not normally available. For example, radiation damage of a cell may give rise to information on radiation effects, and a study of the damaged cells may lead to an understanding of cell development. The physical, chemical, and biological effects of radiation are all under study. Materials are being studied both for changes in their fundamental physical properties, such as thermal conductivity or electrical resistance, under neutron irradiation and for their engineering application as suitable materials for use in high neutron and gamma radiation fields. The metallurgical studies are designed to satisfy the requirements of the nuclear engineering reactor designs. The program of fundamental studies on solid state was stimulated during the year by staff additions and by the presence of Professor J.C. Slater and other visiting theorists from MIT.

Radiation chemistry studies are concerned with chemical changes produced in water and aqueous solutions in exposing them to ionizing radiation. Progress has been made in the firm establishment of reaction mechanisms, the accurate measurement of free radicals and toward the accurate measurement of radiation dose.

The study of biological effects of radiation ranges from the study of simple cells to the application to humans. The facilities in use by the biologists provide x-rays, gamma rays from an 8-c Co source in a greenhouse and a 400-c source (to be increased to 2000 curies in 1953) in a growing field; there is also the new thermal column on top of the reactor which is designed for neutron exposures in biology experiments. A most interesting fact derived by the gamma-field studies is that plant function is selectively disturbed by continuous radiation, which results in not merely stunting, but also in inhibiting some aspects of growth. Recent thermal neutron studies have shown that there are qualitative differences between the radiobiological action of x-rays and thermal neutrons.

The radiation studies in medicine consist of gamma irradiation of small volumes to determine susceptibility of bacterial, viral, and multicellular elements to radiation, and the use of thermal neutrons from the reactor for therapeutic purposes. Eight patients were treated with thermal neutrons for glioblastoma multiforme. One patient received a total of four treatments. Results are promising, and additional research efforts are being applied to all aspects of the treatment problem, e.g., frequency of treatment, boron toxicity, tumor growth evaluation methods, and distribution kinetics of boron compounds in the brain and tumor tissue. The use of short-lived isotopes has received major attention and is a significant feature of the Brookhaven medical program. The therapeutic effects of such isotopes are due to internal radiation effects.

The tools of nuclear and atomic science are in use by all research workers at the Laboratory, generally in the form of tracers or of radiation, either neutron or gamma, in fundamental and applied studies. A large portion of this research effort is in chemistry and the life sciences. Neutron diffraction studies of structure, the kinetics of chemical reactions, photosynthesis, metabolism, protein synthesis, the application of gamma irradiation to the sterilization of foods and pharmaceuticals, and the catalysis of chemical reactions are but a few examples of the application of tracers or radiation to general scientific problems. Source development, as part of the search for the application of waste fission products, has now made available gamma sources of several thousand curies equivalent. The use of radioisotopes has had its greatest use in the hands of the biological and medical researchers where great advances have been made with tracers both in the analysis of biological processes and as sources of internal radiation.

The Laboratory also carries out research and development in areas which are not in themselves nuclear or atomic but which are vital to the development of the atomic energy program. A wide range of studies is pursued, e.g., basic chemical studies of elements vital to fission processes, metallurgy of reactor materials, and heat transfer. The areas extend to engineering studies of complete reactor components. Most of these results appear in the classified reports of the Laboratory. However, results are reported here on the ultimate disposal and the possible industrial use of fission product wastes. Kilocurie sources have been prepared for others for use at the Laboratory and elsewhere on a semi-commercial basis to study the applications to processes involving chemical or biological changes.

Several extensive technical conferences were held in support of the individual research programs in addition to regularly scheduled seminars and colloquia. The Biology Department held its annual conference in August, 1951, and 185 individuals participated in the discussions on the chemistry and physiology of the nucleus. A Fission Products Utilization Conference was held in February and was attended by 73 representatives of government, university and industrial organizations. A number of special committees and AEC groups held conferences and meetings at the Laboratory during the year. Representative of these were the AEC Shielding Group, the US Geological Survey Group, AFSWP Radiological Officers in Training, AEC Chemical Processing Conference, Neutron Cross Sections Committee and ONR Solid State Advisory Panel. Group visits wherein the facilities of the Laboratory were inspected and the Laboratory program was discussed were held for 27 different scientific and professional groups with a total of 985 in attendance.

The general information program directed at acquainting the Long Island and New York area technical and nontechnical neighbors with the Laboratory was continued.

The Laboratory was host on various occasions to a number of groups of scientific and professional persons. Constant effort is being maintained to keep the neighboring communities informed about the general aspects of the work at the Laboratory through the medium of speeches presented by staff members throughout the year and through a Visitors' Day in May. On the last Visitors' Day, 1482 visitors saw the facilities of the Laboratory and inspected exhibits which had been set up specifically to illustrate the research program.

The Public Information Office, which was a part of the Public Education Program of the Corporation, was transferred to the Laboratory organization on February 1, 1952. Public information activities, carried out in close collaboration with the Atomic Energy Commission, now constitute one of the responsibilities of the Director's Office. A wide variety of news media are served through releases and special help to newspapers, magazines, industrial publications, radio, television and newsreels. Brookhaven plays an important role for the AEC since the greater part of the Brookhaven work is unclassified. A file of information, both written and pictorial, has been prepared and is available for the general press and visitors. The Public Information Office was instrumental in carrying out much of the work required for one live television program from the Laboratory.

Personnel trends for the report year have been similar to those in the past in which there was an increase in scientific staff, an increase in technical supporting staff, and a decrease in the general and administrative service units. The extensive program of streamlining the administrative and service organizations has continued; it is felt that although some changes are still possible, the size of this group has now reached its minimum. The scientific staff of the Laboratory was on a continued growth curve throughout the year and the number of scientific personnel would have exceeded that reported for June 30, 1951, had not the budgetary uncertainties for FY1953 occurred in April. At that time, the Laboratory was informed that a research program of the size contemplated for fiscal 1953 could not be supported and as a result, personnel levels were frozen. Only minor changes in staff numbers are expected during fiscal 1953. There will, however, be several changes in emphasis wherein increased staff will be available for some of the applied programs, such as neutron cross sections work and certain reactor studies.

The actual growth of the scientific staff from January 1, 1947 can be seen from Figure 1 on page 8. The actual number of man months of work performed by the scientific staff is plotted for each month. The graph is therefore an indication of scientific services rendered and is also a measure of the average number of scientists present each month. Salaried visitors include scientists and engineers on leave from their institutions, graduate students doing doctoral investigations while 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 participate in the Brookhaven program but receive no remuneration for their services. The increase in numbers in the Guest category continues and reflects an expanding interest on the part of the scientists to make use of the facilities which are now available at the Laboratory. The services of consultants are not noted in the graph; during fiscal 1952 over 31 man months of service were rendered by these consultants.

In the fiscal year 1952, some 150 persons from educational institutions and 35 from other institutions participated in the Brookhaven research program. This is to be contrasted with approximately 90 and 10, respectively, who were engaged in the previous year's work. (In neither case do these numbers include those individuals

Figure 5. Visitors' Day at Brookhaven. Students listen to an explanation of the use of Geiger counters and other instruments used in atomic energy research.

who arrived in June to take part in the summer program. In June 1952, this group consisted of 120 individuals from 45 educational institutions and 5 from noneducational institutions.) The most significant fact about this increased participation program may be seen in a comparison of the 79 participants who received no compensation during FY 1952 as contrasted with 19 during FY 1951. It is quite noteworthy that the Brookhaven facilities and the capabilities of its staff are drawing more and more visitors who wish to take part in the program.

A formal program of participation by undergraduate and graduate students from universities and colleges during the summer period was initiated in 1952. A formal announcement of the opportunities for students to work at the Laboratory during the summer was issued in January. This announcement was circulated to colleges and universities in the northeastern United States and applications were received from 288 students. Selections were made on a competitive basis and acceptances were received from 35 undergraduates and 35 graduates. It is expected that this program of summer work for college and university students will be a continuing part of the Laboratory's activities.

Laboratory funds received from the Atomic Energy Commission are derived from two sources: one, operational funds and the other, plant and equipment funds. Since the Laboratory contributes services for the construction of equipment and in some

instances for the design and construction of facilities items, the total organizational expenditures of the Laboratory in any one year are made up of the total of its operational costs plus an appropriate share representing services rendered to plant and equipment projects. To compare the Laboratory in successive fiscal years it is more appropriate to compare the total organizational costs rather than to compare expenditures for the AEC operations program only. Thus, in fiscal year 1952 the organizational costs were \$9,234,000, an increase of about \$1,238,000 over fiscal year 1951. The increase in expenditures represents the continued expansion in the scientific program with a going annual rate in May, 1952 of about 9.6 million dollars. An operation budget of \$9,444,000 has been approved for fiscal 1953. To this must be added approximately \$200,000 for Laboratory services rendered in the construction of plant and equipment items, thus making the 1953 organizational budget approximately \$9,600,000.

The Laboratory experienced several organizational changes during the year which were, in part, associated with resignations from the staff. Significant organizational and personnel changes occurred in the Physics and Reactor Science and Engineering Departments. Dr. T.H. Johnson was granted leave on December 1, 1951 to become Director of the Research Division of the Atomic Energy Commission. Dr. S.A. Goudsmit served as Acting Chairman until July 1, 1952 at which time he was appointed Chairman for a period of three years. Dr. G.N. Glasoe, formerly of Rensselaer Polytechnic Institute, was appointed Associate Chairman of the Physics Department at that same time. Drs. Marvin Fox and Clarke Williams served as co-chairmen of the Reactor Science and Engineering Department after the resignation of Dr. L.B. Borst on August 1, 1951. The Reactor Department with Dr. Fox as chairman and the Nuclear Engineering Department with Dr. Williams were established August 1, 1952.

The position of Deputy Director was created by a consolidation of the activities of the Business Manager with those of the Assistant to the Director. Dr. G.F. Tape was named Deputy Director in October, 1951. As part of the business office change, an Inventory Management Group was set up under H.R. Cort. Consolidation of receiving and warehousing functions proceeded later with the transfer of the Receiving, Warehousing, and Distribution group to Plant Maintenance and its integration with the maintenance warehouses.

New Division head appointments were made during the year as follows: Electronics Division (Instrumentation and Health Physics) - W.A. Higinbotham; Pathology (Medicine) - J.T. Godwin; Research Hospital (Medicine) - Dr. L.K. Dahl.

PHYSICAL SCIENCES AND ENGINEERING

PHYSICS

During the past year the total personnel of the Physics Department numbered 116. The scientific staff consisted of 56 regular staff members and 12 guests, the technical staff numbered 42 and the clerical staff six. Not included in these figures are summer guests and short term visitors. Of the 12 guests only three were being paid by Brookhaven.

Four staff members were honored by fellowships and will be on leave of absence during the coming year. They are:

D.E. Alburger,	National Science Foundation Fellowship for research at the Nobel Institute in Sweden.
E.M. Hafner,	National Science Foundation Fellowship for research at Cavendish Laboratory, University of Cambridge, England.
A.W. McReynolds,	Fulbright fellowship for research with the Netherlands-Norwegian nuclear reactor at Oslo, Norway.
G.A. Snow,	Fellowship at the Institute for Advanced Study, Princeton, New Jersey.

Thomas H. Johnson, who had been the chairman of the Physics Department since August, 1947, and who was principally responsible for its growth and success, resigned from this position and took leave of absence on December 1, 1951 to assume the post of Director of the Division of Research of the Atomic Energy Commission; S.A. Goudsmit was acting chairman for the remainder of the year.

The present program of the Physics Department may be divided roughly into four major fields:

1. Study of nuclear particles
2. Properties of stable and excited nuclei
3. Neutron physics
4. Solid state research

The nuclear particle study covers primarily the investigation of mesons and, in general, phenomena occurring at very high energies. Until recently the principal means of observation was cosmic-ray research. The past year saw, however, a decided change in direction in this field. With the completion of the Cosmotron approaching, the effort in cosmic-ray study was gradually transferred to preparations for research with the high-energy particles produced by the machine. When the Cosmotron received its initial test, members of the Physics staff were ready to make observations with scintillation counters, photographic emulsions and a diffusion cloud chamber. The coming year will see cosmic-ray research at Brookhaven only as a supplement to the use of high-energy machines.

A significant result of this year's cosmic-ray work is the discovery of a new phenomenon, most likely due to a new particle. An analysis of photographic emulsions exposed in balloons at very high altitudes revealed a small number of heavy tracks which stop in the emulsion and have, issuing from the end point, two straight and very light tracks at 180° to each other. It seems that a charged particle stops and that two very fast charged particles emerge from the point in the emulsion where it comes to rest. One explanation is that the heavy track is caused by a hitherto unknown doubly charged

meson which disintegrates into two high-energy singly charged particles that fly off in opposite directions. Another possibility is that one may be dealing with a long-sought-for negative proton which is annihilated with a hydrogen nucleus in the gelatin, the resulting high energy being transformed into two mesons of opposite charge. The present evidence is insufficient for a definite conclusion to be reached. So far ten of these new events have been observed on the plates.

The research in nuclear properties comprises primarily the study of stable and excited cosmic nuclei and their radiations. Data on nuclear energy levels, magnetic properties of nuclei and their masses will eventually lead to an unraveling of the laws of nuclear structure. The present work at Brookhaven, like last year's, continues to make numerous contributions to this wide field.

Under neutron physics may be listed the study of the properties of neutrons and their interaction with matter. This research has been expanded, especially the measurement of cross sections of various materials for neutrons of different energies. A major achievement has been the completion of the so-called "fast chopper." This machine has a rapidly spinning horizontal rotor containing a slit system which acts essentially like a very fast shutter, giving short bursts of neutrons with high time resolution. It has already operated successfully at 6000 rev/min. At this speed, which gives 1- μ sec neutron bursts, a wider energy range and higher precision are achieved than hitherto for cross section measurements of neutrons up to about 1000-ev energy. After a second rotor is constructed, it is intended to increase the speed to about 15,000 rev/min.

Another valuable achievement is the publication of the Neutron Cross Section Compilation (AECU 2040) compiled at Brookhaven with the cooperation of the Neutron Cross Section Advisory Group of the Atomic Energy Commission. The book contains an explanatory introduction and large graphs showing the critically evaluated results of all neutron cross section data as of March 1952.

In the solid state research at Brookhaven nuclear tools, primarily neutrons, are used to investigate the properties and structure of solids. Neutrons are also used to alter the properties of materials (radiation effects). These studies have been greatly stimulated by a group of visiting theorists, led by J.C. Slater of the Massachusetts Institute of Technology, who spent the year at the Laboratory. The experimental work is still conducted on a rather small scale but is due for some expansion in equipment and personnel in the coming year.

An invited conference on x-ray and neutron diffraction was held at the Laboratory on December 18-20, 1951. About thirty visiting scientists attended this conference. Brookhaven was also host to a meeting of the Office of Naval Research Advisory Panel on solid state physics on May 12-13, 1952.

Nuclear Particles

T-Particles

A new type of event has been observed in cosmic-ray emulsions exposed at about 90,000 ft over Texas. A particle causing a heavily ionized track comes to the end of its range in the emulsion, and the very last grain is crossed by a thin straight track. Examination of the ends (with direction of particle travel determined by scattering) of

Figure 1. Schematic drawing, in projection, of star with T track.

1850 heavy tracks showed ten with end-grains crossed by thin tracks. In nine cases the thin tracks were of the minimum ionization kind, in one case it was a near-medium or "gray" track, and in no case could any angular break in the thin track be detected at its point of contact with the end-grain of the heavy track. The thin tracks are oriented roughly at random with respect to the heavy track, but since in a few cases they are approximately at right angles to it and appear something like the capital letter T, the tracks are provisionally called "T-tracks" and the slow, heavily ionizing particles, "T-particles."

To investigate the possibility of chance coincidence between minimum tracks and end-grains, the sizes of grains and the

numbers and lengths of thin tracks crossing the emulsion were measured. Twenty heavy tracks of a total length of 2.35 cm and containing 30,000 grains were examined for crossings by thin tracks anywhere along their length. Only five such crossings were found. Since 1850 tracks were examined for T-particles, chance coincidences could be expected on the average to produce $1850 \times 5/30,000 = 0.3$ crossings of the end grain alone. The fact that ten such crossings were observed leads to the conclusion that the T-tracks are not due to chance, the probability that they are coincidental being of the order of 10^{-12} .

Scattering measurements of the heavy T-tracks have placed the charge of the T-particles between 1 and 2 units and their mass between $1/2$ and 2 protonic masses. Scattering measurements of the thin tracks have not established the character of the fast particles, the observable track lengths being too short. However, since they produce minimum ionization tracks, the fast particles would have to have energies above 20 Mev, in one case above 500 Mev, if they were electrons; in the case of the one gray crossing track measured, scattering excludes the possibility of it's being caused by an electron.

In four cases, the origin of the T-particles cannot be found, in four cases the T-particles emerge from stars, and in two cases they are seen to originate in the middle of the emulsion with no other associated track. In these two cases, the T-particles arise from the interaction of an incoming neutral particle with a charged particle of the emulsion, and charge conservation then requires that the T-particle be singly charged, at any rate in these two "special" events. The sign of the charge depends on whether the neutral particle has collided with a proton or picked up an electron.

The nature of the T events is not understood, but some possible explanations under discussion are presented with the warning that current theories of particle properties are quite ignored. The T-particle may be (a) a doubly charged elementary particle decaying at the end of its range, with a lifetime longer than 2×10^{-11} sec, into two fast singly charged lighter particles; this case is inapplicable to the two aforementioned "special" events. It may be (b) a singly charged excited particle decaying at rest with a lifetime longer than 6×10^{-11} sec so that the excitation energy materializes as two fast singly charged particles, at the same time imparting to the residual, normal

particle so little kinetic energy (less than 0.1 Mev) as to make its recoil track unobservable. Or it may be (c) a singly charged particle which is annihilated at rest with an electron of the emulsion if the T-particles are positive, and with a proton of the emulsion if the T-particles are negative. The last explanation would include the possibility of the existence of the negative proton, the search for which actually inspired the search for T-tracks.

Unusual Decay of Mu-meson

Another interesting event has been observed in emulsions exposed at high altitude. A particle with a short, highly scattered track, typical of a meson but indistinguishable as to kind of meson because of shortness of the track, is seen to decay into another

Figure 2. Schematic drawing, in projection, of meson decay into three fast particles.

slow, lighter meson with the track of length, grain density and scattering typical of a mu-meson. At the end of its range, this latter particle decays, not into the familiar single electron, but into three fast particles, tracks of which are co-planar within the accuracy of measurement. This event is interpreted as a mu-meson decaying into three electrons, two of one sign and the third of the opposite sign. Although this is a hitherto unobserved mode of disintegration for the mu-meson, such a decay is theoretically possible.

Mu-meson Scattering

The analysis of a cosmic-ray mu-meson and proton scattering experiment has been completed. The momenta of the

particles and their scattering angles in 5 cm of lead were measured at sea level and at 3.4-km altitude. From the momentum distributions at these two altitudes for negative particles alone it was concluded that few, if any, mesons are produced below 3.4-km altitude. From the ratios of the number of positive particles to the number of negative particles at the two altitudes, a proton spectrum at 3.4-km altitude was derived. At this altitude protons were found to form about 20% of the total penetrating component. Mu-mesons were found to be scattered more than can presently be accounted for by elastic or inelastic Coulomb scattering outside or inside the lead nucleus. Corresponding to a cross section of 10^{-25} cm², the excess scattering was strongly forward, producing a "tail" adjacent to the multiple Coulomb-scattering distribution. The scattering cross section for protons of energies between 0.4 and 3.5 Bev was found to amount to $13 \pm 7\%$ of the geometrical cross section, while a total interaction cross section of only $38 \pm 9\%$ was obtained.

Pi-Meson Cross Sections

High-pressure diffusion cloud chambers were placed in the various pi-meson beams from the Nevis cyclotron of Columbia University. For 60-Mev negative pions a cross section of 3 ± 2 mb was obtained for ordinary (not charge exchange) scattering, while for 53-Mev positive pions the cross section amounted to 20 ± 4 mb. For the latter case, an angular distribution was obtained and indicated a $\cos^2\theta$ distribution in the center-of-mass

system. For 100-Mev negative pions a cross section of 10 ± 3 mb was observed for ordinary scattering. A total cross section of 107 ± 27 mb was found for 50-Mev positive pions scattered in helium. Several cases of pion absorption have been observed in helium, in addition to elastic and inelastic scattering.

With a large counter hodoscope the deflection of secondary particles from penetrating showers crossing a magnetized iron block has been observed, and the sign of the charge, as well as the momentum spectrum of such particles, has been obtained. The plus-to-minus ratio is equal to 1.5, which shows that at least 80% of the secondaries are mesons. Previous experiments at this laboratory have shown that mesons produced in penetrating showers are mainly pi-mesons. The energy spectrum shows that the median energy is ~ 1 Bev. The mean free path for interaction of these pions has been determined in carbon (74 ± 7 g/cm²), paraffin (77 ± 8) and lead (208 ± 38) and indicates a 20% transparency at the atomic weight of 12. The measurements in paraffin, intended to supply information about the cross section in hydrogen, do not offer a statistical accuracy good enough for quantitative conclusions. However, the results appear to indicate that the elastic n-p cross section decreases appreciably at 1 Bev energy for the pi-meson, with respect to that measured at cyclotron energies. The spectrum of pi-mesons from penetrating showers, without regard to the type of event observed, has also been obtained in a cloud chamber by observation of multiple Coulomb scattering in a lead plate. The same cloud chamber experiment gives evidence that secondaries of penetrating showers, the majority of which are pi-mesons and the median momentum of which is 1 Bev/c, produce V⁰-particles with a cross section probably larger than 1/100 of the geometrical.

Large Cosmic-Ray Showers

The investigation on air showers, total energy $> 10^{13}$ ev, has been continued by extending measurements up to B29 altitudes. It has been found that from sea level to $\sim 10,000$ ft the nucleonic component in such showers follows closely the altitude dependence of the electronic component, and from 10,000 to 35,000 ft the nucleonic component increases somewhat faster. At an altitude of 11,000 ft, transition-effect experiments have been made in regions near the cores of the air showers. Although the transition effect of the electronic component was easily observed, no transition effect was obtained for the nucleonic component. An experiment designed to obtain evidence of an appreciable local production of electronic component by nuclear interacting particles, the pre-existing electrons being filtered out, gave no positive result. While the problem of the propagation of such large-energy air showers remains unsolved, the evidence collected at present provides rather stringent criteria for hypotheses and theories concerning the study of such high energy events.

Preparations for Cosmotron Experiments

The completion of the Cosmotron and the availability of mesons produced with the Columbia cyclotron at Nevis have led to further emphasis on the construction of apparatus to be used with accelerators. A high-pressure diffusion chamber having an effective length of 6 ft has been constructed. When filled with 20 atmos of hydrogen this chamber will enable one to study details of events in more than 2×10^4 g/cm² per day's run at an accelerator. By distorting the projected photographs to such a shape that the cloud chamber tracks are compressed lengthwise, it is expected that 80 to 90% will be saved of the time now necessary for scanning for a given number of events.

Nuclear emulsions were used to examine the radiation from the Cosmotron. They were exposed at several different localities; the chief interest, of course, centered on those placed in the direct beam and in the control room. Direct measurements of the tracks of charged particles were made and showed fluxes consistent with those expected from the Cosmotron. Neutron fluxes were estimated by counting neutron-induced stars in the emulsions, with the approximation that the cross section for such events is the nuclear geometric cross section. Stars of as many as 16 prongs were observed.

Counter telescopes have been prepared for examination of radiations from the Cosmotron. Several telescopes have been completed, and tested at Nevis. They are essentially of two types: one consists of scintillation counters alone and the other of scintillation counters in combination with a Cerenkov counter. The latter acts as a threshold detector since the refractive index of the counter material determines the lowest velocity of ionizing particles it can detect.

A scintillation counter telescope placed in the forward beam of the Cosmotron showed that the beam was confined, under the best operating conditions, to a well-defined pulse of 1- or 2-msec duration at the end of the cycle. Replacement of the last scintillation counter by a water Cerenkov counter, with a threshold of 0.5 Bev for protons and 80 Mev for mesons, resulted in essentially the same counts, and so it was concluded that the beam consisted predominantly of high-energy particles. The charge fluxes were consistent with those measured with the emulsions.

Besides being used to discriminate between various radiations, Cerenkov counters have been employed to measure particle energies. For this use was made of the fact that the refractive angle of the emitted light depends both on the velocity of the particle and on the refractive index of the counter material. Accordingly "spectrometers" based on this principle have been constructed for resolving the various energies of mesons and protons from the Cosmotron.

Nuclear Properties

Isomers and Shell Structure

The research in nuclear properties has proceeded in full swing, and numerous new results have been obtained. As described in detail in the previous Annual Report, (BNL 131(AS-5)), one of the aims in this work has been to obtain further confirmation of the so-called shell model of nuclear structure by study of the properties of excited energy levels. Especially revealing are excited states that do not immediately decay into the ground state, but have an appreciable lifetime. Nuclei in such excited levels are called isomers. Isomeric transitions have been investigated for a large number of nuclei, and many new ones have been discovered. Precision energy measurements of the gamma rays and beta rays emitted by excited nuclei have made it possible to derive reliable energy level schemes for several nuclei. By observing directional correlation between successive gamma rays emitted by an excited nucleus and by studying the interaction of these gamma rays with the electrons surrounding the nucleus, it has been possible to determine the spin of these energy levels.

The results have not only given a confirmation of the shell structure, but the Brookhaven work has led to refinements of the theoretical model and has helped to explain apparent deviations. A survey of excited states of even-even nuclei has yielded

Figure 3. Three-dimensional model of excited energy levels, based on an isotope chart.

Figure 4. Conversion electron spectrum of Hg^{197m}-Au^{197m}. Analysis of a complex gamma-ray spectrum is achieved by photographing internal conversion electrons with a permanent magnet beta spectrograph.

the conclusion that the n th excited state usually has a spin $I \leq 2n$. For $n = 1$ one finds $U = 2$ (even parity) with very few exceptions, in agreement with theoretical expectations for an even number of equivalent particles. The energy of the first excited state plotted against the number of protons and neutrons in the nucleus varies smoothly and reaches maxima at closed neutron and proton shells. It is illustrated in Figure 3, which shows a three-dimensional model based on an isotope chart. The highest energies occur for "double magic" nuclei. An energy "trough" (~ 80 kev) appears in the rare earth region, and still lower values are reached in the heavy element region. The model has proved valuable for experimental and theoretical investigations.

In the absence of explicit calculations on L conversion coefficients, further progress on an empirical basis has been made. It has been demonstrated that $L_I/L_{II}/L_{III}$ conversion ratios can be very helpful, and often decisive, in assigning the multipole character of isomeric transitions.

A review of the subject of "Nuclear Isomerism and Shell Structure" has been written and is scheduled to appear in the Reviews of Modern Physics.

An interesting isomeric state occurs in the new element technetium. The excited state has a half-life of about 6 hr and decays with a gamma ray of only 2-kev energy,

followed promptly by a more easily observed 140-kev gamma ray. The 2-kev ray is strongly converted; this means that the energy is carried away by one of the electrons surrounding the nucleus instead of by the emission of the gamma ray itself. The behavior of the surrounding electrons can be affected by outside influences. It is possible therefore to cause small changes in the gamma-ray conversion and thereby in the transition probability from the isomeric state. This should be observable as a small change in the half-life of the radioactive Tc. It has indeed been found that a small difference exists between the half-life of pure Tc and the same element in various chemical compounds. For example, the half-life of KTcO_4 is 0.3% shorter than that of the metal. More recent experiments indicate that in this and similar cases compression of the material under very high pressure also causes a small change in the half-life. Such observations give a direct confirmation of the theoretical concepts concerning radioactive transitions. In ad-

Figure 5. Influence of chemical state on the lifetime of a nuclear isomer (Tc^{99} 6-hr) is illustrated by the difference in ionization observed with a double ionization chamber.

dition, a more detailed analysis may lead to a better understanding of the behavior and distribution of atomic electrons in solid materials.

Nucleon Interactions

Two independent measurements of the total scattering cross section of neutrons by protons were made. The purpose of these experiments was to investigate the nature of

the fundamental interactions between nucleons. In particular, when compared with proton-proton scattering experiments, they serve as the most direct test of the hypothesis of the charge independence of nuclear forces. In the first measurement neutrons of 14-Mev energy were used. These were produced by bombarding tritium with deuterons from the small electrostatic generator of the Department of Terrestrial Magnetism. An analysis of the results found the range of the neutron-proton (n-p) singlet interaction to be about 20 % smaller than the corresponding proton-proton (p-p) range. However, the substantial experimental uncertainty still present in the n-p singlet range precludes any conclusive statement to the effect that n-p and p-p intrinsic ranges are unequal.

In the other measurement, which was of higher accuracy, neutrons of 4.75-Mev energy were used. These were made by bombarding a thin-walled deuterium gas target with deuterons from the Van de Graaff generator at Brookhaven. Care was taken to minimize uncertainties caused by neutrons of other energies, unshadowed background, scattering effects, and other causes. An analysis of the results at this energy depends on assumptions about the shape of the nuclear interaction potential function. The n-p range is found to be smaller than the p-p range by much more than the sum of their probable errors if a Yukawa potential is assumed, while the ranges are equal, within the errors, for a square well potential, and for a Hulthen or Yukawa potential attached to a small repulsive core.

Nuclear Masses and Decay Schemes

The Van de Graaff accelerator was used in conjunction with an electron lens spectrometer to study several activities of short half-life. One of these is the 12-sec period of F^{20} . From the results, it is possible for the first time to establish by nuclear data alone an accurate link between the masses of isotopes lighter than fluorine and the isotopes from neon to sulfur. The lens spectrometer was also used by itself to investigate several radioactive substances of longer half-life. An important case was the decay scheme of Rh^{106} , which is of interest because of an unusual angular correlation between the gamma rays emitted. A similar spectrometer is now in use at the reactor for the measurement of both pile-activated sources and neutron-capture gamma rays.

With the magnetic time-of-flight mass spectrometer developed at Brookhaven it was possible to measure the masses of the heavy atoms lead and bismuth and several other elements whose masses had not before been determined with adequate precision. Subsequently published results from other laboratories, obtained with conventional mass spectrometers, showed excellent agreement with the Brookhaven values. This agreement is significant because the measuring techniques used are totally different. It should be noted that the conventional spectrometers are high-precision instruments developed over several decades, whereas the Brookhaven machine is a first, and rather primitive, model using new principles. Making use of the wartime perfection of radar techniques, it derives its precision from the great accuracy with which time intervals can be measured. Its success indicates a promising future for this type of instrument.

In anticipation of the development at Brookhaven, and elsewhere, of modified time-of-flight spectrometers of much higher precision, the mass determinations with the present model have been discontinued. The spectrometer has been simplified and has been found useful in a number of chemical problems. The continuous observation of the whole mass spectrum makes it possible to follow reactions on the oscilloscope.

For example, the observation of the spectra of some decomposing deuterated organic compounds has aided in the confirmation of their structure formula.

Nuclear Moments and Molecular Structure

The nuclear moments program is directed toward the measurement of nuclear spins and related properties of radioactive nuclides by various techniques. For a few years the principal effort has been in the field of microwave spectroscopy. During the past year, some considerable effort was spent on the phosphorus spectra in POF_3 and PSF_3 preparatory to the determination of the spin and quadrupole interaction of the P^{32} nucleus. Unfortunately the chemical problem of preparing the gas containing P^{32} proved to be very severe, and the study was limited to the stable molecules $\text{P}^{31}\text{O}_16\text{F}_3$, $\text{P}^{31}\text{O}_17\text{F}_3$, $\text{P}^{31}\text{S}_3\text{F}_3$. From the data obtained, it was possible to learn some of the structural constants of the molecules. Further work on the chemical phase of this problem is being done at Johns Hopkins University by Professor Walter Koski. Because of the difficulty of the chemical phases associated with the microwave spectroscopy, and the limited manpower available, it is planned that the spectroscope will be kept in a standby condition so that it may be used for cooperation with chemists from outside organizations who may wish to work out the chemical problems.

Two additional problems have been studied with the spectroscope: (a) the structure of the molecule furan $(\text{CH})_4\text{O}$, and (b) the structure of PH_3 , PH_2D , PHD_2 and PD_3 . The work was done in cooperation with the Chemistry Department and supplemented by the use of infra-red spectroscopy. In the latter group the spectra show the effects of centrifugal stretching of the molecule.

The technique of paramagnetic resonance has been used to measure nuclear spins in a few cases in which a paramagnetic ion containing the nucleus to be investigated can be prepared. The value 6 for the spin of the V^{50} nucleus has been found in this way. By further study of this technique with Ni^{59} the possibility of working with radioactive nuclei is being explored. In the course of this investigation a new free organic radical (picryl-*n*-amino carbazyl) was studied. It had a sharper resonance line than had heretofore been observed. The measurements indicate that this material possesses a magnetic anisotropy associated with its crystalline form.

For several radioactive nuclei it is expected that the atomic beam resonance method will give valuable data on nuclear moments. Accordingly attention is now being concentrated on this technique.

Work is also in progress on a high-precision determination of the magnetic moment of the neutron. In this experiment magnetic mirrors are used to polarize the neutrons in conjunction with a magnetic resonance technique similar to that used in atomic beam experiments.

Techniques

Several technical developments have been made. One of these is a new type of fast neutron detector with high efficiency for neutrons but low gamma-ray efficiency. The detector is comprised of lucite mixed with zinc sulfide and molded into a semi-transparent button. This button is then mounted on the face of a photomultiplier tube.

A novel type of pair spectrometer for the measurement of high-energy gamma rays was designed and tested. For fixed momentum resolution, it permits the use of larger converters than have heretofore been possible. The technique of growing scintillation crystals impregnated with radioactive substances has been further developed. It has been used in a variety of new problems (to investigate shapes of spectra, L/K electron capture ratio, etc.) and has become a versatile and simple "spectrometer".

A preliminary investigation of 3-Mev neutrons scattered by a target placed inside a diffusion cloud chamber has established that hydrogen gas in the chamber at a pressure between 3 and 10 atmos can be used as a neutron detector. Thus, for sufficiently high neutron energies, this method can be used to study the angular distribution and energy degradation of the scattered neutrons.

Theory

Quantum electrodynamics has to date been the only successful field theory. The extremely accurate experiments of Lamb on the shift of the atomic energy levels of hydrogen provide a fine test of the theory. For this reason the approximations involved in a previous calculation of the contributions of the fourth-order of quantum electrodynamics to the level shift were investigated. It was found that the approximations are accurate to this order of calculation, $\alpha^6 Z^4$.

Neutron Physics

Neutron Cross Sections

The "fast chopper" was described briefly in the previous Annual Report, and the type of work for which it was designed was discussed briefly. It is a rapidly operating shutter that produces bursts of neutrons of about 1 μ sec duration. The rotor of the chopper is a flat horizontal disk constructed mainly of aluminum. It contains plastic inserts or "arms" in which narrow slits are machined which allow neutrons to pass through the rotor. The rotor is mounted on a vertical axis in an evacuated chamber and is actuated by a direct motor drive for speeds up to 15,000 rpm.

Because of the need for cross sections in the intermediate energy range, the construction of the chopper equipment was speeded up as much as possible during the last few months, and tolerances were relaxed slightly to get the first model into operation. The apparatus is now running successfully at 6,000 rpm, at which speed the burst length is 1 μ sec and the resolution 0.1 μ sec/meter, a higher resolution than is available with any existing velocity selector. The present rotor was tested after several weeks of operation at 6,000 rpm, and no evidence of dimensional change could be observed. Since no weakness has come to light as a result of the initial operation, the second rotor will be identical with the first. Since at the present time there are no electronic circuits for recording the time of arrival of the neutrons at the detector, the pulses are transmitted to the cyclotron building where they are analyzed by means of the timing circuits of the cyclotron velocity selector.

Cross section measurements taken with extremely slow neutrons have been continued by means of the "slow chopper," which has operated successfully throughout the entire year. The equipment has been used mainly for the study of inelastic scattering

Figure 6. Partially assembled rotor (30 in. diameter) of the fast chopper. Some of the plastic pieces that form the slits are shown in place on the lower half of the aluminum disc. The pieces at the periphery are held in place by the teeth machined in the plastic and the aluminum.

of slow neutrons (of wavelength $4 \text{ \AA}$ to $25 \text{ \AA}$). For such slow neutrons (in materials of low capture cross section) the main contribution to the cross section comes from absorption of a quantum of lattice vibration energy (a phonon) by the neutron. Bismuth has been studied extensively during the year, and the data can be explained on the basis of the Debye spectrum of lattice vibrations. The most interesting results have been observed with iron, in which the observed inelastic scattering is about double the theoretical value. The excess scattering may be caused by "magnetic lattice vibrations" or spin waves. Special experiments are now being run above and below the Curie point in iron to elucidate this new type of scattering. Measurements have also been made with paramagnetic materials, and for certain of these the same type of excess scattering has been found.

Neutron-Electron Interaction

The electrostatic neutron-electron interaction, caused by the dissociation of the neutron into a proton and a meson, was measured during the year by a mirror experiment.

Because this interaction is 10^4 times smaller than the neutron interaction with the nucleus, its measurement required high precision, and therefore the technique of balanced mirrors was used. A well-collimated beam of neutrons was totally internally reflected from a bismuth mirror covered with liquid oxygen. From the critical angle for total reflection for graphite-filtered neutrons and the coherent scattering amplitudes of bismuth and oxygen, the neutron-electron interaction was determined. The liquid oxygen was used because it balances the nuclear scattering of bismuth almost completely, with the result that the critical angle is very sensitive to neutron-electron scattering. The free atom cross sections of bismuth and liquid oxygen were determined from transmission measurements made with pile neutrons filtered through various thicknesses of cadmium and boron. Since the incoherent scattering cross sections of bismuth and oxygen are small, the coherent amplitudes follow directly from the free atom cross sections.

The neutron-electron interaction can be represented by a potential well equal to the radius of the electron and a depth of 4200 ev, only a few hundred volts greater than the "magnetic interaction" of 3900 v. The magnetic interaction follows directly from the magnetic moment of the neutron regardless of dissociation. The difference, 300 ev, which is the electrostatic interaction between the neutron and the electron, is smaller than predicted by the meson theory.

Level Densities

The level spacing at an excitation energy about 6 to 8 Mev above the ground level can be obtained from the capture cross section of 1-Mev neutrons as described previously. More information on these level spacings has been obtained during the year by means of the U^{235} converter plate mounted in the shield of the pile. The apparatus has been improved somewhat to allow easy insertion and removal of the samples without pile shutdown. The most interesting result obtained concerns the isotopes of tin, all of which have the magic proton number 50. It has been found that these isotopes have lower cross sections, that is, lower level densities than elements of similar atomic weight. The amount by which these isotopes differ from "normal," however, is much less than the difference exhibited by isotopes of magic neutron number. These results illustrate again the difficulty of comprehending nuclear structure by means of a single model. The observed level densities at the excitation energy agree in general with the prediction of the liquid drop nuclear model, but the behavior near magic numbers is in accord with the shell model.

Compilation Group

As an aid to the work of the Neutron Cross Section Advisory Group, a small working staff operating mainly as a compilation group has been in existence at Brookhaven for about a year. This compilation group has done most of the work involved in the publication of the Neutron Cross Section Compilation AECU-2040 which recently appeared. The group is now organized on a continuing basis and will act as a clearing house for cross section information, collecting, evaluating, and compiling cross sections.

High Neutron Flux Cyclotron

During the past year a small cyclotron has been designed and constructed for the purpose of providing a large flux of high energy neutrons for use in the study of

inelastic scattering. The considerations leading to the design of this cyclotron centered around the use of $H^3(p,n)$ and $H^3(d,n)$ reactions with proton or deuteron beams of about 1 ma incident on the target. Protons of energies in the range of 0.5 to 3 Mev and deuterons of energy up to 2 Mev are to be available with a minimum of difficulty in changing from one energy to another. The construction phase of this small cyclotron and its associated equipment have now been completed. Tests are currently being made on the various components.

Instrumentation for Cross Sections of Neutrons Above 0.1 Mev

The task of measuring differential neutron cross sections, for neutrons of energies ranging from 0.1 to several Mev, involved a proper source of neutrons and proper detectors. As a source the 18-in. cyclotron, described above, will be used. Efforts to develop detectors have led to the scheme of using different detectors for scattered neutrons of different energies. After trials of various proposals, the work has been concentrated on the following instruments: (a) a hydrogen-filled diffusion chamber for neutrons of 1 Mev or greater energy, (b) an He^3 counter for neutrons between 0.4 to 1 Mev, and (c) a fast scintillator for determining the energies of neutrons of energy less than 0.4 Mev by time-of-flight, measured from the instant the pulsed beam (proton or deuteron) of the cyclotron strikes its target.

The diffusion chamber holds 10 atmos of hydrogen and contains the scattering material, on which impinges a collimated beam of monoenergetic neutrons. The scattered neutrons then produce recoil protons in the surrounding hydrogen and the range and direction of the tracks give the energy of the neutrons. Since the n-p cross section is well known, the intensities of scattered neutrons of any given energy can be simply calculated from the number of relevant tracks. This chamber has been tested with satisfactory results with a carbon scatterer and with homogeneous neutrons from the Vande Graaff machine, and its further use awaits the greater intensities of the cyclotron. The lower limit of about 1 Mev to the energies of detectable neutrons results from the shortness of less energetic recoil tracks.

The He^3 chamber depends on the energy of capture of neutrons, the result of the capture leading to the emission of a proton and a triton of known Q value. The principle involved is, then, that a given size pulse corresponds to capture of a neutron of a given energy. The upper limit of its usefulness may be as low as 1 Mev (although it may turn out somewhat higher) because of the possibility of confusion of elastic recoils with the capture process. The lower limit is expected at about 0.4 Mev because of confusion with the always existing background of low-energy neutrons, which are captured much more efficiently by the helium. The chamber has been tested in the neutron beam of the pile and shows, so far, an energy resolution of 11%.

The counter selected to measure the low-energy (below 0.4 Mev) neutrons consists of a slab of uranium, which converts these slow neutrons into faster fission neutrons, and one of the new zinc sulfide detectors to pick up the scintillations from the protons recoiling from the fission neutrons. It was necessary to introduce the uranium converter because of the inefficiency of scintillators for detecting directly recoil protons of 0.4 Mev or lower energy. It was necessary to use the new detector rather than the more conventional scintillators because of its insensitivity to electrons, which result copiously from fission (radioactivity and gamma rays). When tested in the neutron beam of the pile, this counter showed an efficiency of about 1/4% for neutrons in the 0.1 - to 0.4-Mev range, and, by working with the initial rise of the zinc sulfide scintillation,

it can be used for time intervals of 5×10^{-8} sec. With the expected fluxes from the cyclotron, these values lead to the expectation that energies of scattered neutrons in this range can be adequately measured.

Solid State Physics

Structure of Solids

Neutrons can be used similarly to x-rays for investigating the properties of solids. In several ways they are superior to x-rays, and these unique properties of neutrons are the ones that are being extensively studied. Spectrometers have been put in operation for the investigation of crystals by means of scattering and diffraction of thermal neutrons. One of these is the double crystal type, designed for the diffraction analysis of single crystals; the second is a single crystal type. By development of suitable crystal and filter combinations the latter extends the range of crystal monochromators to from 1 to 9 Å for studies of long wavelength neutron scattering and transmission.

A structure analysis has been carried out for KH_2PO_4 , one of a number of crystals to be studied because of interesting dielectric and ferroelectric properties. Since the hydrogen positions are not amenable to x-ray analysis but can be determined by neutron diffraction, there are a large number of hydrogenous crystals to be investigated.

Diffraction techniques have been successfully applied to a study of cold work in brass. Integrated intensities have been shown to be identical in cold-worked and annealed brass with no trace of extinction effects. A new technique of examining the Bragg discontinuities has clearly shown that the major part of the line broadening is attributable to lattice distortions. Extinction effects have been studied both theoretically and experimentally. In polycrystalline media of large grain size the determination of mosaic block size and angular spread has been accomplished. It has been shown that incoherent scattering beyond the diffraction cutoff is a measure of lattice imperfections. Long wavelength transmission measurements are of considerable potential importance in studying lattice imperfections.

Recent work on the inelastic scattering of slow neutrons covered the following problems:

- (a) Calculations of the total one phonon cross section as a function of temperature and wavelength. The theoretical results were confirmed in the case of lead by transmission measurements.
- (b) Theoretical investigation of the inelastic scattering of a single crystal.
- (c) The magnetic scattering of neutrons in paramagnets and ferromagnets with emphasis on the effects arising from the coupling of the ionic spins. There seems to be evidence for this type of scattering from the velocity selector work.
- (d) Theoretical work on the energy distribution of scattered neutrons.

Radiation Effects

The field of radiation effects in solids has been surveyed in order to formulate a more extensive program in this important area. A critical review article, "Radiation Effects in Solids," has been completed for Volume II of Annual Reviews of Nuclear Science.

Theoretical studies have been concerned with the effect of lattice imperfections (vacant lattice sites and interstitial atoms) on various physical properties. Analytical study of the elastic constants of metals as a function of irradiation has been completed. The results indicate that elastic constant measurements may distinguish between vacancies and interstitial atoms. Further theoretical work is in progress on the properties of lattice vacancies -- particularly with respect to their mobility and aggregation into clusters as well as their role in diffusion theory. Theoretical analysis of self-diffusion in graphite has shown that direct interchange of carbon atoms within the hexagonal planes is very probably the dominant mechanism in this substance.

Some metals (copper and aluminum) have been irradiated and studied for radiation damage. Low temperature is required to prevent thermal annealing of the radiation effects; irradiation was carried out in the reactor in a recently completed facility designed to maintain temperatures of -150°C to -195°C . Low temperature (liquid nitrogen) measurements of such properties as electrical resistivity, elastic moduli, internal friction and x-ray line broadening are in progress. Measurements of lattice parameter changes and x-ray line broadening of irradiated quartz crystals and crystals of black phosphorous and copper-silicon are also in progress (the last two in cooperation with B.E. Warren of Massachusetts Institute of Technology), and a number of magnetic materials have been irradiated for damage studies in cooperation with Bell Laboratories. Experimental work in this field is expected to expand considerably during the coming year. Plans have been made for extensive fundamental studies on radiation-induced lattice imperfections and related problems of general solid state physics.

INSTRUMENTATION AND HEALTH PHYSICS

Both the Electronics and Instrumentation Division and the Health Physics Division, which constitute this Department, have dual functions: to furnish services to the rest of the Laboratory and to conduct some independent research and development in the fields of radiation protection and instrumentation. In addition, the Health Physics Division has an important role in training individuals and groups in radiation safety principles and practices. The principal accomplishments of the research and development programs have been described in the Quarterly Progress Reports and, in most cases, in reports or journal articles, so only brief mention will be made of them here.

The Electronics and Instrumentation Division began and ended the year with a staff of 47, comprising 15 scientists and engineers, 30 skilled technicians and two administrative personnel. During the year one physicist, two engineers and the executive aide resigned, and all were replaced. Effective January 1, 1952 W.A. Higinbotham became head of the Division. In addition two visiting scientists and two research assistants have joined the staff for the summer of 1952.

Health Physics, on the other hand, lost six staff members during the fiscal period - four scientists or engineers and two technicians - and ended the year with a total staff of 40, comprising 15 scientists or engineers, 22 technicians and three clerical and administrative personnel. The reduction in staff was offset to some extent by three summer employees and four surveyors who were here for six months on loan from the American Cyanamid Corporation. The departure of these men and the increased workload resulting from growing use of the reactor and the accelerators have forced curtailment of

some research and development activities in the field of radiation dosimetry. The large turnover in the surveyor group is an indication of the fact that after a few years' experience at Brookhaven a surveyor is ready to fill a position with more supervisory responsibilities. The training activities of the Division have been strengthened by the addition of Mr. F.B. Oleson, formerly a professor of physics at the University of Maine, who is devoting most of his time to various aspects of training both for Brookhaven employees and for groups from other institutions or agencies.

Various members of the Department have participated in activities directly related to national defense. W.A. Higinbotham spent three and a half months with the Vista Project study group for the Department of Defense, and J.B.H. Kuper headed a panel, in which F.P. Cowan also participated, for Project East River. Dr. Cowan also spent half time with the Federal Civil Defense Administration for about ten weeks, consulting on radiation instrumentation problems. About ten per cent of the total effort of the Electronics Division was devoted to two classified projects in connection with the fall series of tests at the Nevada Proving Ground at the request of the Armed Forces Special Weapons Project. Three experienced surveyors from the Health Physics Division served ten weeks in Nevada as members of the AEC Radiation Safety Group for the same series of tests.

Electronics and Instrumentation Division

Instrumentation Research

In devising instrumentation for scientists in many different fields, it is not enough simply to build amplifiers or ratemeters as requested. As far as possible the Division tries to keep in touch with the research programs of other Departments in order to anticipate what new developments will be needed. Each individual order generally requires consultation, and most items are designed specifically to fit the customer's need. Any complex instrument is tested under conditions similar to those in which it will be used. In many cases the instrument designer carries out a sample experiment or works with the scientist until useful data have been obtained. While the degree to which this is necessary varies with the problem and the experience of both parties, it is evident that the usefulness of the Division will be enhanced as this policy is extended.

Primary emphasis has been placed on developing and refining scintillation counting techniques. This counting method makes use of the fact that nuclear rays produce light pulses or scintillations in various fluorescent crystals, which scintillations may be detected by a photomultiplier tube. When the intensity of the scintillations is proportional to the energy of the incident rays, the spectrum of the radiation may be determined by analyzing the pulse height distribution from the photomultiplier. Success in growing good scintillating crystals of lithium iodide activated with tin has made possible compact and efficient detectors of thermal neutrons. Pulse height analysis by the photographic method has been thoroughly investigated. The distribution of the scattered radiation in the neighborhood of intense gamma sources has been analyzed with a photographic scintillation spectrometer system.

Beam deflection amplifier tubes with secondary emission have been designed and constructed, and the theory of such tubes has been verified. The results indicate that tubes of this description offer promise for fast scaler applications and for dc amplifiers.

Factors affecting the life of noble gas organic quench vapor G-M tubes have been under investigation for several years. There is convincing evidence that contamination of the cathode by dissociation products of the quench vapor rather than destruction of the vapor itself is the principal limitation to the life of the tube.

In order to determine the maximum speed that can be obtained in photo and electron multiplier devices, a project was initiated to determine the promptness with which secondary electrons are emitted.

Electronic Instrumentation

Among the many instruments produced this year, the following are indicative of the scope of the Division's activity:

1. Counting ratemeter circuits have been improved and several different models have been designed. Accuracy of 0.1% can be obtained together with stability of the zero setting. Both a count ratemeter and a count integrator have been built with a ten times expandable scale for greater sensitivity in automatic recording systems. A simple circuit was devised to give the product of pulse height and pulse rate for random signals.
2. The gray wedge technique has been applied to a Compton gamma-ray spectrometer (as used by R. Hofstadter) and to a delayed coincidence analyzer which measures short time intervals.
3. A ten-channel pulse height analyzer with a cathode ray deflection tube has been built.
4. Two simplified models of the non-overload amplifier (Chase and Higinbotham, Rev. Sci. Instr. 23, 34, 1952) have been produced. One is useful for scintillation counting and the other for proportional counter work.
5. A system has been constructed to provide high power rf at accurately determined frequency for an experiment to measure the magnetic moment of the neutron. The 5 mc of WWV is demodulated, divided, and mixed to produce a large number of precisely fixed frequencies in the region 1 to 35 mc. A stable oscillator is used for interpolation. High power drivers have been built to provide 50 amp with adjustable phase angle in each of two flattened loops.
6. A motor speed control unit was supplied to control the fast neutron chopper at the reactor. It automatically protects the delicate shaft in start-up and in operation.
7. A microsecond high voltage pulser was built to modulate injection to the Cosmotron during the initial tests.
8. Automatic recording devices for plotting velocity, angle and vertical component of the wind were constructed for the Meteorology Group.
9. A device was designed which indicates the tilt in well borings.

Service Activities

The following figures summarize the efforts of the Division for the year: Ten per cent of the effort in Electronics was devoted to the classified projects, about twenty per cent went to repair and maintenance, and the balance was devoted to instrumentation research, development and construction. Fundamental research was carried out on six projects. Some 140 electronics items were produced, representing about 100 different models, of which 70 were novel in some aspect. In addition, 41 meters were repaired and calibrated and 203 electronic instruments serviced.

The glass shop, with three glassblowers, completed about 800 job orders for all departments of the Laboratory.

The calibration laboratory serviced about 2500 instruments, gave instruction to Health Physics trainees, built 22 special instruments, and modernized a number of obsolete items.

The Division has taken over responsibility for maintenance of police radios, intercom systems and similar electronic gear around the site.

The tube shop built or refilled about 180 Geiger tubes, proportional counters, arc lights and ionization chambers; carried on research on Geiger tubes; did evaporating and vacuum leak-testing.

Although the machine shop is maintained to build devices directly related to the work of this Division, it filled 38 orders from other divisions for items which it was especially suited to make.

Health Physics Division

There have been no major changes in the character of the Health Physics program during the past year. However, there has been a gradual increase in the variety and number of responsibilities. Increasing use of the nuclear reactor for experiments and isotope production has augmented the problems of exposure and contamination control. Radiation problems connected with the 60-inch cyclotron have increased gradually. A major new survey responsibility is just coming into focus now that the Cosmotron is at the stage of initial operation.

A small radiochemistry laboratory has been set up to carry out analyses of urine for radioactivity when the need arises. It is also doing analytical studies related to the liquid waste disposal program and some research on chemical dosimetry.

A modest program of research and development has been undertaken as in past years in parallel with the operating responsibilities of the Division. This program was somewhat more ambitious than usual during most of the year, with a number of major projects mainly related to various aspects of radiation dosimetry. Such activities, however, have been greatly reduced at present because of the termination of several staff members and because of budgetary uncertainties that have forced a delay in making replacements.

Research and Development

Several programs of investigation dealing with methods of measuring radiations of various types have been carried on. For instance, a study has been made of the activity induced in indium foils imbedded in paraffin by neutron fluxes of various energies. Since indium is activated predominantly by thermal neutrons, foil activation drops off sharply with increasing depth in paraffin for a beam of thermals, while in a beam of fast neutrons foil activity rises to a maximum at a depth which depends upon the energy of the incident neutrons. Hence, a rough idea of neutron energy can be obtained from a curve of foil activity versus depth in paraffin. By taking advantage of the high sensitivity

afforded by a gas flow counter, it is possible to use these foils for survey purposes in the range of maximum permissible neutron fluxes. The method just outlined appears to be of some practical value since the necessary equipment is normally found in most laboratories. However, more tests with beams of fairly monoenergetic neutrons are needed before detailed procedures for the practical use of the method can be worked out.

Another project concerned with neutron monitoring was the development of a portable BF₃ counter-ratemeter for use in making slow neutron surveys. This instrument uses a small BF₃ counter tube of Division manufacture, an audio-oscillator type of high voltage power supply, and an amplifier and ratemeter of conventional design. It covers the range of fluxes of interest for health monitoring and has been very useful.

With the rapidly increasing use of gamma-ray sources in the 1,000-c range for various experiments, a need has arisen for dosage-measuring techniques applicable to very high dosage rates. One method that has been adopted for practical use is based on the oxidation of ferrous to ferric ions or the reduction of ceric to cerous ions. Small vials of solution are exposed to the radiation, and the chemical effect is evaluated with the spectrophotometer. Once a calibration curve has been established, the method is easy to apply and reasonably accurate, although secondaries from the container walls will affect the dosage rate and must be taken into account, particularly when small vials are used.

A small ionization chamber has also been used for measuring very high dose rates. Spurious responses were avoided by mounting the chamber directly on the end of a coaxial cable. This chamber is fully saturated for a dosage rate of 350 r/sec by a collection voltage of 300.

A method for removing potassium from urine was developed to assay the gross activity being excreted. It is being used, in conjunction with simple evaporation, on samples taken after suspected inhalation incidents. This method is not sensitive enough to detect the slow elimination of radioactive substances well fixed in the body, but a negative result immediately after a possible exposure is reassuring, since sizable counts will be obtained from the rapid initial elimination if an appreciable amount of activity has entered the body. The recovery efficiency, for fission products, of the direct evaporation method is being studied. An adaptation of the Chalk River method is being used for sensitive analysis of urine for fission products in the case of individuals working regularly with such materials.

Waste Disposal

An engineering study has been made of the effectiveness of the filter beds in removing activity from the BNL sewage effluent by adding known amounts of the more common contaminants. It was found that 10 to 12% of the P³² or I¹³¹ that had been added penetrated the bed, whereas only 1 or 2% of added mixed fission products or Sr⁹⁰ came through. The I¹³¹ and mixed fission products came through quickly while the other two appeared in the filter bed effluent over a period of several days.

By studying cores of filter bed material in the laboratory, it was determined that there is little likelihood that the beds will become saturated. It was found that most of the activity removed by the bed is localized in the top 3-in. of sand and that the layer of organic material deposited on the top surface of the bed plays an important role in the removal of activity.

The collection and storage of contaminated solid wastes has been reduced to a routine. A group of small buildings, well isolated from the Laboratory proper, is used for this purpose. This spring fifty-eight 55-gal drums of accumulated wastes containing about 10 mc of activity were properly weighted with concrete and disposed of permanently at sea.

A summary of operating data for the liquid waste system over the past 15 months is presented in Table 1. It will be noted that the concentration of activity at the input to the filter beds is well below the limit of 3×10^{-12} c/cc which is stipulated by present AEC policy. These low levels in the Laboratory sewage system are the result of efficient segregation of activity at the source; they reflect the fact that only dilute wastes are discharged to the sewer from the reactor complex. The more active liquids

Table 1						
Summary of Liquid Waste Data						
Item	April-June 1951	July-Sept. 1951	Oct.-Dec. 1951	Jan.-March 1952	April-June 1952	15-Mo Average
Input to Filter Beds (gal/day)	211,000	247,000	237,000	234,000	282,000	242,000
Output from Filter Beds (gal/day)	156,000	198,000	169,000	191,000	223,000	187,000
Net Loss in Filter Beds (%)	26	20	29	18 1/2	21	23
Stream above Discharge Point (gal/day)	25,000	0	14,300	76,000	412,000	105,000
Stream at Site Boundary (gal/day)	215,000	155,000	179,000	358,000	952,000	372,000
Rainfall (in./mo)	3.03	1.98	5.44	4.81	4.13	3.88
Activity Concentration at Input to Filter Beds (c/cc)	9.0×10^{-13}	9.3×10^{-13}	2.4×10^{-13}	1.9×10^{-13}	5.8×10^{-13}	5.7×10^{-13}
Activity Concentration at Output from Filter Beds (c/cc)	1.0×10^{-13}	3.1×10^{-13}	1.0×10^{-13}	0.7×10^{-13}	1.3×10^{-13}	1.4×10^{-13}
Reduction in Activity Concentration (%)	89	67	58	63	78	71
Activity at Input to Filter Beds (mc/mo)	26	25	5.8	4.6	17	16
Activity at Output from Filter Beds (mc/mo)	1.8	7.2	2.0	1.5	3.2	3.1
Percent of Permissible	33	30	8 1/2	6 1/2	19	20

are diverted to the tank farm or processed in the evaporation plant. Large quantities of I^{131} are used for therapy at the Medical Department but the amount reaching the sewer is kept to a tolerable figure by careful collection of urine, which is held for decay before being discharged to the sewer. Wash water from the decontamination laundry is monitored but, in practice, the activity discharged is normally not large enough to constitute a problem.

Survey Problems

With the nuclear reactor in constant use for a varied program of experimentation and isotope production, a large amount of health physics survey work has centered in this area. The cooperation of the operating group has made possible the use of special facilities, such as the pneumatic tubes and isotope irradiating machine, with a minimum of exposure. Because samples and equipment removed from the pile often give levels as high as 200 r/hr careful planning and monitoring are necessary.

Contamination inevitably spreads locally at times in spite of the best efforts of all concerned, and a continuing battle is carried on to locate, confine and clean up such contamination. Thus far, it has been possible to keep the pile area clean except for the vicinity of the canal and some small regions where contaminated equipment is stored. A system of radiation alarms and dust monitors has been helpful in this connection. The same situation is found at the hot laboratory, although the volume of work here is less.

Large gamma-ray sources are being used increasingly in various parts of the Laboratory, and the H.P. surveyors assist actively in the design of safe installations and in the loading of the active materials. Currently 360 c of Co^{60} are being used at the Biology irradiation field. The 1,000-c sources used by the waste utilization group are loaded under water in the canal and are well shielded so that their use has not posed any serious problems thus far. A new 170-c Co^{60} source for the Medical Department has recently been installed.

Increased use of the pile and large amounts of activity for therapy and animal experimentation by the Medical Department has resulted in a number of exposure control problems, which have been satisfactorily resolved. Gradually increasing radiation levels, resulting from the continuing modification and tune-up of the 60-inch cyclotron, have called for care, but the work has proceeded without undue trouble in control of exposures.

Prior to start-up of the Cosmotron considerable planning of techniques for survey and development of necessary instrumentation was undertaken. Measurement of radiation levels near this accelerator is difficult, both because of the high energy and complex nature of the radiation produced, and because the radiation occurs in very short pulses at intervals of 5 sec. It was found that the dose rate in rep (roentgen equivalent physical) could be measured by means of ionization chambers even under such adverse conditions, and two chambers of different size with necessary auxiliary equipment were provided. They may be used either as integrating chambers with a minometer or with an electrometer. In the latter case, rates may be obtained from individual pulses if desired. It will be necessary to use a conservative estimate of the relative biological effect of the radiation from the Cosmotron until detailed information concerning the composition is obtained.

A limited amount of data was obtained this spring during the initial period of operation of this machine at less than the design voltage. Average radiation levels

ranged from a high of 2000 mrep/hr near the target location to a few mrep/hr in remote sections of the building. Higher levels are anticipated when the machine starts operating again, but a thick shield around one side is expected to make possible safe operation and use of the machine. Detailed surveys will be undertaken and evaluated in the coming year.

Area Monitoring

The chain of area monitoring stations has been in operation now for four years, and a detailed record of both natural background and the effect of reactor operation has been accumulated. A study of this record revealed that the effect of the pile at the outlying stations is very slight. Accordingly, four such stations were moved to on-site locations. Three were located at points on the site boundary where they fill gaps in the coverage provided by the other close-in stations. The fourth has been set up adjacent to the Health Physics headquarters building and is proving to be very useful for training activities and demonstrations for visitors. A complete technical manual covering the equipment and operation of the stations and including a summary of the data collected has recently been published as a BNL report.

Rain and settled dust samples are assayed for radioactivity routinely so that variations in background caused by atom bomb tests can be detected and the resulting disturbances to the records from the background monitoring stations can be properly interpreted. About 100 fall-out samples per week were analyzed for the AEC New York Operations Office during the fall series of tests.

The area monitoring stations presently being operated yield accurate data on gamma radiation but do not measure quantitatively the dose-rate for beta radiation. In order to do this, the dynamic condenser electrometer has been equipped with a thin-walled chamber and calibrated for beta dosage measurements, by means of a closed room and known amounts of pile-activated argon. The instrument measures beta and gamma exposure and the beta exposure is found by subtracting the known gamma value. The sensitivity for A^{41} betas was found to be 15.3 μ rep per cycle of the recorder. Collection of background data with the new equipment is just starting, but enough data has been obtained already to show that soft components (presumably mostly betas) result in a dose-rate comparable with the normally measured harder components. Variations in atmospheric mixing resulting from changing wind conditions or temperature inversions produce large variations in the beta dose-rate which are not observed with the gamma-only chamber.

Personnel Monitoring

The use of personnel monitoring equipment has continued at about the same level throughout the year; average figures per week are given in Table 2.

Exposures of more than the prescribed limit of 300 mrep/wk have averaged about one a month, but these overexposures have been isolated ones of the order of 1 roentgen or less and of no concern. All cases of exposure of more than 50 mr per day are reported for investigation by the surveyors as a precautionary measure. Such cases have averaged about one a day. It is felt that the good record in regard to exposures over the weekly limit (0.01% of the 51,000 badges processed) is due, in large part, to the policy of making these investigations.

Table 2

Use of Personnel Monitoring Equipment

Pairs of pocket chambers	1,470
Regular film badges	707
Visitor's film badges - on site	192
Visitor's film badges - off site	84
Total film badges	983
Neutron films	308
Wrist bands	0.8
Film rings	1.6
Figures have been averaged on a per week basis.	

Since the people working at the reactor account for the bulk of exposures to radiation it may be of interest to summarize the exposure records of this group for the three-month period ending July 1, 1952. Personnel monitoring equipment regularly assigned to 264 individuals showed an average exposure of 7.2 mr/wk. There were 107 individuals with no recorded exposure, and if these are eliminated the 157 remaining averaged 12.1 mr/wk. Of these, 18 averaged more than 30 mr/wk, the top three being 157, 81 and 71 mr/wk.

Training

Various training activities continue to be an important phase of the Health Physics program. Seventeen AEC Fellows in radiological physics spent ten weeks last summer obtaining practical experience in all phases of health physics work. The pro-

gram for the 1952 group includes a two-day indoctrination period and a series of weekly lectures on special topics for the class as a whole.

Brief training programs were provided for fifteen other groups. In some cases these programs consisted of individual lectures or tours, and in other cases they lasted for several days. Among these latter were programs arranged for 20 officers from the Armed Forces Special Weapons Project, three doctors studying industrial medicine, and seven individuals studying reactor technology. In addition there have been on the average of one or two visitors per week interested in some special phase of the Division's work.

Last fall a three-fold program of training for new Health Physics staff members was carried out. A series of tutorial classes in pertinent mathematics and physics was held for technicians, there was a series of lectures on selected phases of health physics work, and new people were assigned in rotation to various parts of the Division for training. Training lectures have been given on occasion to groups of technicians in the various scientific and operating divisions. New members of the pile operating staff are given as a routine matter some health physics training prior to the start of their regular duties.

ACCELERATOR

The major projects of the Accelerator Department are the Cosmotron, which produced billion-volt protons for the first time in May, 1952; the 60-inch cyclotron, which is now supporting some research; the new 18-inch cyclotron, which is being built primarily for neutron cross section work; and the research electrostatic accelerator,

which has already given good service as a research tool. Research carried out with these machines is reported in the appropriate sections of the departments concerned. The major effort of the Accelerator Department has been devoted to the completion of the Cosmotron and to its start-up and initial operation, a summary description of components' status and initial operating results being included in this report. Changes are still being made in the 60-inch cyclotron in order to improve its performance with respect to the production of reliable high-intensity deflected beams. The 18-inch cyclotron was designed and constructed during the year specifically for the production of high-intensity neutron beams; its specifications call for protons to 3 Mev and deuterons to 2 Mev with ion currents up to 1 ma. The research electrostatic accelerator, after some improvement of the ion source, has given a consistently good performance for research. It is still planned to modify the machine during the fall of 1952 for the purpose of increasing the maximum energy available, to improve the general reliability and convenience of operation and to increase the experimental utility of the machine.

On June 30, 1952 the total number of employees was 76 compared to 80 a year ago. Of these 76, 15 were assigned to high energy research with the Cosmotron, 44 to Cosmotron start-up and operations, 10 to the 60-inch cyclotron, 3 to the 18-inch cyclotron, and 4 to the electrostatic accelerator. These numbers do not include the Mechanical Engineering Division, which is administratively attached to the Accelerator Department and has a staff of 28. As the services of this group are required by all of the scientific departments of the Laboratory, a more detailed account of its activities can be found under the Direct Services section of this report.

Cosmotron

The most significant event of the year for this Department was the successful operation of the Cosmotron. On June 10, protons were accelerated to 2.3 Bev, the full energy expected at this stage. Although

Figure 1. Photograph of oscilloscope trace which indicates intensity of accelerated beam during first operation of Cosmotron. Tenth second markers are seen below trace. It should be noted that some part of the beam is accelerated for 0.8 sec. corresponding to 2.3 Bev.

operation was erratic and the beam intensity somewhat lower than anticipated, the performance removed all remaining uncertainties about many of the basic design parameters of the accelerator. It can now be said with certainty that the magnetic aperture is adequate, that the rf and injection systems have been designed with precision controls capable of meeting the very demanding requirements placed on them, and that the vacuum system, magnet power supply, and other unique units are equal to the job.

During a month's operation, it became obvious that an extended shutdown period should be scheduled in which the modifications and additions indicated by experience gained from actual operation could be effected. The writing of this report sees this shutdown ending and the different components being brought into operation again.

With the completion of construction of the Cosmotron, the character of the activity centered on this accelerator has changed. Considerable attention is now being given to the design and construction of supplemental equipment needed for research. In this category are two electromagnets with 18 x 36 in. pole faces, and two liquid hydrogen targets together with equipment to produce liquid hydrogen. Preparations for experiments with the high-energy particles also are being made by scientists from the Accelerator Department, Physics Department and by visiting scientists. New apparatus and techniques from all of these groups will be available soon, and it is clear that an intensive research program will begin when reliable operation of the Cosmotron is achieved. Before turning the machine over full time to research, it is planned to make a careful study of its performance in order to acquire data which can be used in the design of other accelerators.

The activities of the past year fall roughly into two phases, the first being aimed toward completing Cosmotron construction, and the second devoted to bringing the Cosmotron into operation. What follows contains an account, component by component, of developments during the completion phase and then a description of the start-up process for the entire accelerator.

Vacuum System

The complete vacuum system presented a rather difficult problem in engineering. The vacuum chamber, in addition to the usual requirement of being free of leaks, had to be free of electrical shorts between the numerous parts insulated from one another by plastic spacers. This added greatly to the difficulty of construction and handling. Moreover, extremely small clearances were used between the vacuum chamber and the magnet in order to preserve the maximum aperture. In spite of these complications and the general bulkiness of the quadrants, the assembly of the entire vacuum system with its four quadrants, four straight sections and twelve 20-in. diffusion pump units proceeded with little trouble.

The pumps reduce the pressure in the system to less than 2×10^{-5} mm of Hg. It was learned that the synthetic oil used in the diffusion pumps decomposed and that the forevacuum was spoiled because the products distilled over into the mechanical pumps somehow. A change to a petroleum base oil in the diffusion pumps was made and, so far, has solved the problem. The forevacuum has remained for some time at a satisfactorily low level of 35 μ .

Radio-Frequency System

This component increases the energy of the protons each revolution by an amount which compensates for the increasing magnetic field; thus the orbit of the protons is kept within the confines of the vacuum chamber. The low-level part of this component establishes a frequency based on the strength of the magnetic field as it changes during the acceleration cycle. The high-level part of the component amplifies this signal and delivers some 2000 v of rf across the gap where acceleration takes place. Both the low- and high-level parts of the rf system have performed well enough to establish the fact that their design is satisfactory. In the light of operational experience, however, some modifications are being introduced, the most significant of these being made to the high-level amplifier. During efforts to accelerate the beam, it was found that the voltage developed across the acceleration gap was too low at the high-frequency end of the

Figure 2. View along injected proton beam from a point nearly above the Van de Graaff generator. The proton beam is deflected first by the electromagnet in center foreground and then deflected electrically into the correct orbit in the straight section run at the right.

Figure 3. The console in the control room. The vacuum system is operated from the panels to the left, the R.F. system mainly from the right panel. Indicating instruments and critical adjustments are concentrated in the center.

acceleration cycle. One of the amplifier stages is being modified to correct this condition.

Injection

The actual use of the injection system in conjunction with the other components was preceded by a long period of operation as a separate unit. This permitted the working out of voltage control (to 1 part in 10,000), angular adjustment of the beam (to 1/100 of a degree), and production of a pulsed beam of 1 ma of protons from the ion source. By the time operation of the Cosmotron as a whole was attempted, considerable experience had been gained in achieving a condition of stable operation suitable for injection purposes. Performance of the injection system then revealed the need for more reliable operation of the pulsed ion source and a simpler method of making proper adjustments when turning on the Cosmotron after a night's shutdown.

Control Wiring

The control wiring has been completed to the point where all components can now be handled from the console. Henceforth, the Cosmotron will be operated completely from the control room and few, if any, operators will be required on the main floor of the machine while it is running. All vacuum valves and pumps can now be controlled automatically, and pulse length and repetition rate of magnet power supply can be adjusted from the console. In addition, three special oscilloscopes can be used to present such things as magnet voltage, pulse shape, beam intensity during the accelerating cycle, and the character of rf accelerating voltage. It is anticipated that much more efficient operation of the accelerator will result from the concentration of most controls in the hands of a single operator.

Pole-Face Windings

Early in the design of the Cosmotron, it was recognized that after the onset of saturation in the magnet (fields above 8,000 gauss) the radial field would decrease too rapidly from the back to the front of the magnet gaps. In consequence the radial oscillations would no longer be stable; hence the beam would be defocussed and lost. A field of 8,000 gauss corresponds to a kinetic energy of protons a little above 2 Bev. Therefore, if the full design energy of 3 Bev was to be realized, correction windings had to be added to the magnet. The correction windings on pole-face windings (so called because they are sheets of conductors in contact with the pole faces of the magnets) have been mounted upon the magnet structure, tested for shorts, and are now waiting to be powered by four large generators scheduled for installation this fall. In addition to their main function of raising the energy from 2 to 3 Bev, they are also useful for eliminating irregularities in the magnetic field. By means of these windings, the beam can be made to move up or down, and the shape of the field at any time during the magnetic cycle can be modified.

The fabrication of these pole-face windings introduced a new coil manufacturing technique. Bare copper bus bars were first wrapped with glass tape and then formed into the desired bundle, which was bound together with a thermal setting plastic (a polyester resin). Coils fabricated in this way have a better ratio of copper cross section to total coil cross section than has been previously achieved for similar specifications.

Additional Facilities

It was anticipated that radiations from the Cosmotron, since they would be in the billion electron volt range, would be quite directional. It also seemed probable that the sources of radiation could be localized to a considerable extent by proper selection of target position. Accordingly, a shield was designed which, instead of enclosing the magnet of the Cosmotron, merely placed a barricade in the directions where the more intense radiation was expected. The configuration of the shield can be seen from Figure 4.

Figure 4. Bricks which can be removed to form radiation tunnels appear half way up the shield. The pumping station appears in the center and a straight section at the left contains the pick up electrodes used to monitor the beam.

The shielding blocks (numbering 110) weigh about 8 tons each and were fabricated at the Laboratory. They have been placed in a semi-circular arc just outside the eastern half of the magnet to shield the console operator and experimenters in that area. The wall is 8 ft thick with an upper layer of blocks 11 1/2 ft long which provides an overhang of 3 1/2 ft.

A 6-in. layer of bricks made of iron oxide loaded cement permits the forming of tunnels through the shield at magnet gap level. The locations for these tunnels have been determined by calculation of the radiation trajectories leaving a target in the east straight section and may have to be changed after more study of the radiations.

The noise produced in the generator room by the big motor generator set was found to be too much for physical comfort. To correct that condition, an acoustical house has been built over the entire set which has reduced the noise to a very comfortable level.

Initial Start-up of the Cosmotron

The process of bringing the Cosmotron into operation started by obtaining a suitable injected beam of protons. First a short (10^{-6} sec) pulse of protons was obtained from the injection electrostatic generator. This pulse was then properly timed with respect to the magnet pulse, and adjustments in the injection parameters were made by observing the position of the proton beam after one-twelfth, one-fourth, one-half, and then a full revolution. The position of the proton beam could be established by observing the flash that resulted when the protons struck a target coated with fluorescent material. After one full revolution, the spot was less than an inch in diameter. Further adjustments in the injector parameters were made by allowing the proton beam to spiral in toward the back wall of the vacuum chamber as the magnet field rose. No accelerating rf was used at this stage. The number of revolutions made by the proton beam was determined by individual electrical signals obtained by the passage of a short bundle of protons through the so-called "pickup electrodes" placed in one of the straight sections, and by electrical signals from targets interposed at various positions. By further adjustment of injection time and injection angles, the beam was observed to make first 10, then 50, and finally 250 turns corresponding to the maximum number of turns expected without rf acceleration. The rf was then put into operation and adjusted for time of turn on and frequency change during the accelerating cycle. The intensity of the beam during this stage of operation was determined by observing the signals from the pickup electrodes on an oscilloscope. The maximum energy reached was determined by observing the length of time during which the protons were accelerated, which established the final frequency of revolutions of the protons and thus their velocity or kinetic energy.

Initially it was not possible to accelerate the protons for more than about 60 msec corresponding to a few hundred million electron volts. It was observed, however, that increased rf voltage improved matters, and after some modification had been made in the power amplifier, the rf voltage was increased and protons were observed to be accelerated for 0.8 sec, corresponding to 2.3 Bev. It is significant that the 2.3 billion volts is exactly the maximum energy predicted from the magnetic field data. Further increase in energy will have to be achieved by exciting the pole-face windings when their generators are installed.

At this point it was observed that a large number of modifications in all components was desirable and that a great quantity of makeshift apparatus was hampering efficient operation. Accordingly it was decided to suspend operations for an extended period and make improvements.

This short period of running did provide considerable valuable information about the characteristics of the accelerator. Two sets of movable vanes in quadrature were placed in the vacuum chamber in order to diaphragm the beam vertically. The intensity of the beam began to diminish when the vertical spacing was 3 in. and vanished when the vertical aperture was reduced to 1 in. In order to obtain the survival down to 1 in., it was necessary to have an induced current of about 2 amp flowing in a few turns of the front face pole-face windings to correct an irregularity in the magnetic field in that region. The radial excursion of the beam was investigated by means of a target that was moved radially. The minimum radial aperture to permit acceleration of the beam was found to be less than 20 in., as compared to the 28 in. available.

Some simple experiments were performed to establish the extent of gas scattering by observing the loss of beam during acceleration with reduced aperture and somewhat

increased gas pressure. The result was an unexpectedly small loss in intensity. For example, with a 3-in. vertical aperture and a pressure of 2×10^{-5} mm of Hg, 20% survival was observed.

In conclusion, it may be said that these preliminary tests have shown that reliable operation should be achieved without radical changes in any of the components.

60-Inch Cyclotron

Although this cyclotron is operating at a level that makes it useful for research, its potentialities as a high-intensity source of deuterons have not as yet been fully realized, and improvement in its operation continues along with its use for research.

A circulating beam of several milliamperes can be obtained with good reliability. There have been, on occasion, deflected beams up to 170 μ amp. However, good deflected beams have not been obtained with sufficient reliability to allow the cyclotron to be put into routine operation. Faulty cooling of one of the dees causes a distortion of the deflector channel that has had to be compensated. The master oscillator power amplifier has not been reliable at the high dee voltage condition necessary for a good deflected beam. Changes in this system have resulted in considerable improvement and the probable direction of any further changes that may be necessary has been established.

The main emphasis has been placed on obtaining a reliable external beam. Toward this end several irradiations of targets have been made, and the behavior of the cyclotron as a modulated neutron source has been studied. Several types of targets are available and have been used; a consistent target system is being developed.

18-Inch Cyclotron

During the past year a small cyclotron was designed and constructed for the purpose of providing a high-intensity source of fast neutrons for inelastic scattering experiments. This cyclotron was designed to accelerate protons up to about 3 Mev and deuterons up to about 2 Mev with an external beam current as high as 1 ma at the target position. Because of the rather large cross section for (p,n) and (d,n) reactions with tritium as a target it will be possible to obtain a large flux of neutrons at energies up to 14 Mev with such a beam. A further consideration in the design of this cyclotron was the desire to be able to change easily the proton or deuteron energy within the ranges 0.5- 3 Mev and 0.5-2 Mev, respectively.

As designed and constructed this cyclotron has the following characteristics:

Magnet: The yoke is 70 in. long, 51 in. high and 18 in. wide with the members 9 in. thick. The pole pieces are 18 in. in diameter with a 3-in. gap. The total weight of iron is about 6 tons. The total weight of copper in two coils of 12 pancakes each is about 3.5 tons. The total energizing power is about 6 kw (30 amp, 200 v) for a magnetic field of 14.6 kilogauss in the gap.

Vacuum System: The vacuum chamber is made of 3/4-in. aluminum plates welded together to form a square box 24 in. on a side, of 4 in. inside height. The top and

bottom plates of this chamber are vacuum-sealed to the pole tips with "O" rings. The high current specification for this cyclotron makes it necessary to use a high-speed pumping system in order to maintain sufficiently low pressure in the chamber with a large flow of gas into the ion source. Accordingly a 16-in. oil diffusion pump is used, backed by an adequately fast mechanical fore-pump. This system has given satisfactorily low pressure in the chamber with a minimum of difficulty with leaks.

Dees and Radio-Frequency System: The dees for this cyclotron are made of 1/16-in. copper sheet spun into a 17-in. diameter disc shape. In one dee a tungsten septum (beam splitter) is mounted at the 7.5-in. radius.

The radio-frequency system consists of a single water-cooled oscillator tube (ML356) coupled to the dees by a two-wire open transmission line consisting of two 3-in. diameter copper pipes 20 ft long. The operating frequency is varied by changing the length of transmission line between the grounded end and the dee connection. For frequencies between 5 mc and about 17 mc the system is operated as a 1/4-wave line, and at higher frequencies it is operated as a 3/4-wave line. The oscillator tube is capable of 30 to 40-kw output up to 20 mc.

Ion Source: A conventional ion source with a hot cathode is being used to get preliminary operational information. It is, however, planned to try arc sources of the P.I.G. type because of their reported superiority in ion output and also because of the advantage gained by the elimination of the hot cathode.

All major components of the cyclotron and its associated electrical control system have been completed and assembled. The magnet is mounted on concrete piers so as to place the level of the beam 8 ft above the floor. This elevation is provided in order to have the beam target at some distance from the dense material of the floor to reduce neutron back-scattering effects. The cyclotron is presently housed in a light frame structure for the same reason.

The various components have been tested and several necessary changes have been made to improve initial performance. Changes effected in the oscillator have improved its operation with the result that it has been possible to obtain dee voltage up to 35 kv to ground. Some preliminary tests with an ion source and circulating proton beam have indicated the need for improvement in the construction of the arc chamber to reduce the gas leakage from the source at places other than the exit slit.

The cyclotron was constructed and assembled in the Cosmotron test shack. This present location is only temporary. After initial radiation survey tests have been made and neutron fluxes have been determined, a permanent site will be selected and a building constructed to provide the maximum flexibility for carrying out neutron experiments.

Electrostatic Generator

The electrostatic generator purchased from the General Electric Company and delivered to the Laboratory during the summer of 1949 did not meet the 3.5-Mev design specification, and its operational reliability even at moderate voltages left much to be desired. Very little systematic research with the machine was possible until after the ion source system was largely rebuilt during the spring and summer of 1951. Following this, the machine became moderately reliable in the voltage range 0.5 to 2.0 Mev

with ion beam currents of around 5 μ amp of either protons or deuterons. It has been useful for numerous physics experiments, which have been carried out by members of the Physics Department, while plans and preparations for more complete and fundamental revisions have been in progress. Actual major modification of the machine will start in the fall of 1952.

The major aims of the ultimate revisions are essentially threefold:

1. To increase the upper voltage limit of the machine to as near 3.5 Mev as the basic parameters of accelerating tube length and tank diameter will permit.
2. To increase greatly the general reliability and convenience of operation.
3. To increase the experimental utility of the machine.

The present upper voltage limit of about 2.0 million is set by the phenomenon of electron loading in the 6-in. inside diameter accelerating and differential pumping tubes, a phenomenon that was encountered also with the Cosmotron injector Van de Graaff. Experience has shown that with tubes having an excessively large inside diameter it is difficult, if not impossible, to avoid an excessive back electron current drain, which varies approximately with the sixth power of the voltage across the tube and hence acts as an effective voltage limiter. The most effective solution to this problem appears to be that of avoiding the use of tubes of excessively large inside diameter. In short, the gains that were expected to accrue from the greater pumping speed available with large tubes are more than offset by the associated electron loading problems. Tubes of proven design, fabricated by High Voltage Engineering Corporation, are now ready for installation.

Other modifications are being made to improve operational reliability. The external vacuum system is being completely rebuilt along the lines of the Cosmotron injector to secure proper and adequate valving, greater cleanliness and higher pumping speed for hydrogen by use of proper booster pumps. The ion beam analyzing system is being modified to get an adequate analyzing magnet that does not unduly distort the beam at large distances from the machine and to provide adequate ion beam viewers and collimators. The adjustments necessary for aligning the system with respect to the ion beams are being effected.

An effort to increase the experimental utility of the machine is also being made. The ion beam analyzing system is being expanded to include both right and left deflection of the beam from the center line, with three beam parts available on either side. This will permit multiple setups when desired with the beam being easily shifted from one to another. The reconstruction of the vacuum system plumbing, and ion analyzing system will permit more precise beam collimation and control of background radiations emanating from the points where stray ions strike.

CHEMISTRY

The Chemistry Department now numbers 53, of which 38 are members of the scientific staff, 11 are technical personnel, including machinists, and 4 are administrative and clerical personnel. Corresponding figures for June 30, 1951 were 34, 10, and 4,

totalling 48. There were 5 terminations during this period. During the report period 20 visitors engaged in scientific work in the Department; this figure includes ten students participating in the 1952 summer program.

The Department's research program has continued in the general framework previously established, namely: the application of nuclear tools to chemical problems, ranging from the elucidation of the detailed course of chemical reactions to the determination of the arrangements of atoms and atomic magnetic moments in the solid state; the study of nuclear problems in investigations that involve considerable chemical processing of substances, problems whose attack largely involves radioactive substances and their isolation, purification, and measurement; and various subjects of special interest in the context of atomic energy by virtue of the substances involved or the way they are involved, for example, the properties of rare earths and heavy elements, or the chemical changes caused by intense radiation.

The diversion of Department members' effort from basic research to classified work undertaken for national defense has continued on about the same scale as during the previous year, with a corresponding diminished effort in the basic research program. These classified projects are expected to continue into the next fiscal year.

A change of emphasis in the nuclear chemistry activities has resulted in appreciable reduction in the effort given to the study of decay schemes, i.e., the detailed modes in which radioactive substances disintegrate. This has come about through the involvement of the interested individuals in matters outside the basic research program, as mentioned above. One focus of continued interest has been the chemical effects of nuclear transformations, with particular reference to the immediate effects of a nuclear process on the state of motion, excitation, or ionization of the residual atom. Experiments of great interest have been carried out in collaboration with the Physics Department on the effects of the state of chemical combination on the rates of certain radioactive decay processes. Measurement of the cross sections for neutron capture processes and study of products of the successive capture of two neutrons have been continued. Experiments are under way to make improved experimental evaluations of the probability of neutrino capture by nuclei; it is expected that upper limits for this probability will be reduced by several orders of magnitude, although actually to detect the occurrence of the process may not be possible. Another project involving the detection of extremely weak radioactivity is a search for the long-lived radioisotope chlorine-36 as it occurs in nature. If it can be successfully detected and measured it may have interest in connection with various geological and geochronological problems.

The research program in radiation chemistry is concerned with the chemical changes produced in water and aqueous solutions by exposure to intense ionizing radiation. The problems are the characterization of the reactions which occur and their quantitative measurement. One of the main developments of the past year has been the firm establishment of a reaction proposed earlier in which molecular hydrogen is generated from the water; the reaction proceeds jointly with the production of free radicals. Progress has also been made toward the accurate measurement of the free radical yields, and toward the problem of accurate measurement of radiation dose.

Developments in the inorganic applications of tracer isotopes have emphasized so-called electron transfer exchange reactions, i.e., exchanges between different oxidation states of a given element. Further consideration has been given to the ferrous-ferric system, and a suggested mechanism has been disproved. Experiments are in progress

to test another possible mechanism of considerable interest. The mercurous-mercuric system has also been successfully investigated from the reaction kinetics viewpoint.

The research program in organic chemistry emphasizes organic chemical applications of isotopic tracers. A significant development along this line has been the collaborative undertaking of tracer work in plant biogenesis, the purpose of the research being to test possible precursor substances in the formation of nicotine by tobacco plants. Another development is the undertaking of several studies on the "hot atom chemistry" of organic compounds. Here the problems of interest are to determine and attempt to understand the chemical fate in organic systems of atoms formed with excess energy as a result of n- γ and n-p reactions, and of beta decay. To permit the exposure of organic compounds to neutrons at controlled low temperatures, one of the experimental holes at the reactor has been provided with water cooling and a sample handling system. This facility will be very useful in our own program, and interest in its use has also been shown outside the Laboratory.

The program of researches on the chemical effects of isotopic substitution has been fruitfully continued, with further studies of both the reaction kinetic and equilibrium properties of isotopic molecules. Improved calculations of the effects of substituting carbon-13 or carbon-14 for carbon-12 in organic compounds have shown that most existing experimental data can be quantitatively understood in terms of the theory earlier developed, although in a few cases there is still a lack of concordance, coupled with considerable scatter in the published data. Experimental investigations have been completed on the equilibrium of the exchanges of deuterium between phosphine and water and between hydrogen gas and ammonia.

The studies of the spectra and paramagnetism of salts of the rare earths and heavy elements have been continued along the lines mentioned in the previous Annual Report, BNL 131 (AS-5). This work has as its aim the characterization of electronic states and the interactions of the electrons with other ions and with the local electric fields in the crystal.

The developing program in neutron diffraction is also tending to emphasize problems of magnetism and the relation of magnetic properties to structure in the solid state, although not to the exclusion of other structural problems. In the past year the very interesting materials known as ferrites, which are highly magnetic but non-conducting ceramic substances, have been studied extensively, and the results have been related to existing theory about their structure and magnetism. Corresponding work has been carried out on permalloy. In addition a number of order-disorder problems have been investigated with the neutron spectrometer. There has been considerable outside interest and collaboration in this work, especially in the studies of magnetic materials.

Nuclear Chemistry

In determining the yields of nuclear reactions by measuring the amount of radioactive substances they produce, it is necessary to determine the absolute disintegration rate of the radioactive products. This requires a knowledge of the decay scheme for the disintegrations so that the efficiency of the counter or other measuring instrument can be allowed for. Collaborative measurements of this sort have been carried out in connection with studies of the yields of high-energy nuclear reactions (spallation and fission) being made with Columbia's high-energy cyclotron at Nevis.

A case in point is the isotope Fe^{52} , found, for example, in copper and cobalt targets bombarded by 370-Mev protons. This isotope decays by both positron emission and electron capture. The electron capture decay was established by detecting the resulting K x-rays of manganese with the proportional x-ray counter, pulse height analyzer apparatus used in several previous decay scheme studies at this Laboratory. Quantitative measurements on the x-rays and on the positrons also emitted showed that the ratio of electron capture to positron emission in Fe^{52} is 1.6 ± 0.4 .

This result made possible the estimation of relative cross sections for the formation of Fe^{52} , Fe^{55} , and Fe^{59} in copper and cobalt targets, and it was found that the formation of Fe^{55} is about a hundred times more probable than Fe^{52} and also considerably more likely than that of Fe^{59} . These results are relevant to earlier conclusions that the yields of successive atomic number elements in high-energy bombardments tend to have alternately high and low values (interpreted in terms of successive alpha particle emission) and indicate that these conclusions were not well founded. The results are qualitatively consistent with the emission of nucleons by evaporation and knock-on processes.

The x-ray counter spectrometer technique has also been used in continued studies of the ejection of orbital electrons in alpha decay. This process arises from the interaction between the orbital electrons and the departing alpha particle and from the perturbation due to the abrupt change in nuclear charge. The aim of the work is to measure the probabilities of electron ejection from various shells within the atom as a function of atomic number and alpha particle velocity and to compare the results with theory. A similar program for beta emitters is under way.

Figure 1. Pb L lines from Po^{210} .
Counter gas: 670 mm Kr + 70 mm C_2H_6 .

It was found that in the alpha decay of Po^{210} , characteristic x-rays of the daughter lead atom are emitted as a consequence of orbital electron ejection. A typical spectrum is shown in Figure 1. The peaks at 10.6, 12.6, and 14.6 keV are due to lead L_α , L_β , and L_γ x-rays, respectively. (The peak at about 6 keV is due to iron fluorescence radiation from traces of iron in the beryllium window of the counter.) That these peaks are truly due to characteristic L x-rays of lead was established by showing that (1.) the main peak position is identical to that due to the known K-line of arsenic emitted in Se^{75} K capture, which has an energy almost precisely equal to the L_α line of lead. (2.) A Po sample diluted with 40,000 times as much Bi gave a peak intensity closely equal to that of an undiluted sample, which fact shows that the observed radiations cannot be due to excitation of source atoms by the alpha particles after

their emission. By mounting sources on thick plates of various materials, it was also shown (3.) that the radiations emitted from a source mounted on polystyrene gave a main peak identical in position with that from the radiations excited in a thick lead backing, but definitely different from the peak from radiations excited in thick backings of

bismuth or thallium. Critical absorption measurements with selenium and arsenic absorbers identified the L_{β} peak as due to lead. The photons observed cannot be due to L conversion of the weak 0.77-keV gamma ray emitted in Po^{210} decay, since the observed intensities are far higher than could be accounted for even by complete conversion of this gamma. The experimental yield corresponds to a probability of L electron ejection of 8.8×10^{-4} per alpha particle, which is about seven times that predicted by a theory of Migdal.

The net charge remaining on an atom after a radioactive process has had few, if any, unambiguous determinations. This question is of interest in connection with understanding the detailed effect of the perturbations due to the transition, as in the case of alpha decay mentioned above, and also in connection with the chemical effects due to the transition which are, of course, strongly affected by the state of ionization of the daughter atom. A simple method of charge measurement applicable to a variety of radioactive substances has been devised and applied to the case of electron capture decay in argon-37. It depends on a determination of the current produced by the collection of the primary recoil ions from a low-pressure gaseous source whose absolute disintegration rate is known. This is carried out in the apparatus shown in Figure 2.

Figure 2. Chamber for measuring the charge produced in radioactive decay.

The positive ion current to the central electrode is measured with a vibrating reed electrometer; application of a negative potential to the highly transparent grid suppresses current due to secondary emission from the electrode. Measurements on argon-37, produced by irradiating calcium metal in the Brookhaven reactor, showed that in the electron capture decay of this nucleus the average charge on the chlorine-37 product ion is $+3.85 \pm 0.2$. Similar experiments with other radioactive substances are being carried out.

The consequences of electron capture in beryllium-7 are of considerable physical interest, since this is one of the few radioactive transformations in which recoil effects due to neutrino emission are large and, in principle, simple to measure. Ideally, if but a single neutrino is emitted in each electron capture process, a line spectrum of recoils should result in the 90% abundant branch of decay that leads to the ground state of lithium-7. Earlier work has shown a continuous spectrum of recoils with the expected upper limit in energy but

with no indication of a monoenergetic distribution because of energy losses in the solid sample deposit. In the present investigation, exceptional pains (involving preparation and manipulation of sources in vacuo) were taken to prepare sources as near to monolayer deposits as possible. The spectra of recoils from deposits on lithium fluoride and tungsten surfaces were measured with an electrostatic analyzer of two per cent energy resolution. The apparatus is diagrammed in Figure 3. After correction for discrimination effects in the analyzer, the spectra show a single well-defined peak at the high-energy end of the spectrum (Figure 4). This result indicates the conclusion

Figure 3 (Above). Schematic diagram of the apparatus used to study the recoil spectrum of Be^7 .

Figure 4 (Right). Recoil ion energy in electron volts.

that the electron capture process in beryllium-7 involves the emission of a single neutrino. More precisely, it should be said that the energy carried by neutrinos is emitted in a parcel in a defined direction. This type of experiment cannot demonstrate that the parcel consists of only one particle. The only means of examining this possibility is to measure the cross section for the absorption of neutrinos and compare the results with the theoretically expected cross section for single neutrino emission.

Measurement of the cross section for neutrino absorption is barely, if at all, within the limit of available experimental techniques. An experiment using neutrinos from the reactor is in progress to measure, if possible, the cross section for neutrino capture (inverse beta process) in chlorine-37 to give argon-37, or to set new upper limits on this cross section. The experiment consists in exposing a large bulk of carbon tetrachloride to the neutrino flux and subsequently looking radiochemically for the argon-37 formed. At present an upper limit of 10^{-40} cm^2 has been set, in comparison with the best previous experimental upper limit of 10^{-30} for this cross section. The theoretical estimate is about 10^{-44} to 10^{-45} cm^2 for reactor neutrinos.

The nuclear chemistry research program includes the radiochemical determination of the neutron activation cross sections of various isotopes. Of particular interest when the available neutron flux is as high as that at this Laboratory is the study of second-order capture processes, i.e., those in which a given nucleus successively captures two neutrons. A case in point is that of stable Ni^{64} which captures a neutron to give the 2.56-hr beta emitter Ni^{65} , which in turn can capture a neutron to give 56-hr

PAGES

57

AND

58

NOT AVAILABLE

ju

in the ketone, it is concluded that an unsaturated intermediate, possibly acetylenic in nature, is formed during the course of the reaction.

Other organic reactions whose courses have been studied with tracers are the reaction of nitrous acid with o-alkyl hydroxylamines to form nitrous oxide and an alcohol and the reaction between iodosobenzene and iodoxybenzene to form diphenyliodonium iodate. The first was studied with N^{15} tracer, and the following mechanisms were considered.

It was found that the nitrous oxide produced was nearly all in the form $N^{14}N^{15}O$ (rather than $N^{15}N^{14}O$) supporting reaction (2) in preference to reaction (1). The so-called Victor Meyer-Hartmann reaction may be represented

The asterisk represents the position and fate of tracer iodine-131 used in experiments in which Ar represents benzene. The conclusions are that it is only the iodine of the iodosobenzene which turns up in the diphenyliodonium ion, that there is no symmetrical intermediate involving both iodine atoms, and also that the rate of exchange of iodine between iodosobenzene and iodoxybenzene is slow compared to the rate of formation of the iodonium salt.

An investigation of the catalytic reduction of acetone to propane has been carried out with two objectives in view: first, to develop methods of localized introduction of tracer deuterium into organic molecules and, second, to study the mechanism of reduction process. Experiments were carried out with various platinum and platinized charcoal catalysts at temperatures down to 77°K. The different isotopic species in the products were identified by mass spectral analysis. It was found that the synthesis of $(CH_3)_2CD_2$ by this method is not possible because of the exchange of deuterium with an intermediate in the reduction process. The exchange reaction produces polydeuteropropanes up to and including C_3D_8 . Conditions were found, however, for the synthesis of $(CH_3)_2CDOD$.

Numerous methods have been devised for the isotopic assay of carbon and hydrogen in labelled organic compounds. In the usual procedures the emphasis has been laid on the preparation of samples for isotopic assay, and the problem of the associated chemical analysis has been left as a separate matter. It has been found that serious errors in isotopic assay may result when combustions are carried out without analytical control, and it is customary, in any case, for the organic chemist to provide evidence for the purity of his compounds by obtaining acceptable analyses for both carbon and hydrogen. For these reasons a method has been devised for the concomitant chemical analysis and isotopic assay of single micro samples of organic compounds. The method is rapid and accurate and maximizes the amount of information obtainable from a single sample. The procedure consists of the combustion of the sample at about 750°C and one atmosphere of oxygen, with the subsequent removal, by condensation, of the carbon dioxide and water from the oxygen carried at reduced pressures. The carbon dioxide and water are vaporized separately and determined manometrically. The carbon dioxide is then either sublimed into a gas-counting tube, converted to barium carbonate,

or transferred to a bulb for use in a mass spectrometer as required for assay. The water formed can be used for deuterium assay.

In last year's Annual Report the development of an improved method for the determination of deuterium in water was cited. This method is based on quantitative conversion of the hydrogen to ethane through the reaction of water with zinc diethyl. Another very convenient method for the isotopic analysis of hydrogen-containing materials has now been worked out. It is based on the quantitative extraction of hydrogen as element by reaction of the compounds with hot uranium metal, and analysis of hydrogen gas by mass spectrometric comparison with standards. This method of conversion to H_2 has many advantages over methods previously used. The uranium, in the form of turnings, is maintained at $400^\circ C$ to $700^\circ C$ depending on the substance. Water, ammonia, phosphine, hydrogen sulfide, ethanol and propane have been satisfactorily converted to H_2 (95 % conversion in the case of the latter two) by this method. Memory effects are very small.

In the past few years considerable effort at this Laboratory has been expended, on both theoretical and experimental sides, in studying the effects of isotopic substitution on the rates of chemical reactions. Work has also been carried out at other laboratories. The status of present knowledge about these effects was summarized at a symposium held at Notre Dame in June 1952 under the joint auspices of the American Chemical Society and the American Physical Society. Some of the salient points are summarized here. The theory is based on the application of quantum statistics to the transition state method of Eyring, Polanyi, and Wigner. It is convenient to class the effects as intramolecular isotopic effects and intermolecular isotopic effects. In intramolecular isotopic reactions the transition states are isotopic isomers:

where A and A' are isotopes of the same element. Calculations for reactions of this type can be made without any models of the transition state, and the only parameters necessary are the masses of A, B, and A'. Good agreement is obtained with experiments in which combinations of C^{12} , C^{13} , N^{14} , N^{15} , O^{16} , and O^{18} compose the bonds that are ruptured. In view of the agreement between theory and experiment and the fact that no adjustable empirical parameters are introduced into the former, it may be considered that these results are one of the best tests to date of the transition state method in reaction kinetics. In intermolecular isotope effects, the transition states considered have different isotopic composition. Thus one compares

and

In this case the vibrational properties of the transition state must be evaluated from some assumed model. Even so, rather good agreement with experiment is found in most of the cases that have been investigated. A comparison of observed and calculated intramolecular isotope effects on reaction rate is given in Table 2. Table 3 gives a comparison of measured and theoretical intermolecular isotope effects in some decarboxylation reactions.

Table 2				
Intramolecular Isotope Effects				
Reaction	Bonds Intercompared	Temp. °C	k ₄ /k ₃ Experimental	k ₄ /k ₃ Theoretical
1. $\text{CH}_2(\text{COOH})_2 \rightarrow \text{CO}_2 + \text{CH}_3\text{COOH}$	$\text{C}^{12} - \text{C}^{12}$ vs $\text{C}^{12} - \text{C}^{13}$	138	$1.020 \pm .001^{(1)}$ $1.021 \pm .001^{(2)}$ $1.026 \pm .001^{(3)}$	$1.020^{(1)}$
2. $\text{CH}_2(\text{COOH})_2 \rightarrow \text{CO}_2 + \text{CH}_3\text{COOH}$	$\text{C}^{12} - \text{C}^{12}$ vs $\text{C}^{12} - \text{C}^{14}$	150 153 138	$1.12 \pm .03^{(4)}$ $1.06 \pm .02^{(5)}$ $1.087 - 1.105^{(3)}$	$1.038^{(6)}$
3. $\text{BrCH}(\text{COOH})_2 \rightarrow \text{CO}_2 + \text{BrCH}_2\text{COOH}$	$\text{C}^{12} - \text{C}^{12}$ vs $\text{C}^{12} - \text{C}^{14}$	115	$1.41 \pm .08^{(4)}$	$1.038^{(6)}$
4. $(\text{COOH})_2 \xrightarrow{\text{H}_2\text{SO}_4} \text{CO} + \text{CO}_2 + \text{H}_2\text{O}$		100	1.033 (7)	
5. $\text{NH}_4\text{NO}_3 \rightarrow \text{N}_2\text{O} + 2\text{H}_2\text{O}$	$\text{N}^{14} - \text{O}^{16}$ vs $\text{N}^{14} - \text{O}^{18}$	220	$1.023 \pm .003^{(8)}$	$1.026^{(8)}$
6.	$\text{C}^{12} - \text{N}^{14}$ vs $\text{C}^{12} - \text{N}^{15}$	136	$1.015 \pm .001^{(9)}$	$1.016^{(10)}$
(1) J. Bigeleisen and L. Friedman, J. Chem. Phys. <u>17</u> , 998 (1949). (2) J. G. Lindsay, A.N. Bourns, and H.G. Thode, Can. J. Chem. <u>29</u> , 192 (1951). (3) P.E. Yankwich, E.C. Stivers, and R.F. Nystrom, J. Chem. Phys. <u>20</u> , 344 (1952). (4) P.E. Yankwich and M. Calvin, J. Chem. Phys. <u>17</u> , 109 (1949). (5) A. Roe and M. Hellman, J. Chem. Phys. <u>19</u> , 660 (1951). (6) J. Bigeleisen, J. Chem. Phys. <u>17</u> , 425 (1949). (7) J.G. Lindsay, D.E. McElcheran, and H.G. Thode, J. Chem. Phys. <u>17</u> , 589 (1949). (8) L. Friedman and J. Bigeleisen, J. Chem. Phys. <u>18</u> , 1325 (1950). (9) F.W. Stacey, J.G. Lindsay, and A.N. Bourns, Can. J. Chem. <u>30</u> , 135 (1952). (10) J. Bigeleisen, Can. J. Chem. <u>30</u> (1952).				

Table 3
Carboxyl $-C^{13}$ and $-C^{14}$ Intermolecular Isotope Effects in Decarboxylation Reactions

Reaction	Isotopes Intercompared	Temp. °C	k_1/sk_3 Experimental	k_1/sk_3 Theoretical
1. $CH_2(COOH)_2 \rightarrow CO_2 + CH_3 COOH$	C^{12} vs C^{13}	138	$1.037 \pm .002$ (1)	1.035
	C^{12} vs C^{13}	137	1.034 (2)	
	C^{12} vs C^{13}	149	1.041 (2)	
	C^{12} vs C^{13}	173	1.034 (2)	
	C^{12} vs C^{13}	196	1.036 (2)	
2.	C^{12} vs C^{13}	61.2	$1.037 \pm .003$ (3)	1.041
	C^{12} vs C^{13}	60	$1.038 \pm .001$ (4)	
	C^{12} vs C^{13}	92.0	$1.032 \pm .001$ (3)	
	C^{12} vs C^{14}	60	$1.101 \pm .007$ (4)	
3. $Cl_3C-CO_2^- \xrightarrow{OH^-} CHCl_3 + HCO_3^-$	C^{12} vs C^{13}	70.4	$1.0338 \pm .0007$ (5)	1.040
(1) J. Bigeleisen and L. Friedman, J. Chem. Phys. <u>17</u> , 998 (1949) (2) J.G. Lindsay, A.N. Bourns, and H.G. Thode, Can. J. Chem. <u>30</u> , 163 (1952) (3) A.A. Bothner-By and J. Bigeleisen, J. Chem. Phys. <u>19</u> , 755 (1951) (4) W.H. Stevens, J.M. Pepper, and M. Lounsbury, J. Chem. Phys. <u>20</u> , 192 (1952) (5) J. Bigeleisen and T.L. Allen, J. Chem. Phys. <u>19</u> , 760 (1951)				

The only major discrepancy between experiment and theory in these matters is found in some measurements of the C^{14} rate effect and the comparison of C^{14} and C^{13} effects (versus C^{12}). No theoretical explanation has been found for the experiments in which the effect for C^{14} is considerably greater than twice that for C^{13} ; if the effect is real, it poses a very interesting problem.

Careful measurements on the equilibria for two exchange reactions involving deuterium have also been carried out.

The exchange reaction between gaseous hydrogen and liquid ammonia is catalyzed by potassium amide so that it is attained at a convenient rate. A series of measurements of the equilibrium have been carried out in the temperature range 210°K to 295°K. The results may be expressed as $K = 0.972 \exp 509/T$ for the reaction

The data permit a calculation of the difference in zero point energies between NH_3 and NH_2D that is probably the most accurate available since the vibrational spectrum of ammonia has been only incompletely analyzed; the result found is $635 \pm 3 \text{ cm}^{-1}$. Figure 5 shows the measured equilibrium constant in comparison with earlier work at elevated temperatures.

Figure 5. Equilibrium constant for the reaction $\text{HD}(\text{g}) + \text{NH}_3(\text{g}) = \text{NH}_2\text{D}(\text{g}) + \text{H}_2(\text{g})$ as a function of temperature.

The exchange equilibrium between phosphine and liquid water has been measured at 250°C by the use of sulfuric acid and buffer solutions as catalyst. From these measurements and the ratio of vapor pressures of H_2O and HDO , the equilibrium constant for the exchange $\text{PH}_2\text{D}(\text{g}) + \text{H}_2\text{O}(\text{g}) = \text{PH}_3(\text{g}) + \text{HDO}(\text{g})$ has been calculated to be 1.52 at 250°C. The latter experimental value has been combined with a theoretical computation of the temperature-independent factor of the equilibrium constant to evaluate the difference in zero point energies of

PH_3 and PH_2D . This leads to the equation, valid up to about 500°K, $K_g = 0.781 \exp 198/T$. The equation is found to be in good agreement with calculations based on the spectra of PH_3 and PD_3 and the rule of the geometric mean.

Radiation Chemistry

A number of observations on the radiation chemistry of water have been correlated by the idea that the systems observed behave as though the water were reacting simultaneously in two ways, a decomposition into free radicals and also a decomposition into molecules:

The radicals formed in the first reaction are assumed to be responsible for most of the reactions undergone by solutes in irradiated solutions. Consequently, in the presence of solutes that are sufficiently reactive to the radicals, a constant initial yield of hydrogen gas should appear from the second reaction. Hydrogen yields from a variety of oxidizing and reducing solutions, namely bromide, iodide, hydrogen peroxide, and oxygen, irradiated with 2-Mev x-rays, have been determined for the purpose of testing this prediction. The initial yields are found to be constant within experimental error.

Figure 6. Hydrogen produced by x-rays in KBr and KI solutions. o, KBr (10-5000 μM); Δ , KI (10-5000 μM); $\bullet$, KI (0.1 or 1.0 μM).

Figure 6 shows the results obtained for bromide and iodide solutions. The dotted lines extending through the solid points indicate steady state hydrogen concentrations for 10^{-6}M and 10^{-7}M KI solutions. These steady states are believed to result from competition for the radicals produced in reaction (1) between the halide ion and the decomposition products formed in reaction (2). With the more concentrated solutions the dosages employed were not sufficient to reach a steady state level. The mean rate of initial H_2 production in the four kinds of solution was found to be $8.9 \pm 0.25 \mu\text{M}/1000 \text{ sec}$ at a dose rate of about 16 r/sec.

The molecular decomposition probably occurs in the regions of high density of energy release (hot spots) which appear along the track of a fast electron as a result of

the formation of relatively slow secondary electrons. If water molecules in these regions are regarded as decomposing first to radicals H and OH, many of these radicals must immediately combine in like pairs to H_2 and H_2O_2 . Since millimolar solutes have no effects on the molecular yield, the diameters of the hot spots must not be larger than the average distance between solute molecules in a millimolar solution (about 120 Å).

In nitrite solutions exposed to radiation, nitrite is oxidized to nitrate. A tentative reaction scheme has been worked out for this system on the basis of measurements of the rates of nitrate formation and peroxide formation. The system appears to be such that an estimate of the radical yield (reaction 1) can be obtained from these kinetics measurements; and it is hoped to reach an accurate measurement of this quantity. This is an important objective, since one of the fundamental parameters in the radiolysis of aqueous solutions is the radical yield and since existing estimates vary over a considerable range.

In the literature there is considerable variation in the absolute calibration of the usual dosimetric reaction, the yield of oxidation of ferrous sulfate in 0.8 N sulfuric acid (amount oxidized per unit energy absorbed by the solution). The difficulty of accurately measuring the energy input to the solution accounts for these discrepancies. Continued effort is being put on absolute dosimetry. A calorimetric approach is being used, in which the temperature rise in a solution flowing through a reaction cell is

measured and compared to the amount of chemical change.

Spectra, Magnetism, and Neutron Diffraction

The topics discussed under this heading refer mainly to problems of the solid state, although the spectroscopic research includes studies on both solutions and solids.

It was mentioned in BNL 131 (AS-5) that the absorption spectra of uranium and rare earth halides were being measured and compared. Spectra of the following substances have been taken at 77°K: crystals of anhydrous uranium tetrachloride, praseodymium trichloride, uranium trichloride, neodymium trichloride, uranium tetrafluoride, and a solution of uranium tetrachloride in a solvent consisting of propyl alcohol, propene, and propane. A typical comparison of spectra is given in Figure 7.

Figure 7. Absorption spectra at 77°K: (a) UCl_4 solution in 10% *n*-propyl alcohol in 1:1 propane-propene, (b) UCl_4 crystals, (c) PrCl_3 crystals, and (c') PrCl_3 thinner crystals.

To a considerable degree the spectra of the "isoelectronic" ions U^{+4} and Pr^{+3} exhibit a match in the wave numbers of the center of gravity of the separate absorption groups, and the correspondences lead to term assignments for the basic and activated electronic states of U^{+4} , since those of Pr^{+3} are known. Thus, the two least stable electrons of U^{+4} in the basic state, and to a good approximation in the excited states, lie within the 5f shell.

In the program of research on the paramagnetic susceptibilities of heavy element salts, rare earth salts, and other compounds, interest has focussed on the assignment of electron configurations and on the general question of interpreting the temperature dependence of magnetic susceptibility. In the Weiss-Curie law for the temperature dependence of susceptibility, $\chi = C/T + \theta$, the Weiss constant θ may reflect the effect of the crystalline field on the paramagnetic ions or exchange interactions between neighboring paramagnetic ions, or both. In order to separate these effects, a technique of magnetic dilution with an isomorphous diamagnetic salt is employed, whereby the crystalline field is maintained essentially unchanged but the distance between paramagnetic ions is varied. In order to study uranium dioxide, a procedure was devised for growing crystals of solid solutions of UO_2 with ThO_2 from a borax melt. The dioxides are miscible in all proportions. The magnetic susceptibilities of these solutions obey the Weiss-Curie law, and θ decreases with increasing dilution (see Figure 8). The magnetic moment of the U^{+4} ion approaches the "spin-only" value at large dilution. The linear relation between Weiss constant θ and mol per cent UO_2 in the range 31-100 mol per cent UO_2 , extrapolated through the origin at infinite dilution, indicates that θ may be due entirely to exchange interaction in this concentration range. However, the deviation from linearity in more dilute systems may indicate crystalline field effects,

Figure 8. Paramagnetic Curie temperature as a function of composition.

and further work is needed on this and other systems to give a better understanding of the interactions.

The neutron spectrometer has been used steadily throughout the year in studying various solid state problems. Powder diffraction studies have been obtained for cold-worked and annealed brass, and several points of disagreement have been resolved. Careful measurements showed that the integrated intensities under the peaks are identical, with no trace of extinction effects, and evidence was obtained that the major part of the peak broadening in the cold-worked material is due to lattice distortion rather than to particle size effects.

The emphasis of the neutron diffraction work has, however, been concerned with magnetic solids and the relations between their structure and magnetism. A preliminary investigation of the ordering in single crystalline permalloy has been carried out with the objective of finding whether there was any difference in the degree of ordering for the direction parallel and perpendicular to that of the magnetic field applied during the annealing. Such difference had been suggested to account for some of the properties of permalloy. From measurement of the relative intensities of superlattice reflections for the directions of interest, it was concluded that no such difference in ordering exists.

The main effort during the year has been given to neutron diffraction studies of the ferrites. Aside from questions of technology, considerable interest in these materials derives from an explanation of their interesting magnetic properties given by Neel. According to this theory, the saturation magnetic moment is related in a simple and elegant manner to the distribution of magnetic ions among the available lattice sites. However, testing the theory by establishing the precise location of the various cations by means of x-rays presents a difficult problem in many cases of interest because of the similarity in scattering power of the iron group elements. Neutron diffraction as a tool for studying the ferrite problem offers not only the means of distinguishing the different cations but also of determining the location, magnitude, and relative orientation of atomic moments. At the present stage of the work, zinc and nickel ferrites have been investigated at room temperature, and excellent fit with the Neel model has been found.

REACTOR SCIENCE AND ENGINEERING

On July 1, 1951 the staff of the Department consisted of 58 members of the scientific staff and 119 others. Due principally to an accelerated program of reactor components development, expansion to 72 scientific staff members and 133 others occurred by July 1, 1952. Of the total scientific staff membership, 53 are engaged directly in research and development, the rest are chiefly occupied in the various operational

aspects of the Department. In addition, there were ten visitors during the summer of 1951 and 17 during the summer of 1952.

Lyle B. Borst, who was Chairman of the Department from its inception and had the principal responsibility for the design and successful completion of the BNL research reactor, left in August 1951 to accept a position in the Physics Department at the University of Utah. The Department was administered for the rest of the year by Marvin Fox and Clarke Williams as associate chairmen. Warren E. Winsche, who was chiefly responsible for the design of the Hot Laboratory and who directed the chemical engineering work in the Department, left in September 1951 to join the DuPont organization. Orrington E. Dwyer, formerly Head of the Chemical Engineering Department at the University of Rochester, joined the staff to head the Chemistry and Chemical Engineering Division.

The nuclear reactor operated without incident to satisfy the research and radio-isotope production demands on it. A total of 6,371 megawatt days were accumulated during the year through the reactor's operating at maximum power levels during the day shift on weekdays and at reduced power levels during the night shifts, on weekends and holidays. The maximum power level achieved was 31 megawatts during the winter months. Reactor shutdown time, primarily for research, averaged 14 % of each month.

Research usage of the reactor increased rapidly during the year, and more individual research projects are now in progress than it was originally thought feasible to support. More than 30 separate experimental equipment arrays are set up at various positions on the reactor faces, and another half-dozen are in preparation. Moreover, there are numerous special facilities which have been installed to augment the handling of irradiations by the original pneumatic tube and target conveyor systems. These include a water-cooled hole for irradiations at room temperature, a foil slot for irradiating thin samples, two air-cooled holes where the temperature does not exceed 50°C, a vacuum system for the irradiation of gases, and a number of fuel channels devoted to irradiation problems. A very fast pneumatic tube system is in the final stages of construction and will soon be installed. Other significant physical changes, during the year, include: the doubling of the floor space of the first balcony level at the west face, modification of the working area associated with the central core hole on the north face, modification of working areas associated with two experimental holes to accommodate two more crystal spectrometers being built, conversion of the pneumatic tube system from compressed carbon dioxide gas to compressed air in the interest of economy, installation of a second thermal column for use in a classified research program, and the installation of an ion exchange column to remove activity from the canal water.

Graduate students and guest scientists do not require full security investigation and clearance to carry out unclassified research with the reactor. A controlled area (west face of the reactor and associated laboratories) has been provided which is used by regular staff scientists as well as these visitors. Besides this program, Argonne National Laboratory, Westinghouse Atomic Power Division, and California Research Corporation have projects of a more or less continuous nature in progress at the reactor. Experiments of a few days' duration have been conducted by the Signal Corps, Vitro Corporation of America, Cornell Aeronautical Laboratory, Brown Instrument Division of the Minneapolis-Honeywell Regulator Company, Bell Telephone Laboratories, Naval Research Laboratory, National Bureau of Standards, and Massachusetts Institute of Technology.

The reactor continuously irradiates some 50 pounds of cobalt and tantalum distributed among ten to 15 individual sources for the ultimate production of kilo-curie

gamma radiation sources. This results in the production of some 25,000 curies of activity per year, which is being employed in investigations of the Waste Utilization Program of the Atomic Energy Commission. Several of these high-level sources have been delivered to research groups at Columbia, Yale, MIT, and Michigan cooperating in the AEC fission product utilization program. The sources here at BNL have been in continuous use throughout the entire year. Of all the industrial firms that have tried the irradiations here, ten have made repeated use of the facility. As a result more effort will be placed on the development of sources made directly from the fission product wastes.

A number of runs on the I^{132} process for obtaining this short-lived (2.7 hr) isotope for medical experiments have resulted in the production of about a curie of Te^{132} per run, which was successfully "milked" for the I^{132} .

In September, 1951 the Metallurgy Division moved into Building T-480, which had been rebuilt into a metallurgy laboratory. This provides ample space for all metallographic and x-ray equipment, testing machines, heat-treating equipment, rolling and swaging machines, a small shop as well as a number of research laboratories, and floor space with over 20-ft ceiling height for large equipment. In addition the Division has developed and installed a 20-ft drawbench, a vacuum furnace capable of taking pieces 10 ft long at a vacuum better than 10^{-5} mm of Hg, and an apparatus which allows welding in a completely enclosed inert gas atmosphere.

The Department sponsored two large technical meetings during this year. The first, in January, pertained to certain types of fuel processing and was attended by about 50 persons from AEC installations. The second, in February, on Fission Product Utilization, was not classified and attracted over 100 participants including many industrial and institutional representatives in addition to those from AEC sites. An informal lecture course in Nuclear Physics and Elementary Reactor Theory for Engineers, which lasted about four months, was given by Irving Kaplan during the spring. A similar course in radiochemistry given by H.L. Finston is now in progress. Most of the senior members of the Department were involved in conducting an intensive course in Reactor Technology, which took place in June and early July of 1952. This consisted of about 70 hours of lectures in reactor physics and design and various aspects of reactor engineering such as heat transfer, fuel fabrication and processing, reactor operations and instruments, health physics, etc. In addition, about 140 hours were scheduled with the reactor operations crew and for work in the various department laboratories. The course was attended by four naval officers from the Navy Reactor Division and four engineers from various industrial firms interested in the development of atomic power plants.

Because the reactor has been operating at the design power level on a routine basis during the past year, the engineering research and development groups in the Department have been able to devote practically all their time to the development of new components and systems which will lead eventually to economic industrial atomic power plants. The greatest combined effort by the Reactor Physics, Chemistry and Chemical Engineering, and Metallurgy Divisions of the Department has been in the field of liquid metal fuel reactors. Next in total effort has been a program of studies of components for a heterogeneous power and plutonium producing reactor. These studies have included measurements of physical data important in reactor design, such as the buckling, migration area, and neutron density distribution, in an exponential lattice activated by pile neutrons; measurements of local and over-all heat transfer coefficients for cross flow in a system capable of circulating water at high temperature and pressure

at Reynolds numbers up to four hundred thousand or better; and metallurgical studies on various problems connected with the fuel elements of such reactors. In addition some groups have been working on component developments not connected with any particular type of reactor. Detailed information has appeared in various BNL classified reports, in articles in the classified Journal of Reactor Science and Technology, and in the classified quarterly progress reports of the Laboratory.

As a result of BNL developments in the field of reactor components, the four industrial groups* studying the present feasibility of privately financed power producing reactors have visited BNL at various times to discuss the systems on which the Laboratory is working. The Dow Chemical-Detroit Edison group has expressed particular interest in some of this work and has discussed the possibility of BNL's engaging in a cooperative effort with them in these fields.

More detailed information concerning the unclassified research and operations of the Department is presented in the following sections.

Physics

During the past year, the program with the crystal spectrometer has been devoted to the measurement of neutron cross sections. Considerable effort was spent on the development of improved methods for making these measurements, particularly with respect to the precision of the energy scale and the resolution of the instrument. As a result of these developments it is now possible to use the spectrometer over the range from 0.05 ev to about 50 ev with unusually high resolution and precision in energy determination. The instrument operates automatically; hence it is possible to accumulate data on a 24-hour basis.

The total cross sections as a function of energy have been studied for the following elements: rhodium, palladium, silver, cadmium, indium, cesium, samarium, ytterbium, rhenium, iridium, gold, and bismuth. Many new slow neutron resonances have been found among these elements. Attempts are made to determine the isotope responsible for the resonance and to determine the Breit-Wigner parameters of the resonance. The measurement of total cross sections of elements in the latter half of the periodic table will continue as rapidly as new specimens can be obtained.** A program for the development of techniques for measuring activation (n, γ) and scattering cross sections is now in progress and is expected to yield worth-while results during the next year.

During the past year, cloud chamber equipment used to investigate rare events has been operating quite well and has been used for several experiments. First, an experiment on the possible double beta decay from Sn^{124} was completed, and the results were reported in The Physical Review. Secondly, a search was made for the electron-positron

-
- *1. Dow Chemical and Detroit Edison Companies
 - 2. Monsanto Chemical and Union Electric Companies
 - 3. Chicago Commonwealth Edison and Public Service Co. of Northern Illinois
 - 4. Bechtel and Pacific Gas and Electric Companies

**The procurement of samples of suitable quality is difficult and expensive.

Dr. Spedding, of the Ames Laboratory, United States Atomic Energy Commission, has kindly made available several excellent samples of rare earths.

Figure 1. West face of the reactor. From the ground level and from the first two balconies are conducted experiments utilizing neutrons from the reactor.

pairs created by neutron capture in hydrogen gas; the cross section for this process turned out to be $\leq 10^{-28}$ cm². Thirdly, an investigation of the natural tritium abundance and its natural production mechanism was begun.

Fission Product Engineering Studies

The engineering studies at BNL on fission products fall into two categories. The first and larger project is concerned with the development of uses for highly radioactive sources to be produced from fission products derived from the waste streams of reactor processing plants. The second is concerned with ultimate waste disposal. Here the aim is to find a process that will fix the radioactive materials permanently in clays or other inert material so that they can be stored indefinitely without the elaborate monitoring systems required for present types of tank storage.

Fission Products Utilization

The Atomic Energy Commission has expressed interest in a program to investigate the possibility of finding commercial uses for fission products. The project at BNL has been established as a central coordinating agency with the following functions:

1. To engage in research leading to the development of processes for the production of high-level radiation sources from fission product wastes.
2. To aid in the establishment of research projects at universities and in industry by providing high-level radiation sources of isotopes irradiated in the BNL reactor, and by providing a gamma irradiation service at BNL for industry.
3. To investigate the effects of intense fields of gamma radiation on liquid phase polymerization reactions.

During the last year a survey of waste streams from the newer reactor stations has been completed (BNL-161), and a technical-economic study of processes of packaging Savannah River separation process wastes has been made (BNL-191).

Tubular high-level radiation sources of cobalt and tantalum have been made and are now being used at Brookhaven and at Yale, Columbia, MIT, University of Michigan and California Research and Development Company. The gamma irradiation service has been used repeatedly by about ten industrial firms. At least two papers based on industrial work done at Brookhaven are in preparation. More flexible gamma irradiation experimental devices have been designed and it is contemplated that new facilities permitting expanded efforts in gamma irradiation by BNL and by industry will soon be completed in the Hot Laboratory.

Progress has been made in a study of the kinetics of radiation-induced styrene polymerization and is reported in BNL-141 (T-27). Work is continuing in the development of processes for minimizing separation process wastes.

Ultimate Waste Disposal

In trying to solve the problem of ultimate radioactive waste disposal, the study of the thermal fixation of absorbed and exchanged fission product cations in montmorillonite

clays was extended to include all of the longer-lived fission products. It was shown that only a very small fraction of the adsorbed ions were released on prolonged contact of the heat-treated clay with distilled water, saturated calcium bicarbonate solution, or sea water. Column techniques were utilized to determine the effect of high concentrations of extraneous ions on the adsorption of the fission product waste by montmorillonite.

A new method of heat-treating the radioactive clay (950°C) has been developed, wherein the individual particles pass through a gas-oxygen flame and emerge as discrete spheres, roughly 1-5 μ in diameter.

A major operational problem in the study of fission product adsorption on clays has been the uniform contacting of the ionic solutions with the minute clay particles. Because of the well-known advantages of carrying on such operations in fixed-bed columns, a series of experiments has been carried on for the purpose of developing such columns on a laboratory scale. The clay in its natural state is extremely impervious to the passage of fluids, and several methods of bonding the particles into aggregate granules have been investigated. During the coming year it is planned to incorporate the results of these experiments in a flow sheet and set up a lab bench pilot plant for the fixation of the wastes in clay.

Radioisotopes Development

Iodine-132

During the year the permanent processing equipment for the separation of Te^{132} from fission product solutions was completed. After modifying this separation process, three successful hot runs were made, in each of which approximately a curie of Te^{132} was isolated*. It is now felt that this process is not only understood but is reproducible.

Figure 2. Glowing thousand-curie source of tantalum in the reactor canal, to be used in the irradiation of samples.

The "milking" process by which 2.4-hr I^{132} is separated from its 77-hr parent Te^{132} in a "generator" has been performed in a LiCl-KCl melt in a glass generator with qualified success. Although the yields were good on both tracer and full-scale experiments, the glass walls in every case suffered rapid attack, which caused them to crack after a period of from several days to several weeks. Graphite is not attacked and Pt only slightly by the TeO_2 - LiCl-KCl melt, but tracer experiments showed a negligible yield. All other materials tried were rapidly and/or extensively attacked.

Two alternative processes show decided promise. The first is a mixture of TeBr_4 - NaBr which is quite soluble in water without hydrolysis; distilling off the

*Some of this was supplied to Dr. A. Keston (NYU) for his experiments.

water carries the I^{132} with it in fairly good yield. The second is molten NH_4HSO_4 - TeO_2 mixture through which air is passed as in the $LiCl$ - KCl system; yields are lower and more erratic here. Both systems could be used in glass generators if necessary.

Concurrent with the above work, experiments have recently been started on separation of carrier-free Te^{132} for use in $LiCl$ - KCl as a possible alternative to the above systems. This may prove successful, for it has been shown that the TeO_2 is the component that causes the high corrosion.

Some of the other systems for conveniently separating I^{132} from Te^{132} which have been tried without success include:

1. Molten $NaNO_2$ - TeO_2	5. Molten Te - Se eutectic
2. Molten pyridine hydrochloride- TeO_2	6. Molten elemental Te (He sweep)
3. Molten pyridine acid nitrate - Te	7. Molten $TeCl_4$
4. Molten $LiCl$ - KCl - TeI_4	8. Molten Cu_2Cl_2 - $LiCl$ - KCl - TeO_2

In addition the following were also tried:

1. Electrolysis of molten TeO_2 - $LiCl$ - KCl
2. Lining of a generator with inactive massive Te
3. Mo , W , and graphitar as possible generator materials for $LiCl$ - KCl - TeO_2 system
4. Nickel fluoride film as a generator liner for $LiCl$ - KCl - TeO_2 system
5. $TeBr_4$ dissolved in $CHBr_3$, CH_3OH , and C_2H_5OH (separately)

A lead shipping shield has been made to house the generator when the latter is made.

$Cl^{36,38}$ (carrier-free)

Preliminary results in the study of the Szilard-Chalmers process on potassium chlorate indicate that a chlorine activity enrichment factor of more than 50 may be obtained by extracting a reduced fraction of the chlorine with silver.

Ga^{72} (carrier-free)

In a preliminary experiment a radiochemically pure sample of carrier-free Ga^{72} was separated from natural germanium that had been wrapped in cadmium and irradiated in the BNL reactor. The ratios of activities produced indicate that this method can be adapted to the production of at least millicurie amounts of Ga^{72} . The Ga^{72} is formed by (n,p) reaction on Ge^{72} . A search for Ga^{72} arising from (n,α) reaction on As^{75} indicated, as might be expected, that this reaction is negligible with the spectrum of fast neutrons available in the BNL reactor.

Shielding

The work of the Shielding Group continues to be largely concerned with classified data. The early part of the year was devoted to the completion of the studies on the

evaluation of the Brookhaven reactor shield. An investigation into the effects of voids and ducts in shields was then begun and continued to almost the end of the fiscal year. This program was interrupted to carry out some measurements for KAPL on the SIR shield.

Equipment for two other smaller programs is being developed and assembled. One is to investigate gamma-ray scattering through light media at oblique angles; the other is a study of capture gamma-ray spectra over the energy range .5 to 8 Mev by means of a two-crystal scintillation method.

Hot Laboratory Operations

The main facilities of the Hot Laboratory building (hot cells, semi-hot labs, etc.) have continued to give satisfactory operation and, except for the following two items, no major changes or modifications have been made. As was noted in the last annual report there exists a need for a special hot cell designed primarily for physical manipulation of sources. Such a cell is under consideration. In the meantime an electric rectilinear manipulator has been designed, and construction is partially complete. This is essentially a miniature crane with a wrist and finger arrangement; it will be installed on the shielded bench in semi-hot lab #1. Although it will not do all the physical manipulating jobs that may be required in the future, it will nevertheless materially increase present handling ability and alleviate to a certain extent the immediate need for a complete new cell. Under discussion are plans for building in the unfinished area of the Hot Lab a small canal for use by the Waste Utilization Project.

During the year a schedule of charges for space used in the Hot Lab was worked out. Of the available "Class A" or regular work locations, the semi-works area was occupied on an average of 83% of maximum, the semi-hot labs 100%, and the hot cells 36%. The remaining "Class A" locations were occupied 100% of maximum. However, considerably more use could be made of the "Class B" locations, and this probably will be done as more people become familiar with the facilities offered by the Hot Laboratory. Use of the Hot Laboratory was made by groups from New York University, Cornell, Johns Hopkins, and MIT.

During the year the Hot Laboratory Group added a new service to those already offered - namely, that of radiochemical analysis. At present three men devote their full time to performing chemical analyses on radioactive material. Past requests for this work have come almost entirely from the Reactor Science and Engineering Department, but this service is not necessarily limited to that Department.

The design of the waste concentration plant for BNL radioactive wastes was completed this year, and construction will start July 14, 1952; completion is scheduled for around April, 1953. In the meantime the pilot plant, which had been used to design the full-scale plant, was used to concentrate actual waste, about 37,000 gallons of "D" type waste being processed in this manner.

Two men borrowed from the radioisotope development work have spent about eight months on a classified ("Bluenose") project of immediate interest to the AEC.

The following are a few typical pieces of work accomplished during the year by the Remote Control Engineering Section:

1. Design of electric rectilinear manipulator (referred to above) and construction of part of this equipment.
2. Redesign and modification of hot cell periscopes.
3. Preliminary tests and first final tests of closed dissolver.
4. Completion of construction of permanent processing equipment for routine separation of Te^{132} from fission products.*
5. Completion of design and construction of 135-c Co^{60} source and shield at the request of the Division of Biology and Medicine, AEC.
6. Redesign and construction of 80-c Co^{60} cave for use by BNL Medical Department (incorporating improvements suggested by use of prototype).
7. Design and construction of incubator for Co^{60} cave.
8. Design of prototype special three-way valve for I^{132} shipping shield.*
9. Design of improved ball and socket manipulator.
10. Design and construction of spray system with which to decontaminate the interior of hot cells.

Isotope Distribution and Special Materials

The volume of isotopes ordered for the Laboratory from off-site this year has decreased by about 20 per cent from last year, probably because of greater usage of the Brookhaven reactor. The items ordered consisted mainly of stable isotopes, chemically processed isotopes, and labelled compounds, which are not available here.

The number of irradiations performed in the Brookhaven reactor for external and internal users during the fiscal year 1951-52 is shown in Table 1. The growth in routine activity is evident in the record of the target conveyor monthly irradiations for external users, and all indications are that this growth will continue. Customers who have received shipments from Brookhaven are listed in Table 2; those marked with a star are receiving shipments on a routine weekly basis. Table 3 is a listing of the various isotopes shipped.

In addition to the regular facilities offered to external users for irradiations, there have been added the thermal column and a low-temperature water-cooled hole. These facilities may be used by the Biology and Chemistry Departments when there is no interference with the routine usage.

In order to supplement Oak Ridge in the production of small Co^{60} sources, 150 pieces of cobalt, 1/8 in. in diameter and 1/8 in. long, and 50 pieces, 1/8 in. in diameter and 1/4 in. long, were charged into the target conveyor in October, 1951. These were loaded four to a graphite bottle in such a manner that they did not interfere with normal usage of the bottle for isotope production. During the past few months, Brookhaven was able to sell 38 of these sources, each about .5 curie. It is anticipated that more cobalt metal will be loaded into the reactor in the future to support this program.

It was possible through the use of Szilard-Chalmers reactions to meet the needs of two customers who required high specific activity not available by straight neutron bombardment. One case involved Br^{82} , which was obtained from a Szilard-Chalmers reaction on irradiated KBrO_3 . The other involved Cl^{36} from a Szilard-Chalmers reaction on irradiated C_2Cl_6 . This latter isotope is very difficult to produce because of

*See Radioisotope Development.

Table 1

	Bottling Machine Irradiations for External Users (Fiscal 1951-52)												Totals Fiscal Yrs 51-52 50-51	
Month	July	August	September	October	November	December	January	February	March	April	May	June		
Number	27	22	27	28	41	42	27	45	47	48	50	60	464	124
Charge	\$1012	\$871	\$807	\$1011	\$1050	\$1728	\$1161	\$1668	\$2076	\$2204	\$2908	\$2167	\$18,663	\$3,974
Bottling Machine Irradiations for Internal Users (Fiscal 1951-52)														
Month	July	August	September	October	November	December	January	February	March	April	May	June		
Number	19	14	26	34	27	33	27	14	32	17	20	25	288	138
Charge	\$2107	\$1509	\$1018	\$1936	\$1037	\$2246	\$1204	\$1099	\$1042	\$3225	\$1165	\$855	\$18,443	\$8,433
Pneumatic Tube Irradiations for External Users (Fiscal 1951-52)														
Month	July	August	September	October	November	December	January	February	March	April	May	June		
Number	459	0	87	4	0	3	1	11	0	6	0	4	575	60
Charge	\$690	0	\$210	\$40	0	\$30	\$35	\$152	0	\$1615	0	\$159	\$2,931	\$260
Pneumatic Tube Irradiations for Internal Users (Fiscal 1951-52)														
Month	July	August	September	October	November	December	January	February	March	April	May	June		
Number	40	60	97	61	45	69	101	60	42	76	104	64	819	211
Charge	\$200	\$295	\$495	\$305	\$225	\$345	\$500	\$300	\$210	\$380	\$520	\$320	\$4,095	\$1,055
Experimental Hole Irradiations for External Users (Fiscal 1951-52)*														
Month	July	August	September	October	November	December	January	February	March	April	May	June		
Number	0	0	0	0	1	0	3	0	0	1	2	1	8	
Charge	0	0	0	0	\$1350	0	\$1841	0	0	\$2575	\$150	\$55	\$5,971	

*Does not include sale of two kilocurie Co⁶⁰ sources totaling \$11,750.

Table 2			
Summary of Isotopes and Service Irradiation Shipments (by institution)			
Institution	Service	Number of Shipments Fiscal Year	
		1951-52	1950-51
Abbott Laboratories, Inc.*	Gold, Chromium	37	
American Optical Company	Silicon	1	
Argonne National Laboratory	SI	2	
Army Chemical Center	SI	1	
Bell Telephone Laboratories, Inc.	SI, Copper	9	
California Research Corporation	SI	2	
Columbia Medical Center*	Sodium, Potassium, Bromine	28	20
Columbia University*	SI, Mercury, Antimony, Gold, Potassium, Cobalt, Copper	26	2
Cooper-Hewitt Electric Company	Krypton	1	
Cornell University, College of Medicine	Sodium	16	
E.R. Squibb & Sons	Cobalt	1	
Foster D. Snell, Inc.	SI	1	
Goldwater Memorial Hospital	Sodium, Potassium	2	
Harvard University*	Sodium, Potassium, Copper		
	Gadolinium, Gold	124	32
Johns Hopkins University	SI		2
Knolls Atomic Power Laboratory	SI	21	2
Kearfott Company, Inc.	Thallium	1	
Montefiore Hospital	Bromine	4	1
Massachusetts General Hospital	Potassium, Sodium, Copper	3	4
Massachusetts Institute of Technology	SI, Potassium, Cesium, Chlorine	19	10
Naval Research Laboratory	SI	1	
New Brunswick Laboratory, USAEC	SI, Indium	7	1
New England Medical Center	Sodium, Potassium	11	
New York College of Medicine	Sodium, Potassium		29
Peter Bent Brigham Hospital	Potassium, Sodium		4
Patterson-Moos Company	SI	1	
Pittsburgh Plate Glass Company	SI	2	
Princeton University	SI, Arsenic, Sodium	5	1
Rensselaer Polytechnic Institute	Copper, Argon	10	
Sloane-Kettering Institute*	Sodium, Copper	52	
Syracuse University	Potassium	2	
Tracerlab, Inc.	SI, Cobalt	7	
University of California	SI, Cadmium	7	
University of Illinois	Antimony-Beryllium	1	
University of Michigan	Cobalt, Palladium	1	1
University of Nebraska	SI	3	
University of Wisconsin	SI	1	
Veterans Admin. Hospital*	Sodium, Potassium	56	20
Watertown Arsenal	SI	2	1
Westinghouse Electric Corporation	SI	1	
W.K. Mitchell & Company, Inc.	Cobalt	1	
Yale University	Copper, Cobalt, Argon	2	1
		472	131
TOTAL: 42 Users		TOTAL:	603
(SI - Service Irradiation)			

Table 3

Number of Radioisotopes Shipped
to July 1, 1952

Radioisotope	Number of Shipments
Service Irradiation	85
Na-24	212
K-42	154
Cu-64	62
Au-198	52
Br-82	6
Gd-159	1
Si-31	1
Hg-203	1
Sb-122	2
Sb-124	2
As-76	3
A-37	4
Cs-134	3
Cl-36	2
Cd-115	1
In-114	1
Pd-109	1
Ag-110	1
Kr-85	1
W-185	1
Th-204	1
Zn-65	1
Total:	603

its long half-life (4.4×10^4 years) and the Szilard-Chalmers reaction offers a practical opportunity to obtain higher specific activities without going to a higher flux.

A total of 43 special material requests were submitted to the Atomic Energy Commission during the fiscal year 1951-52, as compared to a total of 48 last year.

The number of routine monthly inventories of special materials and source and fissionable materials was recently increased to ten. It is hoped that, in the near future, some of the S/F waste items may be removed from BNL accountability by return to the Atomic Energy Commission for recovery, or disposal with Commission approval.

Reactor Operations

The general features of the nuclear reactor and its operation as a part of the research program have been described at the beginning of this section. In the following paragraphs, the problems associated with operation of the several components of the reactor are discussed.

Cooling System

1. Primary Fans: The regular semiannual inspection and alignment procedures on the primary fan motor units demonstrated that unequal settlement of the foundations is still taking place. In order to correct this, each of the fans was taken out of service in turn to raise the foundations. Inspection showed that wedges and shims had loosened in the stator windings in all motors. Windings of all five motors were rewedged by the end of June.

2. Secondary Air Fan: The secondary air system fan and motor were realigned and inspected in January, 1952. Considerable wear was noted on the oil rings, and it was necessary to rework these rings. The thermocouple in the cooling water for the lubrication system was moved so that it now indicates the temperature of the oil pump beneath the fan bearings.

3. Ducts and Filters: An inspection of the exhaust ducts was made during a shutdown shortly after Thanksgiving Day. There was no evidence of deterioration of any type noted in the area between the exhaust filters and the plenum chambers. A collection of approximately 100 lb of debris, which had collected in the north plenum since the last inspection, was bagged and removed. The radiation level in the heel of the ducts was approximately 200 mr/hr.

The exhaust filters showed only slight discoloration, appearing to have collected only a small load. The manometers indicating pressure drop across the filters have also indicated small loading. The radiation of the filters, approximately 32 hr after shutdown, was 20 mr/hr. In the area between the venturis and the coolers, it was noted that sand and water had seeped in through the porous concrete. The north cooler sump shows evidence of water after each heavy rainfall.

4. Miscellaneous: Inverters - During the year, the motor bearings of both inverters were replaced and the exciter commutators of both units were machined to correct bad runout. The #1 inverter unit was removed from the original rubber mounting and bolted directly to the base for a more rigid installation.

Pumps - One of the large pumps that delivers cooling water has, as yet, not operated satisfactorily. New shafts, bearings, and housing have been procured and installed and the pump is to be tested in the near future.

Instrumentation

The galvanometer system has been modified to derive signals from two enriched-boron ion chambers, newly located at the north and south faces of the reactor. It now incorporates a galvanometer of rugged construction with a 0 - 50 Mw range for accurate indication at normal operating power. A second very sensitive galvanometer can serve as: (1) a check on the first galvanometer; (2) a measure of power level from kw to Mw range; (3) a differential galvanometer to observe very small changes in power; and (4) an independent means of checking the reactor period by means of an exponential shunt.

The automatic power level controller was rewired to operate from either of the two regulating rods. Work is in progress on the design and testing of a variable on-off timer for use with the present instrument to achieve closer control of the power level.

Several n- γ ion chambers were built, which had a coating of enriched boron in a colloidal oil suspension. A neutron-detecting differential ion chamber, of what is believed to be a novel design, was also built and is under test. It does not contain any moving electrodes, and the gamma flux compensation is achieved by rotating the chamber about its axis.

The building radiation monitor system has been rewired to include recorded data of three dust monitors whose sensing elements are located adjacent to the air-conditioning filters in the reactor buildings. A holdup drain and filter were added to the upstream side of the stack air activity chamber to minimize the signal due to short-lived activities and to remove dust from the air samples entering the Kanne chamber.

A considerable amount of work was devoted to improvements in the gas system designed for fuel rod protection, and the operation now is very nearly trouble-free.

Canal

At the start of the period, the canal water was clear, but there was considerable iron rust present, the result of the storage of discharged fuel elements in unprotected steel tubes. The water was kept free of iron bacteria by the addition of a bactericide

(quaternary ammonium chloride) and by continual filter replacement. However, it was essential to remove the rusting tubes. A mechanism was built to break the discharged fuel elements into short lengths, and the units stored in the rusty tubes were processed and stored in buckets. Thereafter, fuel elements were discharged into galvanized wet storage tubes.

Irradiation of the impurities present in the water (including the residual bactericide) resulted in an equilibrium activity of 1×10^{-8} c/cc, and operations in the canal were hampered by contamination problems. Purification of the water by means of an ion-exchange column was investigated and test tube runs with commercially available resins proved satisfactory. A mixed bed deionizing system and associated water softener was installed and put into operation in the canal loading house in June, 1952. During the month of June, 194,000 gal of canal water were circulated through the system. Regenerant waste solutions totalling 6,000 gal were delivered to the Waste Concentration Group via tank truck. These solutions contained a 100-fold concentration of activity of the influent water. Activity of the canal water was reduced to 2×10^{-10} c/cc.

Meteorology

Meteorological work at the Laboratory during the past year has consisted primarily of routine analyses and forecasts for reactor operations, refinement of existing instrumentation and techniques, and the summarization of data on hand. In addition, considerable progress has been made in the comparison of calculated radiation dose-rates from the reactor cooling air with actual measurements provided by the Health Physics Division, and in the development of a new procedure of oil-fog sampling.

The termination of two weather technicians without replacement was accompanied by a reduction in shift work to assure the performance of necessary maintenance and analysis.

Oil-Fog Tests

In many studies where field tests are used, the problem of adequate sampling is a critical one. In the smoke test program, the limitations of quality and number of sampling instruments, as well as time and personnel, restricted the early tests to a form that provided rough quantitative data on effluent concentrations. Fortunately, these data, together with excellent information on the qualitative characteristics of dispersion, proved adequate for the initial empirical solution of the argon-41 radiation problem at Brookhaven.

A new field sampling technique has been used during the past year which utilizes three superior photometric densitometers. This technique consists of making cross-wind traverses at various distances downwind. Given a statistically significant number of traverses, the true crosswind distribution of oil-fog can be closely approximated. Figure 3 shows the data obtained in a typical run. By combining the data from two or more trucks at different distances from the stack, it is possible to evaluate certain parameters in the Sutton equations wholly without reference to any other data. The comparison of such values with those based on meteorological measurements is of considerable interest in dispersion theory.

Figure 3. Cross wind distributions of oil fog at three distances from the stack.

Figure 4. Frequency distribution counter.

Eleven successful tests of this type have been completed since July 1951. The number is disappointingly small, but the necessity of adequate roads and perfect operation of all instrumentation is bound to restrict the percentage of success.

Instrumentation

The basic wind and temperature instruments on the 420-ft tower have been operated routinely throughout the year. No new peculiarities have been noted, and calibration and maintenance procedures have remained virtually unchanged.

The investigation of the characteristics of the instrumentation has been extended considerably. The analysis of the behavior of the Friez aerovanes has been completed and the results published. More recently, the emphasis has been shifted to a study of the effects of solar and terrestrial radiation on the Leeds and Northrup thermohms mounted in the Brookhaven double-walled aluminum shields.

In August 1951, a brief cooperative experiment was undertaken with personnel from New York University, Pennsylvania State College, the Woods Hole Oceanographic Institute, and the U.S. Weather Bureau. One of the purposes of the work was to determine the comparability of various instruments for research in atmospheric turbulence. The results of this study are nearing completion.

Two new labor-saving devices have been perfected in cooperation with the Electronics Division. The frequency distribution counter (Figure 4) utilizes a segmented commutator and brush system to provide automatic frequency distributions of either wind direction or wind speed. Although, basically an electro-mechanical system, counter errors can be held to less than 5%.

The second device is a vertical velocity computer, designed to give a direct recording of vertical wind speed when coupled with the sensing elements of the Brookhaven bivane and a Friez aerovane. The computer automatically corrects for the error inherent in the aerovane measurement when the wind flow is not truly horizontal.

Climatology

Although the meteorological record at Brookhaven is still very short when judged by normal climatological standards, it is sufficient to be of value in many ways. During the past year, the data have been processed to produce a preliminary general climatology and a dispersion climatology. The latter is of particular interest because it is one of the few now in existence.

Figure 5. Monthly percentage frequency of gustiness classes.

The reactor operations forecast program has been based on the gustiness of the wind at 355 ft, as well as the wind direction and speed. Two full years of the best micrometeorological data have been processed to establish the relationship of the wind gustiness to other variables. This study will be published in full at a later date. It is of interest to note in this report the monthly and annual distributions of gustiness shown in Figure 5. The data suggest a new approach to the concept of average dispersion conditions. Between them, the B₁ and D gustiness classes account for 82% of the entire record. Since the B₁ case occurs primarily in the daytime lapse conditions, and the D case during nocturnal inversions, future estimates of dispersion might well be based on two very different characteristic dispersion patterns, each occurring about half the time.

The general climatology of the site has been partially completed for a three-year period, and summaries of temperature, precipitation, humidity, and wind have been distributed. In most of these studies an

attempt has been made to present all data in the form of a percentage chance of occurrence, since that seems to be the most common form of request received by the Group.

Reactor Radiation Data

In the previous annual report (BNL-131 (AS-5)) it was stated that a number of uncertainties in both measurement and theory impeded the comparison of actual and calculated radiation dose-rates received from the nuclear reactor. Two of the most important uncertainties have been clarified. The establishment of a firm value for the slow-neutron activation cross section for argon-41, and a much improved understanding of the performance of the dynamic condenser electrometer have made realistic comparisons possible.

It can now be stated that, on the average, the dose-rates calculated on the basis of the meteorological work are larger than the measured dose-rates by a factor of 1.5 to 2.0. Sufficient new data are now available for comparison to establish the relationship with a higher degree of accuracy.

Preliminary results indicate that the ratio of calculated to measured dose-rates is inversely related to the magnitude of the measured dose-rates in a systematic fashion. Thus, the calculated values appear to be more nearly correct at high dose-rates. This apparent relationship will be investigated more fully, and if the effect is not instrumental, it may have a significant bearing on dispersion theory.

Reactor Operations

The analysis and forecasting of radiation dose-rates, described fully in earlier annual reports, has been carried on daily, except during the few extended periods in which the reactor was inoperative. On six days, recommendations for shutdown or reduced-power operation were made because calculated radiation dose-rates reached the off-site operating level. On three additional days, scheduled routine shutdowns eliminated the necessity of such a recommendation. Of the total, five were foreseen 24 to 36 hr in advance, and four were forecast 8 to 12 hr beforehand.

Geology*

The geologic and hydrologic investigations under the program started at Brookhaven in March 1948 are nearly completed, and a final report is being prepared. The two most important goals have been to determine in detail the pattern of movement of the surface and ground water of the area and the possible results to be expected if radioactive wastes should contaminate these water supplies, or if such contamination should be suspected.

It has been established that the principal water-bearing formation, the upper Pleistocene glacial outwash sand and gravel, is about 200 ft thick and approximately uniform. It does not contain a till member of the so-called Montauk age, and is, in fact, believed to be entirely Wisconsin. The lower 30 ft or so contain small but appreciable amounts of reworked glauconite and nontronite, although the formation, as a whole, has but little clay in it. Hydrologic tests show that the transmissibility of the formation is about 200,000 (gallons per day for each 1 mile width of the aquifer, where there is a gradient of 1 ft to the mile), that the specific yield is about .24, that it contains water with an equivalent thickness of 30 ft, and that this water is moving through it at the rate of about 1 ft per day. Water table contour maps show the direction of movement to be toward the south and southeast, so that the water moving under the western half of the Laboratory area is tributary to the Carmans River, while water moving under the eastern half is tributary to the Forge. Complications are involved, however, in the case of the headwaters of the Peconic River, which drain the east-central section of the Laboratory area. Compared to most other Long Island streams, this portion of the Peconic receives relatively little water from the main water table. The stream channel and its tributaries have been dug out to form ditches as the natural drainage was sluggish and imperfect. In late winter and during much of the spring, these ditches are fed from direct surface runoff, from water stored in swamps, and from shallow basins of perched water. This flow of water to the stream from points at or near the surface is the result of the presence of silt and clay in the top 10 ft or so of the glacial outwash in the area drained by the Peconic. Beneath these clays and silts the ground water moves in a direction different from the flow of the stream above, although it receives some water

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

from the stream. During much of the summer and fall the tributaries go dry, and the main stream continues to flow only because it receives up to as much as 1,000,000 gal a day effluent from the sewage disposal plant.

The path that would be followed by contaminated ground water or sewage effluent can be predicted with some assurance, although the possible patterns are not all simple, and in many cases, a limited number of alternatives are present. It does not, at present, seem necessary to explore much further this aspect of the study, at least until a more specific problem is presented.

There are other points, however, about which very little is known, and by far the most important of these is the change in concentration and rate of movement to be expected from adsorption and ion exchange. Soil materials, and particularly the clay minerals, are effective cation exchange agents, but have much less effect on anions. Metallic ions will, therefore, not only be removed from any contaminated solutions in contact with the ground, but, as is true in chromatographic separations, the rate of movement of those remaining will be retarded. No adequate information on the effects of adsorption or ion exchange for the Brookhaven area is yet available, and therefore, no quantitative estimate is possible of the results to be expected from the accidental release of a particular quantity of radioactive material.

Some thought has been given, to the possible shape and volume that would be taken by contaminated liquid released either as a surface spill or at some point underground but above the water table. Several substantially different cases can be distinguished intuitively; for example, the sudden release of a large volume of liquid, more than sufficient to saturate the soil between the point of release and the water table, as compared to the release of a small volume, which would not change materially the soil moisture concentration below it. In the first case, movement to the water table would take place rapidly; in the second case, only very slowly, and it might well actually be governed by the naturally occurring annual movement of infiltrating precipitation. The movement of moisture through unsaturated sands is only imperfectly understood, and it is not possible to predict what would actually happen in any particular case.

Upon reaching the water table, the contaminated liquid will build up a slight "mound" and will move radially out from the area of contact. Some approximation of the resulting shape of the contamination may be deduced, but no exact figure attained, since such factors as the relation between vertical and horizontal permeability are only known approximately.

If the contaminated liquid has a density greater than that of the ground water, it will tend to displace the ground water and settle through it. In this case, some approximation of the rate of movement is also possible, if the differences in density are known, although it must still be remembered that the value of the vertical permeability is less well known than the horizontal. Brief preliminary experiments suggest that tests with models might provide helpful results, although no actual work is contemplated at present.

After the body of contaminated liquid has joined the ground water, it will be entrained by it and carried forward with it at a rate of roughly 1 ft per day. Theory suggests and experiments show that this lateral motion through the sand aquifer will not of itself cause any widening of the contaminated body, but there will be a lengthening of the body in the direction of motion. This lengthening is demanded by the theory of movement of the liquid through the sand, and it has also been observed and briefly studied. It is not yet possible to predict just what the lengthening will be, although the

length does appear to be a simple function of the distance traveled, producing a Gaussian distribution of concentrations along the axis of movement.

It must be concluded, then, that while the investigations so far conducted have identified and described all the parameters normally needed for the solution of hydrologic problems, there are present here important and novel elements for which it has not been possible to provide quantitative answers. These problems are not peculiar to Brookhaven, however, and are not in a sense a local responsibility. In recognition of this fact a program of research into such questions as the adsorption of radioisotopes by soils has been undertaken by the Geological Survey under the direct sponsorship of the Atomic Energy Commission.

What has been said above applies to the movement of surface water and of the ground water in the glacial sands. Beneath most of the Laboratory area, and extending at least as far south as the line of the ocean beach, these glacial sands are underlain by the Gardiners clay, a brackish water interglacial clay, probably of pre-Wisconsin age. Although it is only 10 ft or so thick, it forms an effective though not complete seal between the water table aquifer and the clays and sands of Cretaceous age which underlie it. The Gardiners clay does not extend as far north as the northern edge of the Laboratory area, however, and there is considerable recharge to the deeper formations, not only north of its northern edge, but also to some extent through the northern part of it. Over most of its area, however, the pressure gradient across the clay is directed upwards. This reversal is due to the steeper slope of the water table to the south as compared to the slope of the piezometric surface of the water just below the Gardiners clay in the upper part of the Magothy formation.

These relations make it virtually certain that any contamination getting into the water in the glacial sands will not penetrate deeper, and that the Cretaceous aquifers, which are largely recharged upstream from the possible sources of contamination, would remain unaffected.

Two wells, each drilled 1,600 ft to bedrock, were used to explore and define these deeper aquifers. Below the Gardiners clay there is roughly 800 ft of bedded sand and clay known as the Magothy formation, although there is no proper correlation possible with the type locality of this formation in New Jersey. The bottom hundred feet or so of this formation were found here, as they have been over much of the Island, to be sufficiently permeable to yield large quantities of water to properly constructed wells, and smaller water-yielding lenses of relatively clay free sand, containing some gravel, were also encountered locally by one or the other of the wells.

Below the so-called Magothy is the clay member of the Raritan formation, over 100 ft thick and of very low permeability. Between it and the bedrock is the deepest aquifer on Long Island, the Loyd sand member of the Raritan, which in Nassau County and in the western end of Long Island produces very appreciable amounts of water. Both Brookhaven wells and a test well drilled at Port Jefferson showed that the Loyd in this general area contains too much clay to be a good water producer. It is very unlikely, therefore, that wells will ever be drilled into it for water much east of the Nassau-Suffolk line, so that the possibility is presented of pumping contaminated water down into it through the second of BNL's deep wells, as a method of cleaning up the far more important glacial aquifer in the event of a serious spill.

Changes in thinking during the last year have also had a bearing on the water sampling program. A routine procedure involving the collection of samples from 30

surface water and ground water points, at the rate of two a week, which has been followed, now appears unrealistic. The stream monitoring would be best served, not by periodic sampling, but rather by some continuous process such as running a small part of the stream flow through an ion exchange column, which would insure that contamination did not pass the sampling point between samples. The ground water sampling does not offer a timing problem, however, as the elongation of the contamination in the direction of movement and the relatively slow movement of the ground water make it necessary to sample any given point only infrequently. The location of the sampling points is much more difficult, however, for the failure of the contamination to widen out as it moves means that the sampling well would have to be located in just the right spot, and screened at just the right depth to intercept it. The concept of a "picket fence" of wells around the southeast perimeter of the Laboratory grounds, so spaced that they would detect any contamination getting loose anywhere in the area, is entirely fallacious.

Calculations show that if a certain one of the Laboratory's supply wells was deepened, and by far the larger part of the water supply pumped from it, then its core of influence would intercept all possible flow lines originating at the waste storage tanks, the pile, the hot laboratory, and in fact, from virtually all of the points where appreciable quantities of radioactive materials are used or stored.

LIFE SCIENCES

BIOLOGY

The activities of the Department reflect the varied disciplines of biology represented, and the specific problems attacked are dictated to a considerable extent by the interests and training of the individual scientists. The research program is more fully described later in this report under six headings, namely: mammalian physiology, plant physiology, general physiology, metabolism, biophysics and genetics. Through the presence of a staff having a wide range of interests it is hoped that any university biologist, who might find it advantageous to utilize the ideas and techniques of atomic energy in his research, can come to the Laboratory for a limited stay and find at least one staff member well acquainted with his field of work and ready to cooperate with him.

The staff of the Biology Department now totals 55, which is only a little larger than it was a year ago. The failure to increase the staff as planned was due to budget limitations rather than to a lack of good men. There have been seven visiting scientists on the staff during the year. During the summer of 1951 there were 14 visiting scientists and the summer of 1952, 31 visiting scientists and students. This latter figure represents a marked increase over the previous year, and means that the research carried on during the summer in conjunction with the faculty members and students from eastern universities constitutes a substantial part of the program.

The additions to the scientific staff have continued to emphasize the many ramifications of the atomic energy program in the biological sciences. A recent addition to the staff in the field of veterinary medicine not only increases the areas of biological science now represented at the Laboratory, but will provide additional research help in the animal studies currently under way. The program in bacterial genetics has been terminated with the departure of Dr. Benjamin A. Rubin.

The annual Symposium sponsored by the Biology Department was held on August 15-17, 1951 on "The Chemistry and Physiology of the Nucleus." It was open to all interested scientists, and about 185 persons were in attendance. The speakers were carefully chosen leaders in their field of endeavor, and the discussions which followed were excellent. The Symposium papers together with all discussion have been published.

Construction of the second phase of the Biology building was begun in August 1951 and completion is expected in October 1952. When completed, the present temporary buildings now occupied by a portion of the staff will be abandoned and all the work of the Department will be under one roof.

The cobalt source in the gamma field has been increased from 200 to 400 curies, and the field continues to be used extensively. A new greenhouse has been built which is attached to the old greenhouse and has an 8-curie source of cobalt in it which is used in irradiation studies on greenhouse plants in the same way the gamma field is used for field plants. A beta-ray source has been developed for irradiation of the growing tips of trees and shrubs. The source is very light and can be carried easily from place to

Figure 1. Present state of the new part of the Biology building; the old part can be seen in the background. Completion is expected late in October.

place to make the irradiations. A dosage rate of about 25,000 rep/hr can be achieved, making possible many high intensity exposures in a day.

During the past year many interesting results have come from the gamma field. Perhaps the most interesting is the fact that plant function is selectively disturbed by continuous radiation. This means that plants are not merely stunted in their growth, but some aspects of plant growth are inhibited, others seem little affected even by very high doses, and others seem enhanced. The field will probably prove very useful not only as a tool for the analysis of radiobiological action, but also as a tool for studies in basic plant physiology and plant genetics.

During the year considerable effort has gone into the design and construction of a thermal neutron exposure facility at the reactor. The construction of the column is such that biological samples can be inserted and removed from the column without interfering with the operation of the reactor. The design problem centered mainly on the question of the gamma-ray contamination of the thermal neutrons.

The exposure chamber itself is a 10-in. cube at the center of a 5-ft cube of graphite, with appropriate lead, bismuth, boron and steel shielding. It is possible to put specimens into the exposure chamber by means of a maze without disturbing the operation of the pile. The thermal neutron flux is about 1×10^9 n/cm²/sec; the cadmium ratio about 10^4 and the gamma-ray contamination about 50 r/hr. This is considerably better than other existing thermal columns. Calibrations are not yet complete but present indications are that for the first time it will be possible that the major biological effects will be caused by thermal neutrons and only very small or insignificant effects caused by the gamma rays.

Recent thermal neutron studies have shown that there are qualitative differences between the radiobiological action of x-rays and thermal neutrons, and this finding throws serious doubt on current theories of radiobiological action.

A continuation of studies on the effects of x-rays in rats has shown that if rats are deprived of food following radiation their chance of survival is enhanced. By a study of weight changes following irradiation, it has been found that rats lose weight and do not regain it as quickly as they would if they were fasted for a comparable period. Other experiments have shown, however, that there is no apparent change in metabolism, and that the weight loss following irradiation is due primarily to an inhibition of intestinal absorption. The endocrine glands play an important part in the radiation syndrome, but all recent attempts to increase survival following irradiation by endocrine therapy have failed.

The very precise methods for C^{14} analysis which were developed here have been put to use in a study of the formation of cholesterol phospholipids from ingested labeled sucrose in mice. This work is beginning to give some insight into the way in which these molecules are formed. In another biochemical study, labeled phosphorus is used to study the defect caused by diabetes, and the role of insulin in sugar metabolism.

An important study has shown that cancer of the pituitary gland in mice may be caused by treatment with a dose of I^{131} sufficient to destroy the thyroid together with a dose of total body x-rays. Neither treatment alone is sufficient to produce the tumor. This gives a completely new insight into the carcinogenic properties of x-rays.

Research

The research of the Department continues to center around the special facilities provided by the Laboratory. The individual problems are best discussed under the six headings which follow.

Mammalian Physiology

The work in this area has centered chiefly around the problem of the physiological effects of radiation in mammals. The first of these is the change in metabolism of the rat, as indicated by the change in weight. It was first shown that under accurately controlled conditions the weight of a rat is a remarkably good indication of the condition of the animal, and a dose of as little as 50 r is easily recognizable. In an attempt to find the reason for the weight loss, rats were fasted for varying periods. These fasted animals lose weight only a little quicker than irradiated animals, from which fact it is concluded that the weight loss is due to loss of appetite and decreased intestinal absorption. In this connection it is interesting to note that when irradiated animals begin to grow again, their growth curves are parallel to those of the fed control groups. In the fasted group, the animals grow at an accelerated rate when put on food. This gives striking proof of the fact that the damage caused by radiation is basically much more subtle than an interference with appetite and intestinal absorption.

The problem of the disturbance of water metabolism as a result of radiation has been carried on in two phases. It was reported last year that there are two periods of

diuresis associated with the radiation syndrome and that the first of these is due to the decreased output of antidiuretic hormone from the pituitary. It has now been found that the second is a simple response to food intake when the irradiated animals start to eat again; the same phenomenon occurs in fasted animals when they start to feed again. The second phase of this work is an attempt to find the factors responsible for the inhibition of the pituitary. First it was shown that when the first period of diuresis is prevented by doses of pituitary extract, survival of the mice is unaffected. Next a histological study was undertaken to determine the nature of the response of the gland to radiation. It was found that there was a distinct response both to radiation applied only to the gland, and also to radiation applied to the rest of the body with the head shielded (indirect effect). However, the method is not accurate enough to define the nature of the response.

It was found by Gorbman, at Columbia University, that mice treated with 30 μc of I^{131} had their thyroid glands destroyed but if they were treated with 200 μc they also developed a pituitary tumor 12 to 14 months later which would kill them. This problem has been carried on here in collaboration with Dr. Gorbman, and it has recently been found that animals given 30 μc of I^{131} plus a dose of x-rays also develop the tumor. This is the first recorded instance of x-ray production of a tumor in a specific locale. Needless to say, it opens many fields of research on both fundamental endocrinology and the carcinogenic effects of x-rays.

During the year a study has been initiated on the capillary circulation of the hind limb of the cat. An apparatus has been built which will measure capillary permeability of most substances, and with this a study of capillary dynamics is being undertaken. A new program of research in veterinary pathology has been also initiated.

Plant Physiology

The work in plant physiology has involved two general studies: first, on the cytological and morphological changes taking place in plants as a result of radiation, and the second a study of the mechanisms by which plants synthesize and utilize sugars.

During the past year the apparatus for the measurement of the absorption spectrum of individual parts of cells, noted in the last report (BNL 131 (AS-5)), has been put to use. The total amount of desoxypentose nucleic acid (DNA) as indicated by the Feulgen reaction has been studied and the degree of polymerization as indicated by the methyl green reaction. Measurements from other laboratories on extracts from irradiated tissues have shown that there is a decrease in total DNA and a decreased polymerization. A careful study of the individual cells showed that for those that could be called cytologically normal, there was no change in total DNA content per nucleus or in the degree of polymerization of DNA. However, there were an abnormally large number of cells with small nuclei which showed a decreased DNA content. These degenerating nuclei or nuclear fragments largely make up the "debris" described by histologists. Depolymerization may occur to varying extents in any of the various sizes, but occurs only in relatively few instances. This means that DNA depolymerization does not occur as a general effect of radiation, but rather as a phenomenon loosely associated with nuclear degeneration. Nuclear degeneration, on the other hand, is an end effect of x-radiation but it is not dependent on depolymerization, nor is depolymerization a necessary adjunct of degeneration.

Work in the gamma field continues to yield interesting results. One of the most striking effects observed so far is that in certain plants at certain dosage levels there is an apparent stimulation of certain phases of the plant growth. For example, irradiated tobacco plants flower much earlier than the controls if grown at a dosage rate of about 200 r/day whereas flowering is retarded at either higher or lower dosage rates. This effect is illustrated in Figure 2. These phenomena, together with the growth abnormalities reported last year, indicate that chronic radiation is interfering with some of the physiological mechanisms of the plant. Thus, this field is rapidly becoming a very important tool for fundamental studies on growth and differentiation in plants.

Very significant results have been obtained on the biological effects of thermal neutrons, with dormant seeds of barley, wheat and corn as the test objects. Following irradiation with either x-rays or thermal neutrons, these seeds are planted and their growth patterns followed and cytological abnormalities studied. It is found that the neutron-treated seedlings exhibit a very uniform growth pattern although the growth rate is slower than that of the controls by an amount proportional to the dose. The x-ray-treated seeds show a growth pattern that is very non-uniform and it becomes less uniform with increasing dose. This finding is very difficult to interpret in the light of current theories of radiobiological action and represents the first demonstration of a qualitative difference between thermal neutron irradiation and x-irradiation. Furthermore in barley seedlings for equal growth inhibition as produced by x-rays and by thermal neutrons, there is a great deal more chromosomal damage by neutrons than by x-rays. The commonly accepted hypothesis that radiation inhibits growth by chromosomal damage is seriously challenged by these findings.

There is some evidence indicating that the mechanisms of carbohydrate catabolism are the same in higher plants, yeast and muscle but direct evidence on this point is rather limited. During the year, it has been possible to isolate triosephosphate dehydrogenase and glucose-6-phosphate dehydrogenase from pea plants. These are enzymes which catalyze the oxidation of glyceraldehyde-3-phosphate and glucose-6-phosphate, respectively. Furthermore, the triosephosphate dehydrogenase isolated from leaves acts in conjunction with a different coenzyme from the triosephosphate dehydrogenase isolated from the roots. It is of interest to speculate that the former enzyme participates only in photosynthesis, i.e., in the conversion of phosphoglycerate to triosephosphate, while the other dehydrogenase is concerned in carbohydrate catabolism. The presence of a glucose-6-phosphate dehydrogenase indicates that plant tissue may degrade hexose by a mechanism similar to that of yeast or animal tissue. A number of other enzyme systems associated with the carbohydrate metabolism of plants and microorganisms are under active investigation.

General Physiology

The work in this field for the past year has been concerned almost entirely with the study of trace element metabolism. The first is a study of the copper metabolism of *Drosophila*. The radioactive tracer technique is particularly valuable for such studies. Uptake distribution and excretion of copper by larvae of four species of *Drosophila* have been followed by determining the activities of dissected larvae at intervals after feeding with copper-64 on various media with a series of copper concentrations. These studies have shown that there are two independent paths of uptake: one for free copper and one for copper which has been incorporated in yeast. Excretion is slower than up-

Figure 2. Photographs taken on the same day of *Nicotiana rustica* plants growing in the gamma field show early flowering and stunting at high dosage rates. The plants represent (left to right) the controls and dosage rates of 22 r/day, 61 r/day, 101 r/day, 348 r/day, and 575 r/day.

Figure 3. Aerial photograph of the center portion of the gamma radiation field. The two dark bands are corn plants; the less congested areas contain gladiolas, cotton, tobacco and tradescantia. The field is plowed in a circle so that similar plants can be placed at specific distances from the source of radiation in the center.

take and is performed chiefly by cells of the middle mid-gut. Autoradiographs show the greatest relative concentrations of copper-64 in the middle mid-gut cells with a decreasing concentration in other regions of the mid-gut and in the malpighian tubules.

Another study has involved the mineral constituents of fresh-water clams. These studies throw considerable light on the relation between environment, generic characters and localized physiological processes in the uptake by this species of calcium, manganese, iron and copper.

Metabolism

As described in the last report, whole-body x-irradiation in ducks decreases the metabolism of erythrocytes in the blood drawn during the first few days post-irradiation. This phenomenon has been studied primarily from the point of view of localizing the metabolic defect. There is no conclusive evidence so far, but present indications are that there is a decreased concentration of one or more of the essential enzymes.

The work on phosphorylation reactions has been concerned this year primarily with a study of the role of phosphorylation reactions in diabetes mellitus. These studies have been carried on chiefly by in vivo studies of the liver of rats, and in vitro studies of the diaphragm muscle of the rat. These data make it apparent that there is no qualitative departure from normal in the operation of the phosphorylation cycle of diabetic animals. This evidence, obtained by tracer studies, adds to the already impressive accumulation of indications that the metabolic defect in carbohydrate metabolism in diabetes is quantitative and not qualitative.

During the year, the analyses of the metabolic products of labeled sugar fed to mice have been extended to include cholesterol, phospholipid and neutral fats. The interpretation of the data is still obscure but present indications are that these substances are probably not synthesized by the commonly accepted mechanisms, but what mechanism is employed is still uncertain.

A new program has been initiated involving a general study of the mechanism of action of enzymes. A first step in this study was an analysis of alkaline phosphatase, an enzyme known to catalyze the hydrolysis of alkyl and aeryl esters of phosphoric acid and to cause cleavage of the phosphorus-oxygen bond in the hydrolysis of glucose-1-phosphate. One possible mechanism is a nucleophilic attack on the phosphorus atom with displacement of the OR group. If this mechanism is correct the phosphatase should cause phosphorus-oxygen cleavage during the hydrolysis of all substrates and should catalyze the exchange of oxygen between inorganic phosphate and water. This was tested in experiments with the use of H_2O^{18} . It was actually found that in the presence of phosphatase, there was an exchange of oxygen between HPO_4^{--} and water, whereas without the enzyme there was none.

Biophysics

The design and calibration of the thermal neutron column at the reactor represents a good deal of the effort that has gone into this field.

The work on the effects of radiation on aqueous solutions has continued with a study of the shape of the fibrinogen molecule and the way in which it is changed by radiation. Centrifuge data have been obtained which, when combined with flow-birefringence data, give some indications of the changes in shape of the fibrinogen molecule in urea solutions. It appears that fibrinogen in water is a rod-shaped molecule some 18 times as long as its cross section. When dissolved in urea, the molecule appears to approach a spherical shape without much change in the length of the major axis.

A new study has been started on the inactivation of virus by heavy particle bombardment. This is part of the general problem of effect of specific ionization on radiobiological effects. So far, irradiation facilities have been constructed for use in conjunction with the 60-inch cyclotron and exposures should take place in the near future.

Genetics

Work has been concentrated mainly on an attempt to analyze the way in which mutations take place in bacteria. To this end, methods have been developed for analyzing the nucleic acid content of bacteria, by means of which it has been found that the nucleic acid content changes in a characteristic way depending upon the growth cycle. When cells were subjected to continuous radiation as intense as 5,000 r/hr, they continued to undergo division and the same change in nucleic acid content was noted for the culture as for the controls. It has previously been shown that there is no difference in the mutagenic effects of x-rays resulting from the varying number of cell divisions during the irradiation. These results would argue in favor of the idea that the process of mutation occurs as a result of the interference of radiation not with the correct synthesis of the genetic material but with the integrity of the completely formed "gene molecule."

The work in corn genetics during the past year was concentrated on an effort to determine the time during pollen development at which mutations were most likely to occur. Kernels with endosperm mutations resulting from gamma-irradiated pollen were grown to determine whether the mutation affecting the endosperm also changed the embryo. Since the rate of mutation is rather low, concomitant mutations in both embryo and endosperm would be expected only about four times per 10,000, which rate is almost negligible. For three endosperm mutations, 24% of the plants showed mutations indicating that the embryo and endosperm were of the same genetic constitution. There was one mutation locus, however, in which 78% had endosperm and embryo alike. It thus appears that all genes do not mutate at the same time during pollen development. The earlier the mutation the more likely it is to affect both embryo and endosperm. This finding may explain why certain loci exhibit spontaneous mutation rates markedly different from others.

A new program has been initiated on radiation genetics in *Drosophila*. Sex-linked recessive lethal mutations have been studied from successive batches of eggs laid by female *Drosophila* irradiated with 4000 r of x-rays. The initial mutation frequency is 10% corresponding closely to that found in males treated the same way. However, in eggs laid on successive days the frequency decreases until at about 10 days it is only 60% the initial frequency. This decline in frequency is probably due to the elimination in immature germ cells of induced lethal mutations. This result has important implications relative to the minimal allowable dose of radiation in man.

MEDICINE

The growth of the Medical Department since its organization three years ago has been so rapid that, at the writing of this report, some research projects can be referred to only with the merest outline because of the size of the program as a whole. The scientific work will be described under the appropriate division heading.

During this three-year interval there has been developed gradually a program of investigation that makes use of the nuclear reactor and isotopes of a few days' half-life. It is only now after three years of constant thought about these problems that work is beginning obviously to break away from earlier channels on short-lived isotopes problems. Discussions concerning possible work in the future are now centering about isotopes with a few seconds' half-life instead of a few days'. This has required the development of safe methods for handling these shorter-lived isotopes effectively for their specific purpose.

The possibilities offered by the reactor are ever present in the thinking of the Department, and many problems are being developed for exploration with the reactor. In this phase of investigation the work is hampered by the lack of reactor facilities that lend themselves readily to medical purposes, but the difficulties are being overcome although at a real cost in time and effort to the staff. Enthusiasm tempered by some knowledge and experience of these difficulties exists in the Department for the possibilities of reactor use in the medical field and the study of biological effects of neutrons.

The program of remodelling temporary buildings for present use has continued with the completion of the Biophysics Laboratory in the Physiology Division and of the Pathology Laboratory. With the exception of additional animal quarters, only relatively minor additions remain to be accomplished, although further modification of a few existing laboratories must be made because the program has developed more rapidly than was initially believed possible. The operational needs to be met at a future date by a permanent building are being detailed through day-to-day experiences.

At this time it may be well to look at some of the developments of the medical program that pertain to education, personnel, and training. During these three years 44 persons have been appointed to the Department. Of these, 24 have returned to their own or sister institutions after having spent up to three years working on problems at Brookhaven. Five more men will leave the Department within four months to take up work at other universities. Thus it can be seen that a rotation scheme is actually working with a high degree of effectiveness in the Medical Department. Of the 24 persons who worked here, all but five were with us for six months or longer; hence they were able to develop a real knowledge of and proficiency in working with radioactive isotopes. It is the continuing policy to provide on the medical staff opportunities for interested physicians and investigators to obtain experience in the field of isotope medicine.

On June 30, 1952, the scientific staff totalled 26 members, 23 on full time and three on part time. Total personnel in the Department as of this date was 126, compared with 101 one year ago of whom 21 were on the scientific staff. Dr. John T. Godwin assumed his duties as head of the Division of Pathology on September 1, 1951.

Dr. Van Slyke while on guest status has remained as head of the Division of Biochemistry and has been carrying out numerous investigations in its laboratories as will be seen later. On October 1, 1951, Mr. W.A. Finn transferred to the Medical Department as Executive Aide and on January 8, 1952 was appointed Hospital Administrator.

During the year the operational methods of the Department have been under constant study. It has been possible to simplify and improve many of the procedures with a resulting reduction in both cost and effort. Extremely careful analyses from a cost viewpoint have been made of Department activities, especially in regard to the hospital. As a result it has been possible to maintain an excellent control of costs despite a rapid enlargement of activities.

On January 28, 1952, the isotopes committee of the Hospital of the Rockefeller Institute for Medical Research visited the Department to learn in detail our procedures for handling and controlling radioactive isotopes. Many scientific problems of mutual interest were also discussed. On April 1, 1952, the isotopes committee of New York Hospital paid us a one-day visit to discuss the use of radioactive isotopes in medicine and avenues of collaboration open to the two institutions. On June 5, 1952, the Queens Pediatric Society visited the Hospital and Department as part of its annual outing day. A tour of certain other Laboratory installations was provided. On May 4, 1952, the Department collaborated with the American Medical Association on a live television program showing the actual use of isotopes in the hospital and facilities for their separation in the Hot Laboratory. The program was widely exhibited later by kinescope in areas not on the coaxial cables, and the effort has been very well received.

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, together with visits by Dr. Godwin to the Memorial Center, have provided a two-way path for exchange of ideas and information between the staffs of the two institutions. Close association has also been maintained with the neurosurgical service of the Massachusetts General Hospital by having one of their residents at Brookhaven for four months. During the coming year the association will be maintained but will be modified as experience has shown to be desirable in relation to the patient load and the problems under investigation.

Division of the Hospital

During the past year the Division of the Hospital has shown a marked increase in activity. The patient capacity has remained constant at 26 patients throughout the year, though at times this number has been exceeded, rising as high as 33 patients for short periods. As shown in Table 1, during the past 12 months there were 238 admissions and 242 discharges, as compared with 112 admissions and 114 discharges the previous year. The use of beds has improved, but better scheduling in admission of patients is still desirable while the capacity is limited to only 26 patients, since a group of this size does not always provide a sufficient number with specific disease manifestations for treatments under development at any given time. With a larger total number of patients the constant availability of suitable candidates could be better maintained.

Table 1		
	1951	1952
Patient Days:		
Research	6555	7953
Employee compensable	28	0
Employee non-compensable	61	21
Employee dependent	<u>143</u>	<u>87</u>
Total	6787	8061
Admissions	112	238
Discharges	114	242
Deaths		12
Autopsies		10

The total nursing staff numbered 39 on June 30, 1952 as it did a year ago. Of this number at present 28 are registered nurses, 5 are ward maids and 6 are ward orderlies. All nurses are experienced in handling patients to whom isotopes have been administered or who have received neutron irradiation. To a remarkable degree the nurses and their assistants have been able to create a personal atmosphere for each patient. This is a reflection of their genuine interest in each patient's welfare and of their real desire to anticipate needs and applaud accomplishments of their charges.

The work of the two dietitians has markedly increased during the past year with the large increase in patient days. Despite constantly rising food costs during the period, the high culinary standards of the hospital have been maintained at constant cost per meal through the development of ingenious diets and appetizing means of preparing foods. The marked nutritional improvement of patients during a stay in the hospital is eloquent testimonial to the success of the dietetics section.

All activities relating to the social welfare, recreation, rehabilitation and education of the patients have been centered in the section of occupational therapy. Two full-time qualified therapists have given much of their own time and effort to provide for the patients an interesting and instructive program. The caliber of work done by the patients has shown a very high degree of excellence and the emotional outlets provided have been of inestimable value. Participation of the patients in various activities of occupational therapy totaled 2881 units as compared

Figure 1. The "Brookhaven Express", built by parents of a child from the nephrotic ward.

with 1155 units for the preceding fiscal year. The average daily attendance was 12 patients.

Among the patients with thyroid malignancies it was noted a correlation could be established between their myxedema and occupational therapy activities. When myxedema was at its height the patients were unable and had no desire to avail themselves of facilities provided. It was found that no amount of urging altered the situation. Recognizing that factor and correlating it with BMR measurements then made possible a replanning of activity to fit the patient's medical condition.

For seven school-age patients, tutoring was provided. The individual attention accorded each scholar permitted him to make the maximum advance possible during the school year and narrow the gap between his school age and chronological age. Thanks are due to all neighboring organizations and individuals who with their kind gifts made Christmas time cheerful for the patients.

Statistics for the patients in the hospital are shown in Table 1. An increase will be noted of about 19% in patient days for fiscal 1952 over 1951; however, this is accompanied by an increase of over 100% in the number of admissions during the year. The number of employee and dependent patient days decreased from 231 in fiscal 1951 to 108 in fiscal 1952. During the year research patients were admitted with diagnoses of:

Carcinoma of thyroid	Polycythemia
Carcinoma of ovaries	Sickle cell anemia
Carcinoma of breast	Hydrocephalus
Carcinoma of trachea	Glioblastoma multiforme
Carcinoma of parotid gland	Xanthromatosis tuberosum
Thyrototoxicosis	Gastric ulcer
Non-toxic diffuse thyroid	Alcoholism, chronic
Sublingual thyroid	Pyelitis, chronic
Leukemia	Hepatomegaly
Nephrosis	Gastroenteritis, acute
Leukopenia, cause undetermined	Influenza

It is planned to change the hospital organization considerably during the coming year. All research patients will be placed under the Chief of the Research Medical Service for supervision of their medical care. The responsibility for the scientific direction of clinical problems will remain as at present within the various divisions, but a degree of correlation not previously existing will be achieved through the new chief of service. The total number of beds will be assigned in specific numbers to the various research projects, and it is expected that one or more physicians will have cognizance of patients in each research project. It is believed that by this arrangement the beds will be used to greater efficiency and that prosecution of clinical work will be speeded up, particularly in any developmental phases of clinical investigation. This organizational pattern has been used successfully in other hospitals and was always planned for Brookhaven. However, while the diagnoses were relatively homogeneous in type, the procedures few in number, and the problems thoroughly known by the physicians, further administrative segregation was not believed necessary. Now with expansion to eight basic clinical problems under constant investigation, it is highly desirable that the new organization pattern be instituted. It is planned to begin the new program on or about July 1, 1952.

Division of Industrial Medicine

There was a moderate rise in the total number of clinic visits as compared with the preceding year, and it is to be noted (Table 2) that the increase is in all categories except "compensable illness, accidents, etc." The increase in termination examinations reflects the first full year of this procedure since the data for the previous year covered only the last five months.

Table 2		
Clinic Visits		
	1951	1952
Compensable illness, accident, etc.	1107	1036
Loss-of-time prevention	3519	3836
Pre-employment examination	434	461
Annual examination	1050	1207
Termination examination	113*	352
Subcontractors	213	106
Total occupational causes	6436	6998
Dependents	705	627
Total clinic visits	7141	7625
*Represents last five months only.		

In Table 3 are shown the statistics for x-ray services during the past year. The small increment in the total is largely due to the hospital's increased use of the x-ray. The figures under "loss-of-time prevention" category represent in many instances examinations for possible fractures; the x-rays frequently show that the employee is able to remain at his job with suitable ambulatory treatment.

Contamination accidents to personnel of the Laboratory have fortunately been few in number and none of them serious with respect to exposure or potential hazard. Accidents occur to those who in haste neglect or seek to short-cut the approved practices, and the accident rate can be kept low only by thorough indoctrination of new employees and re-emphasis to older ones of the importance of following the safety procedures.

As of June 30, 1952, personnel of the Division comprised a total of 14 as compared with 16 one year ago. The reduction reflects a transfer of personnel to other divisions in the Department where their work more properly belongs. The professional staff has remained at two full-time and three part-time physicians with no change in this group during the year. The staff is smaller than is desirable and it is hoped that during the coming year it can be brought up to optimum size. Analysis shows that the type of work falls between that of a university department of health and a standard industrial plant type of medical practice. A select group of physicians is required to meet the demands made by this type of medical work.

Table 3
X-Ray Examinations

	1951	1952
Compensable illness, accident, etc.	113	95
Loss-of-time prevention	189	170
Annual and pre-employment examinations	1433	1581
Total occupational causes	1735	1846
Dependents	80	88
Hospital patients, BNL personnel	26	3
Hospital patients, research	148	306
Total hospital	174	309
Total x-ray examinations	1989	2243

Division of Bacteriology

Studies are being carried out on the mechanisms of immunity, how they are affected by radiation exposure, and the similarities and differences between control of bacterial infections, virus infections, parasitic infections and transplanted and primary tumor growths. It has been found that very definite qualitative differences can be demonstrated in the response of immune processes to radiation in each of these invasive agents. Bacterial immunity has been studied from the aspect of resistance to bacterial cell invasion and to the products of the bacteria as typified by tetanus toxin. The influenza virus is the virus under present investigation, and the infestation of *Trichinella spiralis*, the causative agent of trichinosis, has been studied as representative of the parasitic infections. The studies, while revealing the effects of radiation on immunity, are also yielding much important information on the effects of pre-existing and latent infection in the response of an animal to radiation. It is possible to determine statistically the ability of a tumor to maintain itself after transplant from one animal to another, and then by irradiation to observe the effects of radiation of the receptor animal in its response to tumor transplant and the effect of tumor radiation upon growth after transplantation into a nonirradiated animal. It is not yet feasible to determine the effects of local irradiation of tissue immediately surrounding a tumor on the ability of that tumor to grow locally and perhaps lead to widespread invasion of the body, but it is hoped that at some time such an evaluation may be made. Information is being obtained which pertains to the optimum time for an immune stimulus to be most effective after a radiation exposure, as well as whether any additional degree of general immunity may be required under such conditions to overcome the temporary inhibition of certain unspecified local controlling influences. A number of these studies have been documented to a degree in the quarterly reports of the Laboratory during the past year, as well as in papers which have been published or are being prepared for publication.

During the year there has been a marked development of radiation sources for this work. The latest acquisition is a cobalt source capable of radiating small volumes

under carefully controlled conditions at the rate of 860,000 r/hr. This will be of great value in determining susceptibility of bacterial, viral and multicellular elements to radiation, and the resulting change, if one occurs, in immune response of the host may yield information on the nature of the radiation effect in the stimulating agent used. It is thus evident that data are being obtained not only on the basic phenomena of immunity but also on the chemical site of radiation effects. The latter may be of great interest in leading investigators to a direct biological dosimeter.

There has been developed during the year a glioblastoma multiforme in mice which can be regularly transplanted without any loss of its histological characteristics. It is hoped that this tumor can be used advantageously in studying the conditions under which thermal neutron radiation can be used most effectively for control of brain tumors. This tumor is also being studied to compare its response to gamma radiation with results from other types of radiation.

The staff of this Division comprises a total of 11 persons: three on the scientific staff, seven on the technical staff, and one secretary. This is an increase of one in the technical staff over the number a year ago.

Figure 2. Bacteriological sample being placed in new 860,000 r/hr cobalt-60 gamma source.

Division of Pathology

There have been developed during the year procedures whereby radiated animals are made available to the Pathology Division for histological study regardless of the

division carrying out the primary radiation study or its purpose. In the same manner extensive histological studies on tissues from patients are planned whenever possible after local or intravenous isotope treatment and after radiation. Observations are being made on the effects of short-lived isotopes which have a high rate of delivery of radiation dosage. An extensive study has been started on the long-term effects of I-131 administration on rats in so far as carcinogenesis is concerned. The rats are receiving a dose of I-131 roughly comparable to the dose received by a patient in treatment of thyrotoxicosis. Over a three-year period the carcinogenic effects will be studied. Extensive histological studies are under way on brain tumor tissue specimens in an endeavor to obtain a more precise evaluation of the radiation effects and the procedures to follow. Methods of improving radioautographic techniques are under study.

During the period from September 1, 1951 through December 31, 1951, 840 slides were prepared for histological study. Of these, 490 slides were of tissues obtained in 9 autopsies, 90 slides were of biopsies and smears from 35 patients, and 360 were of animal tissues following or as a part of a special study. From January 1, 1952 through June 30, 1952, 7,235 slides were processed. Of this number 45 were of tissues obtained in one autopsy, 270 were of biopsies and smears from 95 patients, and 5,980 were of animal tissues as part of special studies.

The Division of Pathology was moved during the year to a different building. The move was made desirable by the development of the program of radioautography and much increased emphasis on tissue pathology. The new location permitted remodeling to provide a darkroom, tissue-cutting room and other special requirements at a much lower cost than would have been possible with the building the Division was originally housed in.

The research in this Division at the present time is carried out by one scientist with the assistance of the members of the technical staff.

Division of Biochemistry

The work of the Division continued to center about the chemical synthesis of protein. The rates of incorporation of labeled amino acids into cell protein are being studied. To provide more precise information on the way in which protein is made in the cell, studies are also being done on the rate of entry of a labeled compound to the cell and its fate -- whether incorporated or metabolized. A high degree of technical skill to carry out the requisite analytical procedures, as well as great ingenuity in the design of the experimental studies is required so that the desired information may be obtained. On several occasions it has been necessary to modify old or to develop new methods so that the desired accuracy in analysis could be obtained.

In general, there is one great difference between the studies carried on in the Division laboratories and those carried out on protein synthesis elsewhere. While recognizing the importance of understanding the relationship of one constituent to another, the enzymatic systems available, and the general precursors and products of the compound under study, the Division has emphasized the necessity of integrating this detailed knowledge with observations obtained on intact animals since it is only in the

latter circumstance that the reactions are normally carried out. The use of the intact animal as the object of study at once lends greater medical interest to the results obtained and at the same time demands an exceptionally high degree of ingenuity in carrying out the study.

Figure 3. A new cholesterol determination method being performed in clinical chemistry laboratory as part of comparative study of improved clinical methods.

The disposition of C^{14} -labeled alanine in the rat has been studied with both the D and L forms of this amino acid as well as the racemic mixture. The unnatural form of the amino acid may yield more information regarding normal metabolic pathways than the natural form because of the extreme rapidity of the reaction involving the L forms. The work on this problem is just beginning and over a period of time it is planned that a number of different amino acids as well as a number of different proteins will be studied as representative of their ultimate incorporation into body structures.

The Division has worked out an improved method for the analysis of the protein-bound iodine in the blood, which is generally accepted as a measure of thyroid function. It is at present engaged on work using paper chromatography and a fraction cutter for the study of amino acids in blood plasma and other body fluids.

Various members of the Division have engaged in biochemical studies on patients in the hospital. These studies have been concerned largely with the significance of protein-bound plasma iodine determinations in young children with the nephrotic syndrome. Additional studies have been done on patients with thyroid carcinoma.

Figure 4. The amount of CO_2 from burned tissue has been determined in the Van Slyke apparatus and is now being transferred to counting tube to determine C^{14} present.

As the various studies of the Division continue they will become increasingly productive since only during the past year has it been possible to develop from the foundation state of basic laboratory organization and training to the pursuit of demanding technical investigations. As the results accumulate the data will permit testing of a greater number of hypotheses of protein synthesis.

As of June 30, 1952, the Division of Biochemistry had a scientific staff of six, a technical staff of seven, and one secretary. This is an increase of one in the scientific staff over the number a year ago. During the year, one AEC Fellow and one guest scientist from England worked with the Division; they participated in the problems of the Division and made a genuine contribution to the results.

Division of Physiology

In this Division the section of biophysics has been undertaking more refined measurements of the spectrum and flux of the medical facility at the reactor and the construction of a test setup at one

of the ports on the face of the reactor. Many problems of design to provide both protection and accessibility were presented in this endeavor. By the end of the year studies in instrumentation suitable for the medical problems at the reactor, on depth dosage of neutrons, and on analytical methods useful in these studies were well under way. There has been close collaboration in some of these problems with Dr. Rossi and others of Dr. Failla's department in Columbia University. It is believed that the beginnings are sound and that the program will markedly augment the therapeutic efforts which make use of the reactor.

By the end of the year a total of eight patients had been treated with thermal neutrons for glioblastoma multiforme. A significant alteration in the treatment during the year was the introduction of multiple treatments for an individual after animal studies had shown a sufficient degree of safety. One patient received a total of four treatments, one three, and one two. The results indicated that much more information was needed in order to determine the frequency of treatment from the standpoint of safety and from the standpoint of maximum tumor control. Better methods are necessary to evaluate tumor growth and direction of growth so that radiation can be applied most effectively. Additional problems lie in the toxicology of boron and its compounds, as well as the nature of extracellular fluid of the brain and the kinetics of distribution therein for most effective timing of the radiation procedure. Complete histological

studies of patients treated with boron and thermal neutrons are now in progress. Until these are completed conjecture about effectiveness can have but little meaning.

During the early fall and the last half of the year extensive studies were begun on some interesting aspects of boron toxicology and the effectiveness, biologically speaking, of the boron capture reaction as a radiation source in normal animals. Fundamental studies were completed and it is now believed that sufficient data are available to permit some critical testing of effects relative to concentration of both boron and neutrons. These studies will be pursued further during the coming year.

Extensive work has been done on the use of various radioactive isotopes in the measurement of the extent of what may be termed extracellular fluid of the body, as well as in laying the ground work for kinetic studies on distribution and factors affecting the final equilibrium. Sodium-24, chlorine-36, chlorine-38 and bromine-82 were studied, and their distribution volumes compared with inulin and sucrose as well as stable bromine. The great advantage of the radioactive isotopes over the sugars for this type of measurement lies in the simplicity of the methods when adequate counting facilities are available. Much of this work has now been completed to a degree that will permit publication of the results, and papers are being prepared for early submission to suitable periodicals.

As a special phase of extracellular fluid studies, observations have been made on the rates of passage of various elements into ventricular fluid of patients and cerebrospinal fluid of dogs and the effects thereupon of thermal neutron radiation both with and without the administration of boron. To date it appears that the barrier mechanisms operative in the central nervous system are not significantly altered by the amount of thermal neutron radiation that has been administered. Further extensive and careful tests of the nature and strength of this physiological barrier are highly desirable and are planned for the coming year.

Further studies have been carried out with I-131 on thyroid function of nephrotic children and on the possible losses of thyroid hormone by virtue of proteinuria. Studies on extracellular fluid volumes and their relation to certain manifestations of the disease have also been carried out.

The studies on patients with hyperthyroidism and thyroid carcinoma which relate to predictable effects of I-131 administration and effects of hormone administration in its uptake have been carried out. Part of this work has been reported at scientific meetings and is being prepared for publication. The characteristics of radioactive gases have been studied and several trial experiments carried out on their usefulness in certain biological studies.

This spring Dr. E.G. Gross, professor of pharmacology, Dr. R.M. Featherstone, professor of biochemistry, and Dr. C.B. Pittinger, instructor in anesthesiology, all of the State University of Iowa College of Medicine, spent three weeks at Brookhaven on a collaborative study with Drs. Steinfield, Robertson and Stickley of the Laboratory staff. Work has been carried on at Iowa recently to explore the use of stable xenon as an anesthetic gas. It has been found to give good surgical anesthesia in patients but to be not so effective in dogs. Since xenon is an inert gas, the mechanism whereby it produces anesthesia is of great interest. The purpose of the collaborative effort was to study the tissue distribution of xenon administered in anesthetic quantities to dogs.

The concentration of the gas could be determined relatively by using a known concentration of radioactive isotope, and absolutely by weighing the tissue measured. Studies

Figure 5. Blood is being poured into air-driven high-speed centrifuge in order to separate cells from plasma.

were done on distribution in the central nervous system and other organs of the body. A large amount of data was obtained that has now been calculated and is being prepared for publication. The exceptionally fruitful results of this collaboration are a testimonial to the careful planning and training of the participating scientists. It is hoped that many additional collaborative efforts will follow.

Tracer theory is being studied and developed by Drs. Robertson, Tosteson and others in a variety of problems. Prominent among these are studies on rate of exchange of sodium and potassium across red cell membranes in normal and sickled red blood cells. This provides an excellent and useful mechanism to obtain desirable information about the red blood cell, as well as to test numerous hypotheses of tracer theory. Intensive work has been carried on throughout the year, and many of the results of the detailed experiments have been reported in the various quarterly reports during the year.

The studies on the effects of injury on N-15 incorporation into tissue proteins and their breakdown has been brought to at least a temporary conclusion. All experiments have been finished, and analyses are completed. If the data warrant, a special report with complete details will be issued.

The work on splenogenic anemia, intrasplenic pressure, pancreatitis, and the effects of cortisone on fat metabolism in rabbits with chloroform-injured liver has likewise been brought to a temporary conclusion. The numerous data of these experiments are being worked up and manuscripts prepared for publication in suitable periodicals.

On June 30, 1952, there was a total of 23 individuals in the Division, 13 scientists, nine technicians, and one secretary. This compares with a total of 10 persons one year ago, of whom six were scientists and four were on the technical staff. On July 1, 1952, the Division moved to a different building which after some alterations was suitable for the activities of the Division. The major alterations were required for the counting and preparation rooms of the section of biophysics under Dr. Robertson; this section totaled three scientists and three technicians on June 30, 1952. The completion of alterations in the building now provides adequate facilities for the determination, measurement and preparation

Figure 6. Semi-hot bench in new isotopes receiving and preparation room.

for use of all radioactive isotopes used in the Department. All procurement and standardization of radioactive isotopes used in all divisions is done by the biophysics section.

DIRECT SERVICES

The direct services of the Laboratory include those functions that provide direct supporting service to the research programs of the various scientific departments. These services are of a technical nature; they include drafting, shops, photography, library, technical publications, and mechanical engineering and design. While the work load of most of the groups covering these functions has increased, reflecting the over-all progress of the Laboratory's research program, their staffs have remained almost constant.

Technical Information

The staff of the Technical Information Division has numbered 21 during this review period, the same figure as for the previous year.

In recent months, there has been a noticeably steady increase in the work load of the Division in its various functions of the assembling and disseminating of technical information, both within the Laboratory and to other atomic energy sites. This growth is naturally explained by the over-all progress of Brookhaven's research program, and therefore it is not expected that a levelling-off period has yet been reached.

In the Research Library, the Reference Section has processed an average of 82 questions per month, the greatest number being handled during the summer. No major bibliographies have been recently compiled, though a number of literature searches in highly specialized fields have been made at the request of members of the scientific staff. The reading room attendance has increased by 25% over the figure for 1950-51.

At the Circulation Desk, a 22% increase is reported in the number of books, periodicals and documents charged out to staff members. Outside loans of similar material have grown by 90%; most of these requests reflect the increasing interest being taken by industry and education in the peacetime applications of atomic energy, since they come from industrial research organizations and universities. Unless such requests originate in the northeastern area, they are generally referred to the nearest appropriate source.

The collection of translated Russian scientific articles, started in late 1948, has grown to over 700 items. Loans from this pool have increased by 25% during the past year and contributions to it are coming in steadily, not only from research groups and libraries in this country, but also from Canada and Great Britain.

The Classified Library can also report an increase in the demands on its services during the past year for the processing of incoming material as well as outgoing Brookhaven classified reports. In order to relieve as much as possible the future work load and the storage space problem, an intensive destruction program is still under way. Another partial solution lies in the use of microcard copies of the less-used documents, instead of the actual reports themselves. Plans are being made for the AEC to start

reproduction of such material in microcard at an early date, and Brookhaven's Technical Information Division has been vigorously encouraging the program. The Classified Library is now in the process of conducting a Laboratory-wide inventory of all classified material on the site.

The Division's Publication Group has edited and processed for publication 60 major documents originating within the Laboratory, including 35 classified reports. These figures indicate a 58% increase over the preceding year. Also issued, under the supervision of the Research Library, is the Weekly Selected Reading List, which continues to appear on a routine basis. The Guide to Russian Scientific Periodical Literature is another continuing project, although it is no longer being issued as a regular monthly publication, but rather on an irregular basis. Each issue now bears the title of the most important translated article it contains.

In addition to its responsibilities in the publishing of Brookhaven reports, the Division also handles all technical manuscripts written by Laboratory staff members for publication in the scientific and professional journals. During the past year, over 240 such items (including abstracts of speeches) have been processed, a 20% increase over the preceding report period.

The Division's functions in distributing the Laboratory's unclassified reports within the national atomic energy project have continued, with a steady increase in the size of the distribution lists. With the cooperation of the AUI Trustees, a system has now been developed by which members of the scientific departments at the various Associated Universities can receive reprints, extracted from the Laboratory's Quarterly Progress Reports, of those sections of the reports in which they would be especially interested. By this means, it is hoped to foster a closer interest at the universities in the research projects and facilities at Brookhaven.

On May 23, prior to the annual convention of the Special Libraries Association in New York City, a visit to the Laboratory was arranged and the Technical Information Division served as host to over 200 librarians from all over the country. In addition to being shown many of the research facilities, they were naturally very interested in the Library, and spent part of their stay there, to the mutual benefit of visitors and hosts.

Technical Photography and Duplicating

The staff of the Division now numbers 29, and one additional summer helper. The various activities are located in four buildings.

The photographic unit experienced a marked increase in its work load, the number of negatives having doubled over the previous year. A temperature-controlled apparatus for cinephotomicrography has been developed to be used initially in time-lapse studies in connection with the work of the Biology Department. A processing technique was developed with the Electronics Division for its work on a photographic pulse height analyzer. A brief motion picture showing the use of kilocurie sources is in production.

Early in 1952, the illustration section was reorganized with the purpose of consolidating all art work for publications, slides, etc. within one group. This involved the addition of two tracers from the Design Group, bringing the total strength up to five.

In addition to the preparation of graphs, charts, schematics, etc., the section also plans layouts for Laboratory publications.

The photo-offset, copy preparation, and mimeograph operations were consolidated into the Duplicating Group, which now consists of 12 persons. To handle the increase in the volume of reports for reproduction, a 17-in. x 22-in. offset press is being procured, which will permit the running of four pages at one time.

The Division's most important production figures for the period are as follows:

Photographic negatives	4,344
Photomicrographs	1,471
Lantern slides	2,983
Prints	25,393
Photostats	32,789
Offset impressions	2,610,415
Offset plates	2,469
Offset negatives	4,681
Mimeograph impressions	1,886,400
Stencils cut	3,510
Ozalid prints	187,046
Sheets collated and bound	769,775
Report copies issued	28,945

Approximately 10 miles of 16-mm film were processed for the area monitoring stations and other users of motion picture cameras.

Mechanical Engineering and Design

The Division is currently staffed with 8 engineers, 18 designers and draftsmen, and 2 clerks. The various activities are located in three buildings: the Shops, Accelerator, and Nuclear Engineering offices. The groups in the last two locations design and supervise the construction of machines and apparatus for the associated departments, and the group in the Shops office performs a similar function for the Laboratory's other research staffs. The functions of the Division are not rigidly compartmentalized, and projects are assigned to the group that is best able to execute the work.

The following projects were undertaken by the Division during the past year:

Accelerator Office

For the Cosmotron: the assembly, installation and testing of the vacuum chamber, and associated pumping equipment and the pole face windings; the design and installation of beam-viewing devices and vacuum locks; the design of shielding, analyzer magnets, and liquid hydrogen targets.

For the 18-in. cyclotron: the design, construction and installation of the magnet, the vacuum chamber, the pumps, the focussing magnets for the external beam, and all associated structural equipment.

For the nuclear reactor: the design and installation of a water-cooled and shielded "hole" to permit the loading and unloading of organic test samples while the reactor is in operation.

Nuclear Engineering Office

The design, preparation of purchase requisitions and specifications, inspection, and supervision of the construction of 16 projects for the Reactor Science and Engineering Department. Of major interest is the equipment for the Reactor Components Test Program, consisting of a fuel rod assembly for "exponential" tests, and a hot water pumping system with electrically heated rods for making heat transfer measurements at exceedingly high Reynolds numbers, with an alternate array of rods for insertion for vibration testing. Of additional interest are a series of stainless steel sealed loops through which molten metals are pumped, to secure data needed in the design of certain types of reactors.

Shops Office

The design, and in some cases the supervision of installation, of equipment for the following departments and groups:

Physics	14 projects
Chemistry	5 projects
Biology	6 projects
Medical	14 projects
Shops	11 projects

Of particular interest was the work for the Physics Department on the fast neutron chopper, which comprised the design of collimation and vacuum systems, as well as modifications on the rotor and stator housing. The design and development of an atomic beam magnet was worked on, in conjunction with the Nuclear Moments Section. In addition, designs were completed for two large neutron spectrometers and a fast pneumatic rabbit at the reactor.

Shops

At the close of the present report period, the total staff of the Shops Group numbered 81, a reduction of six productive employees during the year. Continued efficient operation of the Group is expected at this present level of employment. Operation of the shops has been approximately the same during this fiscal year as in the past, except that the work load is now largely expended in support of the direct research effort rather than on the construction of new facilities.

The major emphasis for the year has been the manufacture of smaller devices for use in research by all the departments of the Laboratory. Of the 103,000 productive hours worked this past year, over 75% was for small devices, requiring an average of 10 hours each. Continued use of the shops is expected in the production of this type of equipment, and a considerable effort has been made to coordinate the work load for this type of manufacture with that in the various staff shops.

During the past year, several important facilities of the Laboratory, with contributions by the shops, were completed. Among these was the assembly of the Cosmotron vacuum chamber and miscellaneous other construction appurtenances on this machine. The shops also built and installed the high-speed pneumatic rabbit at the reactor for use in the measurement of short half-lived isomers. The 18-in. cyclotron was completely fabricated and installed in its temporary location. A remote-control mechanical manipulator for the Hot Laboratory was built.

The important pieces of capital equipment fabricated included a single crystal neutron spectrometer which was installed at the reactor, and a duplicate of this which was shipped to Philipps Petroleum Company for use with the Materials Testing Reactor at Arco, Idaho. Work on a double crystal spectrometer was begun. The fast neutron chopper with collimator was completed and installed at the reactor for use by the Physics Department. A target box and miscellaneous equipment were provided for the 60-in. cyclotron. A large magnet and associated equipment were built for use at the Nuclear Moments Laboratory. Miscellaneous devices in considerable number have been completed for the Medical Department. A lengthy program involving highly specialized welding of stainless steel pipe and vessels is under way at the Nuclear Engineering building. Several large magnets for use at the accelerators are under construction.

ADMINISTRATION AND MAINTENANCE

Included in this section are reports on Personnel, Architectural Planning and Plant Maintenance, Business Operations, and Security and Plant Protection activities.

The Personnel report covers the status of both the scientific and nonscientific staffs, although some of the broader aspects of the program for the procurement of scientists and engineers are discussed more appropriately in the general introduction to the Laboratory's report.

The report of the Architectural Planning and Plant Maintenance Department, which makes significant contributions in the direct technical support of the Laboratory's research program, is included in this section since its major work is associated with the operation and maintenance of the Laboratory. During the year, the Receiving, Warehousing and Distribution Group was transferred to this Department, and its functions were combined with those of the Maintenance Warehousing. This unification and the procedures introduced have greatly improved operations and have increased the service rendered to all departments of the Laboratory.

The activities of the Budget Office, Fiscal Division, Purchasing Division, and Inventory Management are reported under the general classification "Business Operations." At the time of reorganization of the Receiving, Warehousing and Distribution Group, the Budget Office was charged with the establishment of an Inventory Management Group to coordinate activities relating to the establishment and supervision of inventories and inventory levels. This Group is also active in the program of disposition of surplus materials resulting from the analysis of Laboratory needs.

It has not been considered necessary to cover in detail in this report the various functions grouped under Office Services. These general services, which consist of the Mail and Messenger, Telephone, Archives, and Office Machine Repair functions, have continued routinely as in the previous year.

Since the Laboratory has undertaken more classified projects during the past year, the activities of the Security and Plant Protection Division have necessarily become increasingly varied. This factor, together with the large number of visitors to Brookhaven's research facilities, has resulted in a slight increase in the Division's personnel. Thanks in great measure to the cooperation of the entire Laboratory staff, there have been no serious incidents involving the Police or Fire Groups.

Personnel

Scientific Staff

The composition of the scientific staff for the past three years is given in Table 1. It should be noted that Research Associates, who hold appointments similar to those of postdoctoral fellows for a maximum of two years, are included for statistical purposes under the heading of "visitors." The most striking change over the past year

Table 1
Total Scientific Staff Employed June 30, 1952
Compared with June 30, 1950 and 1951

By Appointment Category	Regular Staff			Visitors					
				Salaried			No Compensation		
	1950	1951	1952	1950	1951	1952	1950	1951	1952
Senior Scientist	32	35	33	7	4	5	-	-	2
Scientist	20	20	29	5	8	5	-	3	16
Associate Scientist	99	109	153	17	14	12	1	4	20
Research Associate	-	-	-	1	5	13	1	2	4
Junior Scientist	55	53	30	4	2	1	-	-	2
Junior Research Associate	-	-	-	12	12	7	9*	21*	26*
Research Assistant	3	-	2	19	26	63	-	2	1
Total	209	217	247	65	71	106	11	32	71
By Academic Degree									
Ph.D. or M.D.	106	125	152	27	26	29	2	9	31
M.S. or equivalent	41	38	36	13	17	11	-	5	15
Bachelor	56	50	54	23	26	38	9	18	25
No degree	6	4	5	2	2	25	-	-	-
*Includes Radiological Physics Fellows									

has been in the increase of both salaried and nonsalaried visitors, the total of the two being almost twice that of 1951. During the fiscal year, 77 new appointments to the regular staff were offered to scientists and engineers 60 of which have been accepted and 17 declined. The regular staff increased from 217 to 247. This net increase of 30, however, does not reflect the actual magnitude of the change in individual personnel which consisted of an influx of 63 new members and a departure of 33. These figures indicate the contribution made by the Laboratory to the professional experience of scientists and engineers through appointments to its regular staff.

The increase in the number of salaried visitors by June 30, 1952 over the number as of June 30, 1951 is 35. This increase consists almost wholly of undergraduate students who were offered opportunities to work at the Laboratory during the summer of 1952. There is, however, a marked increase in the number of visiting scientists who received no compensation from Brookhaven; this number has more than doubled. The net increase for the fiscal year 1952 of all visitors who worked at the Laboratory is 74. Again, however, this number does not reflect the flow of the scientific staff from other institutions into and out of the Laboratory. During the year, 213 reported for work and 139 departed. The continued increase in the flow of scientific personnel into and out of the Laboratory is gratifying.

A more detailed analysis of the participation of individuals from other institutions in the work of the Laboratory is set forth in Table 2. The figures there are for the years from June 1, 1950 to June 1, 1951 and June 1, 1951 to June 1, 1952. The figures for 1951, there-

Table 2												
Participation in Brookhaven Program by Persons from Other Institutions												
June 1, 1950 - June 1, 1951 and June 1, 1951 - June 1, 1952												
<u>Universities & Colleges</u>	Salaried		No Compensation		Total		More Than 3 Months		Less Than 3 Months		Institutions Represented	
	1951	1952	1951	1952	1951	1952	1951	1952	1951	1952	1951	1952
Faculty	33	27	1	20	34	47	7	17	27	30	21	28
Postdoctoral*	9	17	2	7	11	24	11	24	-	-	2	5
Graduate students	31	47	7	14	38	61	20	31	18	30	16	22
Undergraduate students	3	3	-	-	3	3	-	-	3	3	3	3
Radiological Physics Fellows	-	-	5	17	5	17	-	-	5	17	1	1
Subtotal	76	94	15	58	91	152	38	72	53	80	27	39
<u>Non-Educational Institutions</u>												
Staff members	6	14	4	21	10	35	7	31	3	4	5	24
Total	82	108	19	79	101	187	45	103	56	84	32	63
*Includes Research Associates												

Table 3			
Consultants' Services			
Item	For Fiscal		
	1950	1951	1952
Total contracts	149	124	105
No. of consultants	63	38	51
No. of man-days of service	780.5	338	691

fore, include only the summer appointees for 1950 and the figures for 1952, similarly, only the summer appointees for 1951. In all, 47 faculty members from 28 different educational institutions participated in the work of the Laboratory in the year ending June 1, 1952. This increase occurred in the group which received no compensation from the Laboratory. Of the 61 graduate students, 24 were pursuing doctoral investigations here; 11 of these pre-doctoral students completed their theses during the year. Among the institutions represented by faculty and students were 27 from the northeastern region, 11 from outside the northeastern region and one foreign institution.

During the past year, there was a marked increase in the number of staff members from non-educational institutions working at the Laboratory. This increase also was large in the group which received no monies from the Laboratory. The total number of different institutions represented by participants in the Laboratory program increased from 32 to 59 in the two years that have been compared.

The services rendered by consultants are set forth in Table 3 where comparisons are made for fiscal years 1950, 1951 and 1952.

1952 Summer Program For Students - In January 1952, for the first time, a formal announcement was issued of opportunities for students to work at the Laboratory during the summer. These announcements with application forms were sent to 122 different educational institutions in the northeastern region. Applications were received from 288 students representing 76 different institutions. Of these, 197 were from undergraduates in 63 different institutions. Selections from these applicants were made on a competitive basis. Forty appointments have been offered of which 35 have been accepted. Of the 91 graduate students who applied, 45 have been offered summer appointments. Of these, 30 have accepted. Six additional graduate students have accepted appointments in a special category either to carry on work on the basis of their previous experience at the Laboratory or to assist in the carrying out of collaborative research projects initiated by staff members of their universities. In all, there will be 36 graduate students and 35 undergraduate students working at the Laboratory during the summer representing 35 different colleges and universities.

Organization

The Personnel Division has placed continuing emphasis upon consolidation of its various functions in an attempt to obtain optimal efficiency as well as to continue the development of a staff possessing broad experience in all phases of personnel relations. A further step in this direction has been the integration of the functions of the Employee Services Group into the Employment Group, with the subsequent dissolution of the Employee Services Group as a formal entity.

Employment

The total number of Laboratory employees on June 30, 1952 was 1412, representing a net increase of 39 staff members during the fiscal year of 1952. This moderate augmentation of personnel reflects an increase largely among the scientific staff, with a concomitant reduction of the already low ratio of 1 scientist to 4.7 nonscientists on June 30, 1951 to an even lower ratio of 1 scientific staff member to 4.2 nonscientists on June 30, 1952. Pertinent personnel statistics are set forth in Table 4.

Table 4						
Staff Data	Fiscal Year Ending					
	June 30, 1951			June 30, 1952		
Total number of employees	1373*			1412**		
Turnover Data	Total Numbers	Annual Rate (%)	Average Monthly Rate (%)	Total Numbers	Annual Rate (%)	Average Monthly Rate (%)
Accessions	337	25.21	2.10	302	21.45	1.79
Separations (turnover)	289	21.64	1.80	252	17.84	1.49
Net accessions	48	3.54	0.30	50	3.62	0.30
Replacements (net turnover)	259	19.38	1.62	226	16.02	1.34
*Not including 44 temporary appointees and 4 employees of the AUI Public Education Office.						
**Not including 89 temporary appointees.						

It may be noted that the net annual turnover rate of 16.02% for the 12-month period ending June 30, 1952 is approximately 3% lower than the analogous figure for the comparable preceding period. While both net turnover figures may be considered to reflect a satisfactorily stabilized employment situation within a reasonably "normal" range of variation, the lower figure reflects in part a temporary Laboratory policy of nonreplacement of terminating personnel which has been in effect since about April 1, 1952 owing to the indefinite budget situation that has existed since that time.

At the request of the Atomic Energy Commission, the Laboratory is cooperating with the Bureau of Labor Statistics in furnishing to that organization monthly reports of labor turnover, employment, payroll and hours.

Labor Relations

The collective bargaining contract negotiated with Federal Labor Union No. 24426, AFL, on July 21, 1950 extends until June 30, 1955 without interim reopening provisions. In accordance with the provisions of this contract, the second and third semi-annual cost-of-living adjustments for employees in the bargaining unit covered by this contract were made effective, respectively, on January 7 and July 7, 1952 (one upward, one downward); the second annual improvement factor also was made effective on July 7, 1952. Only four grievances during the year required the use of the fourth step of a five-step grievance procedure. It has not been necessary at any time for either the Union or the Laboratory to utilize the fifth step of the grievance procedure which provides for arbitration on a limited number of issues. Although several organizational rearrangements have been required by the Laboratory in the interests of increased operating efficiency, the Union and the Laboratory have reached satisfactory agreement on all of these matters within the scope of the existing five-year contract. The limited use of the last two steps of the grievance procedure and the willingness and ability of both the Union and the Laboratory to meet problems that are within the scope of a long-term contract but that could not possibly have been foreseen during its

drafting clearly indicate the desire of both the Union and the Laboratory to work together harmoniously in the interest of the Laboratory and its employees.

Wage and Salary Administration

The periodic wage and salary survey conducted by the Personnel Division in Nassau and Suffolk Counties indicated that present Laboratory rates of pay have been on a par with rates paid for comparable jobs by other organizations in the survey area. Therefore, no major revisions of the wage and salary schedules were necessary. In accordance with the Laboratory policy, however, the performance and progress of all Laboratory employees were examined at the semi-annual reviews, and appropriate increases were made on a merit basis. As a result of organizational changes, it was necessary to establish several new jobs and eliminate others in the wage and salary schedules.

All wage and salary actions have been taken in accordance with both the letter and the spirit of wage and salary stabilization regulations, although the Laboratory as a nonprofit educational corporation has not been required to submit these actions for Wage and Salary Board examination. However, recently announced Atomic Energy Commission policy requires henceforth the processing for examination of certain actions that heretofore have been exempt from this requirement.

Policy Manual

Experience of more than one year with the Supervisor's Manual of Personnel Policies has indicated that this document serves as an extremely useful instrument for supervisory personnel in carrying out their regular responsibilities in personnel administration. Several new additions to the manual have included a formal statement of Employment and Promotion Policy and Rental Policy for Summer Appointments. Minor modifications have included amplification of such topics as leave of absence and leave without pay, a "time-off plan" and compensatory holiday provisions for non-exempt monthly personnel, and similar routine subjects on which operational experience indicated a need for more detailed statements. A much more efficient system of handling requests for Reimbursement Authorization with the Atomic Energy Commission has also come about through use of the manual.

Employee Benefit Program

Employee participation in the hospitalization and group insurance programs continued at about the same relative levels with approximately 85% of the staff enrolled in the group insurance program and 80% of the staff in the hospitalization program. Participation in the retirement plan, however, increased from about 45% to 60% during the fiscal year.

The Retirement Resolution of Associated Universities, Inc. was amended in June 1952 to allow each participant in the retirement plan, at his option, to participate in the new College Retirement Equities Fund (CREF). This arrangement makes it possible for each staff member who holds a TIAA Annuity Contract to assign 50%, 33 1/3%, or 25% of the regular TIAA premium to the CREF as a premium for an

Equities Fund Certificate. The portion of the premium placed in TIAA provides a guaranteed fixed dollar annuity; the portion placed in CREF provides a variable annuity based in part upon the valuation of equity-type investments, which are considered more sensitive to economic fluctuations. The new option affords to staff members a degree of flexibility in their program of retirement income which makes the Retirement Plan more attractive. Approximately 30% of all TIAA Annuity holders submitted applications for participation in CREF within 15 days after the initial announcement was distributed.

Selective Service

As a matter of practice, the Laboratory notifies selective service boards as soon as an employment offer has been accepted by scientific personnel subject to draft. The boards are given additional, detailed information when the new staff member reports to work. The various local selective service boards have been extremely cooperative both in notifying the Laboratory of classification actions and in granting deferments to scientific personnel. This cooperation has enabled the Laboratory program to continue without any serious impedance by national mobilization activities.

Employee Activities

The Brookhaven Employees' Recreation Association continued to sponsor some 20 social, cultural and physical activities, which function without direct subsidy from the Laboratory. "BERA Activities Night" has now become an annual function. The program for this event last fall included a short play by the Theatre Group, a showing by the Film Study Group, a display by the Camera Club, a demonstration by the Model Railroad Club, and several selections by the BERA Band, all in an exhibition of BERA activities to which the entire staff was invited. Over five hundred persons attended this function, which concluded with an evening of dancing in the gymnasium.

Certain specific BERA activities were augmented in the past year. The Band gave several performances for local charities, the Film Study Group replaced its monthly schedule with semi-monthly showings, and after a successful fall and spring season the Concert Group is planning two summer concerts particularly for the enjoyment of summer visitors. BERA also has initiated renovation and redecoration of the Recreation Building on York Lane by providing drapes for the auditorium and lounge as a first step toward improving the usefulness of this facility.

Residence Services

Negotiation of a renewal contract with the Suffolk Improvement Company for 12 apartments at Hawkins Hill, Stony Brook, Long Island resulted in more favorable terms than those of the original contract, permitting somewhat lower rentals than heretofore for the second floor units and consequently, a more attractive basis for occupancy. These units are considered the most economical protection available to the Laboratory in the form of supplemental housing facilities for use of "on leave" and "term" appointments. They have special value because of the increasing industrialization of the surrounding community which is diminishing the quality and quantity of available housing facilities, particularly those on a rental basis. At the present time,

occupancy at Hawkins Hill is more than 80%.

The apartments on the Laboratory site continue to receive active use, with summer occupancy at capacity and winter occupancy not less than 60%. Increased winter occupancy is being made possible by allowing dormitory residents to occupy vacant apartments between September 15 and May 15, when the demand for these apartments is at its lowest.

The annual survey of rentals charged for housing in neighboring communities was made during January 1952. This survey indicated that rentals for "off-site" housing were comparable to those charged by the Laboratory for "on-site" housing. Accordingly, no modification of the "on-site" rental rates was indicated.

Continued emphasis has been placed on making living conditions more pleasant for the dormitory residents. To this end, lounge and service facilities have been provided in the Women's Dormitory (and Women's Dormitory annex), and the "Commandant's House" on Bell Avenue has been equipped as a lounge for the general use of all on-site residents.

Safety Engineering

The disabling injury frequency rate for the fiscal year 1952 represents an almost 50% improvement over the preceding fiscal year. When accident rates reach the low proportions indicated by the frequency figures for these years, however, the importance which can be attributed to moderate variations in rate cannot be considered overly significant in a statistical sense. Nevertheless, the Brookhaven National Laboratory frequency rate of 1.66 for the 12-month period ending June 30, 1952 may well be compared with an average frequency of 3.42 in all AEC operations and an average frequency of 5.48 in the chemical industry for the 12-month period ending December 31, 1951. Pertinent disabling injury frequency rate data are recorded in Table 5.

Table 5		
Rate	Fiscal Year Ending	
	June 30, 1951	June 30, 1952
Frequency*	3.14	1.66
Severity**	.04	.04
*Number of disabling injuries per million man-hours worked. **Days lost per thousand man-hours worked.		

During December of 1951, a safety survey of the Laboratory was made by Mr. Sidney J. Williams, assistant to the president of the National Safety Council and consultant to the Atomic Energy Commission on safety matters. In concluding his report to the General Manager of the Atomic Energy Commission relative to the Brookhaven National Laboratory, Mr. Williams noted that "the accident record and trend and the safety staff and program are to be highly commended."

With the assistance of the Safety Engineering Group, the special committee appointed by the Director to consider the electrical safety problems of the Laboratory completed the initial phases of this complex study, and the recommendations of the committee defining areas of electrical responsibility between distribution and utilization facilities were embodied in a Standard Instruction which constitutes an integral portion of the Safety Manual. Further additions to the Safety Manual included Standard Instructions on use of carbon tetrachloride, cadmium, mercury and lead, which were made a part of the Hazardous Chemical References Series. These additional chemical references are indicative of the increasing demand on the Safety Engineering Group for industrial hygiene engineering service both from the scientific and service departments of the Laboratory.

With the concurrence of the Radiation Safety Committee, the Safety Engineering Group now conducts personalized orientation talks with all new members of the scientific staff, covering the Laboratory policy on radiation as well as nonradiation safety matters. Further direct service to the scientific program initiated during the past year now provides for a safety review on a more formal basis than heretofore of experimental setups at the reactor.

In the belief that "outside" inspection of elevators, cranes and other hoisting equipment would be desirable, semi-annual inspection service by the Liberty Mutual Insurance Company of these facilities was initiated during the past year.

Cooperating with the Architectural Planning and Plant Maintenance Department, the Safety Engineering Group reviews all proposed plans and specifications for new construction and alterations to existing facilities to insure the inclusion of requisite safety and fire protection engineering features. By continued emphasis on fire protection engineering, particularly in new construction, and continuing improvement of existing facilities through the installation of fire walls and doors, automatic fire protection and detection devices, and similar fire-safety features, the Laboratory is gradually achieving the state of "improved-risk" fire protection required by AEC policy. Although it has been impossible to raise certain facilities to this level as yet, the hazards are recognized by all concerned and have been carefully calculated and evaluated. In fiscal 1952, as in fiscal 1951, the Laboratory fire loss ratio continued at nil.

Architectural Planning and Plant Maintenance

During the fiscal year ending June 30, 1952, the Architectural Planning and Plant Maintenance Department reduced its personnel by 12 from 270 to 258 (exclusive of the personnel (5) in the Maintenance Warehouse Service). This decrease took place in spite of increasing responsibilities, including among others: increased number and size of buildings, such as the new metallurgical laboratory and the pathology laboratory for the Medical Department, maintenance of the Laboratory alarm system (formerly a function of Security and Plant Protection), and laundry service for the Research Hospital.

The services performed by Architectural Planning and Plant Maintenance for the Laboratory (exclusive of the Receiving, Warehousing and Distribution function acquired during the year) can be grouped into four general categories. The manner in which these services are distributed among these four categories is as follows:

1. Site operations	50 %
2. Maintenance	32 %
3. Facilities and work for others (technical services)	15 %
4. Architectural-Engineering Planning and Design	3 %

The building painting program, started in the spring and continued throughout the summer of 1951, was resumed last May to include the painting, both exterior and interior, of buildings used by the Medical Department.

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 Contractors

1. Facilities added:
 - a. Metallurgical laboratory for Nuclear Engineering Department, approximately 17,100 sq ft
 - b. Pathology laboratory for Medical Department, approximately 3,800 sq ft
 - c. Isotope receiving and storage addition to physiology laboratory (Medical Department), 600 sq ft
 - d. Waste holdup system for Medical Department
 - e. Upton Road bridge and approach reconstruction
2. Heat transfer equipment installation and shack near Nuclear Engineering building, approximately 1,500 sq ft
3. Changes to and extension of various laboratory services and equipment (piping, electrical work, air conditioning, dehumidification, furniture and hoods), approximately 1,500 sq ft
4. Physical improvements to and maintenance of buildings (exterior painting and repairs, roof painting and repairs, fire and security protection, floor gratings, and floor structural supports), 30 jobs
5. Additions to and modifications of site-wide facilities (steam lines, electric power lines, water and sewage lines, grading and paving) five jobs

B. Planning and Design (approximately 160 jobs, excluding minor operational and maintenance engineering)

1. For new facilities:
 - a. Biology laboratory (second phase)-collaboration with architect-engineer and the AEC during equipment approval period and during construction, approximately 25,000 sq ft
 - b. Waste concentration plant for Nuclear Engineering Department - close collaboration with architect-engineering firm under separate AEC contract, including preparation of preliminary drawings, checking engineering design drawings and specifications and equipment approval, approximately 1,500 sq ft
 - c. Pathology laboratory for Medical Department, approximately 3,800 sq ft
 - d. Cosmotron motor generator house (dc power for experimental work), approximately 1,500 sq ft

e. Upton Road bridge and approach repairs

2. Heat transfer facilities near Nuclear Engineering building (shack and equipment installation only), approximately 1,500 sq ft
3. Improvements and modifications of space in various buildings for new facilities; about six jobs, including the modification of the old pathology laboratory for use as the physiology laboratory and modification of a portion of the bank building for archives.
4. Changes to or extension of laboratory services; about 75 jobs, including electrical work, piping, ventilation, air conditioning, dehumidification, furniture and hoods.
5. Miscellaneous physical improvement to existing buildings and laboratories; about 40 jobs.
6. Site work; about 30 jobs, including general site report, maps, engineering studies for utility systems and the design of changes and additions to the electric power, sewage, water and steam distribution piping, which included detailed engineering design and drawings for the main Rochester Avenue tie.

Receiving, Warehousing and Distribution

In November 1951, when the Inventory Management function was established in the Director's Office, the Receiving, Warehousing and Distribution Group, merged with the Maintenance Warehouse Service, was transferred to the Architectural Planning and Plant Maintenance Department. On July 1, 1951 the Receiving, Warehousing, and Distribution group had a staff of 37, the total for the group numbering 42 when the merger was effected. By June 30, 1952, this total had been reduced to 39.

Working in close coordination with other groups (Inventory Management, Purchasing, Fiscal Division) concerned with allied problems, the group launched an intensive program of reorganization and reorientation with the primary purposes of better service to the users and faster handling of materials. (Some idea of the volume of materials handled by the Receiving, Warehousing and Distribution Group is given by the fact that the daily receipts of materials vary from 50 to 120, with an average of about 80, while the monthly issues from stores amount to about 3300.) The principal changes instituted thus far by the reorganization program are discussed below.

1. Rearrangement of the working procedures in the Receiving Room, where all the materials purchased by the Laboratory are received and checked; better equipment, such as a hydraulic lift at the platform and canvas bag trucks; a new form combining the purchase order and the receiving report; and the establishment of specific truck delivery routes on fixed schedules have so speeded up the work that substantially all materials received are now checked in and delivered within a 24-hour period from the time of receipt.

2. Elimination of duplication in stores items, establishment of realistic stock levels based on usage, the development and use of improved storage methods by means of better bin design, removal from the active stockrooms of excess or surplus materials

and of bulk items, the introduction of display boards, to mention but a few of the means used: these have permitted the consolidation into two buildings, instead of the ten buildings previously required, of all the various categories of stores in active use (electronics, glassware, chemicals, tools, stationery, safety equipment, plastics, laboratory supplies, electrical, plumbing, etc.) that do not require special storage facilities, such as gases, lumber, paints, and dangerous chemicals do. Enough space has been gained in these two buildings to install the cutting tools required to issue such materials as plastics, plywood, etc. in the amounts actually requested instead of in full sheets or lengths. This consolidation, saving of space, and orderly arrangement of the stocks have eliminated much of the confusion and consequent waste of time inherent in crowded storage areas and by facilitating the work of the stores clerks, result also in better service, elimination of errors, and better identification of the stored materials and supplies.

3. A telephone order system has been instituted, and the stock items so ordered are delivered twice daily through the truck delivery system originally developed for the distribution of purchased materials. The delivery time is in general less than four hours from the time of order. This system has proved to be a time saver and the resulting consolidation of deliveries by buildings and departments is adding to the overall efficiency of the distribution and issuing operations.

4. Branch stockrooms under inventory and fiscal control have been established in three locations (Reactor Building, Nuclear Engineering Building and Hot Laboratory) which are remote from the Central Stockroom and show considerable stock activity. In addition to their normal duties, the storekeepers in the branch stockrooms also obtain from Central Stores the items not stocked in the branch stockrooms and serve as a focal point for the delivery of purchases. These branch stockrooms have been an important factor in the noticeable reduction of bench stocks throughout the laboratories which they serve.

5. The Laboratory uses approximately 600 cylinders of 21 different types of gas each month. Attention has been given to the matter of receiving, storage, distribution and return of these cylinders, involving also the problem of demurrage charges. A locator file system has been instituted. A delivery and pick-up service on a scheduled basis for both gases and dry ice has resulted in faster service, as well as reduced demurrage time. A continuing effort is being made to return empty cylinders and to transfer partially used tanks to more active locations in the laboratories. A new system of stocking and handling liquid gases (particularly liquid nitrogen) is being considered.

6. A good start has been made toward providing of warehousing and storage service for the scientific departments and projects of the Laboratory. Most of the specialized equipment and materials being held for the departments and projects have been segregated, sorted out, listed, and arranged in three buildings for easy access and identification. It is hoped that this service will provide for greater re-use of such equipment either by the departments storing it or by exchange between departments.

7. Another important phase of the work undertaken during the last year concerns surplus and excess materials that have been placed in bins and shelving, segregated by type, inventoried, and listed. This process, which will not be completed for several months, will not only simplify the disposal of these materials, but will prevent, with a minimum of effort, the purchase for current use of items which may be on the surplus and excess lists still in the custody of the Laboratory.

Business Operations

The Fiscal Division assumed responsibility for the maintenance and inventory of material supplies at the beginning of the fiscal year. All other previous activities of the Division were continued. The Division has played a major role in the constant review of reporting procedures deemed necessary by the Director's Office and by the Budget Officer and has provided in its reporting procedures specialized information for management purposes. The development of management information is continuing and is being refined for FY 1953.

The number of employees in the Division has remained essentially constant, there being 57 on June 30, 1952 compared with 58 the end of the previous fiscal year.

Through special arrangements made by the Corporation and the AEC, the fiscal work for Project East River was carried on by the Division. The major portion of this work was completed during the fiscal year. Project East River reimbursed the Laboratory for services rendered.

Purchasing

During the report period, the Purchasing Group wrote 11,019 purchase orders, which together with 1,647 change orders, totalled \$1,922,135.71. Table 6 reflects the purchasing activity over the past several fiscal years. The effect of practical completion of the Cosmotron is noticeable in the dollar value of the purchase orders issued.

Table 6				
	FY 49	FY 50	FY 51	FY 52
No. Personnel (6/30)	23	17	18	16
No. Purchase Orders Issued	11,588	11,548	11,333	11,019
No. Change Orders Issued	1,963	1,499	1,442	1,647
Total Orders Issued	13,551	13,047	12,775	12,666
Total Dollar Values	\$4,177,000	\$2,335,000	\$2,419,000	\$1,922,000

Table 6 also shows a further reduction of 11 per cent in the Group's personnel, with a compensating reduction of only 1 per cent in purchase orders and change orders issued. To support this reduction in personnel, the Group has revised its procedures to minimize paper work, not only within its own operations, but also in its necessary relationships with Fiscal Division, Warehousing Group, and the operating activities of the Laboratory. One significant change has been the redesign of the purchase order so that with one typing of a twelve-part form it has been possible to eliminate a thirteen-part typed purchase order, a four-part pencilled tally-in sheet, and a six-part typed receiving report.

The wide variety of materials required for the Laboratory's research and service operations has been in fairly good supply, with reasonably prompt delivery. Metals were the exceptions, particularly stainless steel and monel and fittings of these materials.

The Purchasing Group is also handling the sale of excess materials in cooperation with Inventory Management.

Inventory Management

During this fiscal year, the Laboratory undertook a further overhauling of its inventory, warehousing, and stock-handling procedures. As a result, there was established in the Director's Office the function of Inventory Management; this function comes under the supervision of the Budget Officer and comprises part of his responsibilities for financial planning.

Inventory Management undertakes, in cooperation with the research and other supply-consuming activities, to establish satisfactory choices of supplies, to determine adequate stock levels, to investigate new items and/or technological improvements in standard items, to effect wherever possible maximum standardization of items in general use, to remove from active inventory those items in excess of the needs of the Laboratory, and to arrange for the disposition of excess inventories. The effective cooperation of the Laboratory's several organizational units, particularly in the case of active inventory, is reflected in Table 7.

Table 7			
Inventory Changes			
Type of Inventory	Fiscal Year		
	1950	1951	1952
<u>Active Inventory</u>			
Opening Active Inventory July 1	\$1,218,947	\$1,080,884	\$ 803,322
Net of Purchases, Stores Issues, Adjustments, Additions to Inventory, Transfers to Excess	-138,063	-277,562	-251,183
Closing Active Inventory June 30	1,080,884	803,322	552,139
<u>Excess Inventory</u>			
Opening Excess Inventory July 1		38,843	180,568
Net of Transfers from Active Inventory, Dispositions, and Adjustments	38,843	141,725	131,287
Closing Excess Inventory June 30	38,843	180,568	311,855
<u>Total Inventory</u>			
Opening Total Inventory July 1	1,218,947	1,119,727	983,890
Net of Purchases, Stores Issues, Adjustments, Transfers to Excess and Dispositions	-99,220	-135,837	-119,896
Closing Total Inventory June 30	\$1,119,727	\$ 983,890	\$ 863,994

In continuous cooperation with the Fiscal, Purchasing and Warehousing units, Inventory Management is trying to determine the most economical buying policies and handling procedures for standard items in regular demand. Every opportunity to buy in bulk for on-site storage, to acquire the surpluses of other organizations, and to purchase in bulk on a "when needed" delivery basis is explored. Advantage is taken of such opportunities when consistent with good management.

The disposition of excess inventories has been slower than had been hoped. Inventory Management is responsible to some extent for the slower pace, inasmuch as it recalled all excess lists outstanding about the middle of the year. Since then, much time has been devoted to the re-examination of excess items, the development of new procedures to obtain an orderly flow of work and responsibility, and the revision of the listing of excess items for easy identification by prospective buyers. The comparison of dispositions with the previous fiscal year follows.

	<u>FY 1951</u>	<u>FY 1952</u>
Book values of excess inventory sold	82,700	77,400
Loss on disposition of excess inventory as reflected on the Balance Sheet	63,400	43,700

It is anticipated that dispositions of excess will reach a higher level in fiscal year 1953.

Security and Plant Protection

The activities of the Security and Plant Protection Division during the past year have fluctuated considerably in volume, and there has been a great variation in assigned details. This latter condition was due to the more varied needs of staff members in their classified work rather than to any greater restrictions caused by security requirements. As a result, the Division has been increased by 4 to a total of 118. There has been a large turnover in the staff, because of the loss of men to more lucrative positions in defense plants.

The manning of the regularly scheduled security and protection posts, which are mandatory for the Laboratory, has alone required the services of approximately 24 men on duty each 8 hour tour, 7 days per week. In addition, over 11,000 hours have been devoted to various special needs, which cannot be anticipated but for which provision must be made for security protection to comply with the existing AEC regulations. Among these special assignments are the following: declassified face of the reactor, special patrol of Cosmotron, new construction in the restricted areas, escort service for non-cleared subcontractor's employees, emergency alarms, after-hours work in the metallurgy laboratory, and classified projects outside the regular exclusion areas.

During the past year, the Division has processed approximately 13,000 visitors, 1300 clearances, and 3500 conference visitors; there were also 1500 Fire Group inspections and 56 Fire Group responses, in addition to other normal protection functions. There have been no serious incidents involving the Police or Fire Groups, owing as much to employee cooperation as to continuous activity on the part of the Division.

To meet the new and unusual problems arising from the Laboratory's developing research program, emphasis has been continued on the specialized training of the Police and Fire Groups. The former completed a special course conducted by the Fire Group, which resulted in qualifying most of the police officers as Auxiliary Fire Fighters. Thus, the Laboratory is afforded a ready reservoir of man power for emergencies. The Fire Group, as in the past, held daily practice for its personnel, in line with its established program for keeping abreast of the latest techniques.

APPENDIX

A. UNCLASSIFIED PUBLICATIONS, JULY 1, 1951 - JUNE 30, 1952

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, 1950 - June 30, 1951 (BNL 131 (AS-5))
Quarterly Progress Report, July 1 - September 30, 1951 (BNL 132 (S-11))
Quarterly Progress Report, October 1 - December 31, 1951 (BNL 149 (S-12))
Quarterly Progress Report, January 1 - March 31, 1952 (BNL 177 (S-13))
Quarterly Progress Report, April 1 - June 30, 1952 (BNL 189 (S-14))
Conference Reports:
 The Chemistry and Physiology of the Nucleus (Academic Press)
 Fission Product Utilization (BNL 171 (C-14))
Guide to Russian Scientific Periodical Literature 4, # 7-12 (BNL-L-88 to 93)
 5, # 1 (BNL-L-94)
 # 45 (BNL-L-95)
Weekly Bulletin 4, # 49-52; 5, # 1-49
Weekly Selected Reading List 4, # 17-52; 5, # 1-17

STAFF PUBLICATIONS AND ABSTRACTS

Accelerator Department

Courant, E.D.
 Meson production by nucleons in coulomb fields (A)
 Bull. APS (RA-4) 27, 41 (1952)
Golian, S.E. and Reilly, E.G.
 A magnetic orientation device
 Rev. Sci. Instr. 22, 753-7 (1951)
Sternheimer, R.M.
 The density effect for the ionization loss in various materials
 Phys. Rev. (In press.)
Sternheimer, R.
 Double focusing of charged particles with a wedge-shaped, non-uniform magnetic field
 Rev. Sci. Instr. (In press.)
Sternheimer, R.
 Effect of the atomic core on the magnetic hyperfine structure
 Phys. Rev. 86, 316-24 (1952)
Yuan, L.C.L. and Poss, H.L.
 Particle localization by means of a scintillation detector
 Rev. Sci. Instr. 23, 10, 553 (1952)
Yuan, L.C.L. (See Kouts, H.J., Reactor)
Yuan, L.C.L. (See Poss, H.L., Physics)

Architectural Planning and Plant Maintenance

Ruddy, J.M.
 Counting room electrical design data
 Electrical Construction and Maintenance 51, 58-9 (1952)
Ruddy, J.M.
 Gamma ray shielding (for engineering reference)
 Am. Soc. of Civil Engineers (In press.)

Ruddy, J.M.

Rodent quarters air conditioning design criteria
Heating and Ventilating 49, 95 (1952)

Biology Department

Bowen, V.T. and Sutton, D.

Comparative studies of mineral constituents of marine sponges. I. The general Dysidea, chondrilla, terpios

J. Marine Research 10, 153-67 (1951)

Bowen, V.T. (See Poulson, D.F.)

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

Bowen, V.T.

The uptake and distribution of barium¹⁴⁰ and lanthanum¹⁴⁰ in larvae of Drosophila repleta

J. Exp. Zool. 118, #3 (1951)

Caldecott, R.S., Frolik, E.F., and Morris, R.

A comparison of the effects of X-rays and thermal neutrons on dormant seeds of barley

Proc. Nat. Acad. Sci.

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

DeMoss, R.D. and Gibbs, M.

Mechanism of ethanol formation by Pseudomonas lindneri (A)

Bacteriological Proc., P30 (1952)

Denegre, M. (See Sparrow, A.H.)

Dollinger, E.J.

1. Pseudostarchy

Maize Genetics Cooperation News Letter 26, 5, March 17, 1952

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

Edelmann, A., Healey, R.B. and Mateyko, G.M.

Effect of nitrogen mustard on water metabolism in the rat (A)

Fed. Proc. 11, # 1 (1952)

Edelmann, A., Mateyko, G.M., Charipper, H.A. and Gordon, A.S.

Effects of direct cathode ray particle irradiation of the hypophysis and whole body X-irradiation on the adrenocorticotrophin, gonadotrophins, and thyrotrophin of the pituitary gland of the rat (A)

Am. J. Physiol. 167, 808 (1951)

Edelmann, A.

Survival of adrenalectomized rats with and without replacement therapy following X-irradiation

Am. J. Physiol. 167, 345-8 (1951)

Edelmann, A. and Katsh, S.

Survival of rats adrenalectomized after X-irradiation

Am. J. Physiol. 168, 626-7 (1952)

Gastel, R. (See Gibbs, M.)

German, F. and Bowen, V.T.

A technique for growing plants under sterile conditions

Plant Physiol. 26, 840-2 (1951)

Gest, H. and Gibbs, M.

Preparation and properties of a cell-free "formic hydrogenlyase" system from Escherichia coli

J. Bact. 63, 661-4 (1952)

Gibbs, M. and Wood, W.A.

The effect of substrate on the endogenous respiration of Pseudomonas fluorescens (A)

Bacteriological Proc., P11 (1952)

Gibbs, M. and DeMoss, R.D.

Ethanol formation in Pseudomonas lindneri (L)

Arch. Biochem. and Biophys. 34, 478-9 (1951)

Gibbs, M. and Gastel, R.

Glucose dissimilation by Rhizopus

Arch. Biochem. and Biophys. (In press.)

Gibbs, M. (See Gunsalus, I.C.)

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

Gibbs, M. (See Gest, H.)

Gibbs, M.

Triosephosphate dehydrogenase and glucose-6-phosphate dehydrogenase in the pea plant

Nature 170, 164 (1952)

Gunsalus, I.C. and Gibbs, M.

The heterolactic fermentation: II. Position of C¹⁴ in the products of glucose dissimilation by Leuconostoc mesenteroides

J. Biol. Chem. 194, 871 (1952)

- Healey, R.B. (See Edelman, A.)
- Katsh, S. (See Edelman, A.)
- King, R.C.
The mutagenic effectiveness of radioactive phosphorus in Drosophila melanogaster (A)
Records of the Genetics Soc. of Am. 21, 39 (1952)
- King, R.C.
Sterility and recessive lethal mutation following X-irradiation of female Drosophila melanogaster
Am. Naturalist (In press.)
- King, R.C.
The uptake and distribution of phosphorus in adult Drosophila melanogaster (A)
Anat. Record 113, 550 (1952)
- Klein, J.R.
Decrease in oxygen uptake of duck erythrocytes following whole-body X-irradiation (A)
Fed. Proc. 11, #1 (1952)
- Klein, J.R. (See Sharpe, L.)
- Konzak, C.F. (See Singleton, W.R.)
- Konzak, C.F. and Singleton, W.R.
The relationship of polyploidy to the effects of thermal neutron exposure on plants (A)
Records of the Genetics Soc. of Am. 21, 40 (1952)
- Konzak, C.F.
A temporary mounting medium for determining pollen abortion percentages
Maize Genetics Cooperation News Letter 26, 7-8 (1952)
- Koshland, D.E., Jr.
Displacement mechanisms in enzymatic reactions -- criteria of reaction mechanism (A)
Am. Chem. Soc. Meeting, September 14-9, 1952
- Koshland, D.E., Jr. (See Stein, S.S.)
- Koshland, D.E., Jr.
Retention of configuration and the mechanism of enzyme action (A)
Fed. Proc. 11, #1 (1952)
- Krishnan, P.S. (See Sharpe, L.)
- Mateykó, G.M. (See Edelman, A.)
- Mateyko, G.M.
A reproducible method for sampling and counting cells in the adenohipophysis
Proc. Soc. Exp. Biol. Med.
- Matthews, D.L. (See Singleton, W.R.)
- Matthews, D.L.
Shrunken - 3
Maize Genetics Cooperation News Letter 26, 6, March 17, 1952
- Mikaelsen, K.
The protective effect of glutathione against radiation induced chromosome aberration
Science 116, 172-4 (1952)
- Moses, M.J. (See Sparrow, A.H.)
- Moses, M.J. and Yerganian, G.
Desoxypentose nucleic acid (DNA) content and cytotoxonomy of several Cricetinae (hamsters) (A)
Records of the Genetics Soc. of Am. 21, 51 (1952)
- Moses, M.J.
Quantitative optical techniques in the study of nuclear chemistry
Exp. Cell Research, Supplement 2, 75-94 (1952)
- Nims, L.F. (See Scheraga, H.A.)
- Nims, L.F. and Sutton, E.
Weight changes and water consumption of rats exposed to whole body X-irradiation
Am. J. Physiol. (In press.)
- Perry, M.F.C. (See Rubin, B.A.)
- Pieczur, E.A.
Growth of corn endosperm tissue in vitro
Maize Genetics Cooperation News Letter 26, 6-7, March 17, 1952
- Pond, V. (See Sparrow, A.H.)
- Poulson, D.F., Bowen, V.T., Hilse, R.M. and Robinson, A.C.
The copper metabolism of Drosophila
Proc. Nat. Acad. Sci. (In press.)
- Poulson, D.F. and Bowen, V.T.
Organization and function of the inorganic constituents of nuclei
Exp. Cell Research, Supplement 2, 161-81 (1952)
- Rubin, B.A., Perry, M.F.C. and Thanassi, F.Z.
Metabolic factors affecting the recovery of radiation induced bacterial mutants (A)
Bacteriological Proc., G32 (1952)

- Rubin, B.A., Perry, M.F.C. and Thanassi, F.Z.
The uptake and distribution of phosphorus in *E. coli* B/r (A)
Bacteriological Proc., P10 (1952)
- Rubinson, A.C. (See Poulson, D.F.)
- Sacks, J. and Sinex, F.M.
Dinitrophenol and phosphate turnover in the diaphragm (A)
Am. J. Physiol. 167, 822 (1951)
- Sacks, J. and Sinex, F.M.
The effect of insulin on phosphate transport and glucose metabolism (A)
Fed. Proc. 11, # 1 (1952)
- Sacks, J. and Sinex, F.M.
The effect of 2-4-dinitrophenol on the turnover of the acid-soluble phosphorus of rat diaphragm
Arch. Biochem. Biophys. 39, 205-13 (1952)
- Sacks, J. and Lutwak, L.
Two new nucleotides from rabbit liver (L)
J. Am. Chem. Soc.
- Scheraga, H.A. and Nims, L.F.
The action of X-rays on fibrinogen solutions
Arch. Biochem. Biophys. 36, 336-44 (1952)
- Sharpe, L., Krishnan, P.S. and Klein, J.R.
Uptake by duck erythrocytes of iron added to blood
Arch. Biochem. Biophys. 35, 409-18 (1952)
- Singleton, W.R.
Genetic diversity in foreign corn
Maize Genetics Cooperation News Letter 26, 7, March 17, 1952
- Singleton, W.R., Konzak, C.F. and Matthews, D.L.
Microspore and megaspore mutation rates in maize (A)
Records of the Genetics Soc. 21, 70 (1952)
- Singleton, W.R. (See Konzak, C.F.)
- Singleton, W.R. (See Van Reen, R.)
- Singleton, W.R. (See Sparrow, A.H.)
- Sparrow, A.H., Moses, M.J. and Steele, R.
A cytological and cytochemical approach to an understanding of radiation damage in dividing cells
Brit. J. of Radiology 25, 182-9 (1952)
- Sparrow, A.H., Pond, V. and Sparrow, R.C.
Distribution and behavior of supernumerary chromosomes during microsporogenesis in a population of *Trillium erectum* L.
Am. Naturalist (In press.)
- Sparrow, A.H., Moses, M.J. and DuBow, R.
Relationships between ionizing radiation, chromosome breakage and certain other nuclear disturbances
Exp. Cell Research, Supplement 2, 245-67 (1952)
- Sparrow, A.H., Denegre, M. and Haney, W.J.
Somatic mutations in antirrhinum produced by chronic gamma irradiation (A)
Records of the Genetics Soc. of Am. 21, 71 (1952)
- Sparrow, A.H.
Some cytological and morphological changes induced in plants by ionizing radiation (A)
Science 114, 488 (1951)
- Sparrow, A.H. and Singleton, W.R.
The use of radiocobalt as a source of gamma rays and some effects of chronic irradiation on growing plants
Am. Naturalist (In press.)
- Sparrow, R.C. (See Sparrow, A.H.)
- Steele, R. (See Sparrow, A.H.)
- Steele, R., Van Slyke, D.D. and Plazin, J.
The fate of intravenously administered polyvinyl-pyrrolidone
Ann. N.Y. Acad. Sci. 55, 479-84 (1952)
- Steele, R.
The formation of amino acids from carbohydrate carbon in the mouse
J. Bio. Chem. 198, 237-44 (1952)
- Stein, S.S. and Koshland, D.E., Jr.
Mechanism of action of alkaline phosphatase (L)
Arch. Biochem. Biophys. 39, 229-30 (1952)
- Stein, S.S. and Koshland, D.E., Jr.
Mechanism of phosphatase-catalyzed hydrolysis of phosphate esters (A)
Am. Chem. Soc. 1952 Fall Meeting, September 14-19
- Sutton, D. (See Bowen, V.T.)
- Sutton, E. (See Nims, L.F.)

- Thanassi, F.Z. (See Rubin, B.A.)
 Van Reen, R. and Singleton, W.R.
 Sucrose content in the stalks of maize inbreds
 Agronomy J. (In press.)
 Wood, W.A. (See Gibbs, M.)
 Yerganian, G.
 Cytogenetic possibilities with the Chinese hamster, Cricetulus barabensis griseus (A)
 Records of the Genetics Soc. of Am. 21, 82 (1952)
 Yerganian, G. (See Moses, M.J.)

Chemistry Department

- Allen, A.O.
 Mechanism of decomposition of water by ionizing radiations
 Discussions of Faraday Society
 Allen, A.O. (See Johnson, E.R.)
 Anderson, R.C., Delabarre, Y. and Bothner-By, A.A.
 The chemical analysis and isotopic assay of organic compounds
 Anal. Chem. 24, 1298-1303 (1952)
 Anderson, R.C.
 The impact of radioisotopes on organic chemistry (A)
 Am. Chem. Soc. Meeting, January 17, 1952
 Bigeleisen, J., Perlman, M.L. and Prosser, H.C.
 The conversion of hydrogenic materials to hydrogen for isotopic analysis
 Anal. Chem. 24, 1356-7 (1952)
 Bigeleisen, J.
 Disproportionation in deuterated ammonia (L)
 J. Chem. Phys. 20, 1495 (1952)
 Bigeleisen, J.
 The effects of isotopic substitution on the rates of chemical reactions
 J. Phys. Chem. (In press.)
 Bigeleisen, J. (See Perlman, M.)
 Bigeleisen, J. (See Weston, R.E., Jr.)
 Bigeleisen, J. (See Bonner, F.)
 Bigeleisen, J.
 A theoretical evaluation of the nitrogen isotope effect in the thermal deamination of phthalamide
 Canadian J. Chem. 30, 443-7 (1952)
 Bonner, F. and Bigeleisen, J.
 Non-exchange of oxygen between water and some compounds of nitrogen (N)
 J. Am. Chem. Soc. (In press.)
 Bothner-By, A.A. (See Anderson, R.C.)
 Bothner-By, A.A. and Vaughan, C.W., Jr.
 The gross mechanism of the Victor Meyer and Hartmann reaction
 J. Am. Chem. Soc. 74, 4400-1 (1952)
 Bothner-By, A.A. and Medalia, A.I.
 The ionization constants at 50° of meta- and para-iodoxybenzoic acids
 J. Am. Chem. Soc. 74, 4402-4 (1952)
 Bothner-By, A.A. and Friedman, L.
 An N¹⁵ tracer study of organic azide reactions. I. The Curtius rearrangement of 3,5-dinitrobenzazide-N¹⁵
 J. Am. Chem. Soc. 73, 5391 (1951)
 Bothner-By, A.A. and Friedman, L.
 The reaction of nitrous acid with hydroxylamine
 J. Chem. Phys. 20, 459-62 (1952)
 Corliss, L. (See Weiss, R.J., Physics)
 Davis, R., Jr.
 Nuclear recoil following neutrino emission from beryllium-7
 Phys. Rev. 86, 976-85 (1952)
 Delabarre, Y. (See Anderson, R.C.)
 Dodson, R.W. (See Eimer, L.)
 Dodson, R.W. (See Silverman, J.)
 Dodson, R.W. (See Wolfgang, R.L.)
 Eimer, L., Medalia, A.I. and Dodson, R.W.
 Effect of oxygen on the ferrous-ferric exchange reaction (L)
 J. Chem. Phys. 20, 743-4 (1952)
 Eimer, L. and Medalia, A.I.
 Exchange between the tris-(5,6-dimethyl-1,10-phenanthroline) complexes of iron (II) and (III)
 J. Am. Chem. Soc. 74, 1592-3 (1952)

- Elliott, N. (See Perlman, M.)
- Freed, S. and Sancier, K.M.
The absorption spectra of solutions of chlorophyll a and of chlorophyll b at the temperature of liquid nitrogen
Science 114, 275-6 (1951)
- Freed, S. (See Sancier, K.M.)
- Freed, S. and Sancier, K.M.
Equilibria between species of chlorophylls in solution
Science 116, 175-6 (1952)
- Freed, S. and Sancier, K.M.
Experiments on compound formation in solutions at low temperatures. Iodine and olefins.
J. Am. Chem. Soc. 74, 1273-5 (1952)
- Friedlander, G. and Miller, J.M.
The decay of Fe^{52} (L)
Phys. Rev. 84, 588-9 (1951)
- Friedlander, G. and Orr, W.C.
The decay of I^{125}
Phys. Rev. 84, 484-6 (1952)
- Friedlander, G. and Alburger, D.E.
The decay scheme of Cu^{66}
Phys. Rev. 84, 231-4 (1951)
- Friedlander, G. (See Miller, J.M.)
- Friedman, L. and Irsa, A.P.
The determination of deuterium in water
Anal. Chem. 24, 876-8 (1952)
- Friedman, L. and Turkevich, J.
The mass spectra of some deuterated isopropyl alcohols
J. Am. Chem. Soc. 74, 1666-8 (1952)
- Friedman, L. (See Bothner-By, A.A.)
- Friedman, L. and Turkevich, J.
Studies on the catalytic reduction of acetone
J. Am. Chem. Soc. 74, 1669-71 (1952)
- Grunwald, E.
Acetolysis rates of the cis- and trans-2-chloro- and 2-bromocyclohexyl p-bromobenzenesulfonates
J. Am. Chem. Soc. 73, 5458 (1951)
- Hastings, J. (See Weiss, R.J., Physics)
- Irsa, A.P. (See Friedman, L.)
- Irsa, A.P. (See Thompson, S.O.)
- Johnson, E.R.
Decomposition of hydrogen peroxide by high energy X-rays (L)
J. Chem. Phys. 19, 1204-5 (1951)
- Johnson, E.R. and Allen, A.O.
The molecular yield in the decomposition of water by hard X-rays
J. Am. Chem. Soc. 74, 4147-50 (1952)
- Katcoff, S.
Thermal neutron capture cross section of A^{40} and observation of A^{42}
Phys. Rev. 87, 886-8 (1952)
- Loftfield, R.B.
The Favorskii rearrangement of α -halo-ketones
J. Am. Chem. Soc. 73, 4707 (1951)
- Medalia, A.I. (See Eimer, L.)
- Medalia, A.I. (See Bothner-By, A.A.)
- Medalia, A.I.
A test for traces of organic matter in water
Anal. Chem. 23, 1318 (1951)
- Miller, J.M. (See Friedlander, G.)
- Miller, J.M. and Friedlander, G.
Yields of iron isotopes in high energy nuclear reactions (L)
Phys. Rev. 84, 589 (1951)
- Miskel, J.A. and Perlman, M.L.
Average charge produced by electron capture in A^{37} (L)
Phys. Rev. 87, 543-4 (1952)
- Orr, W.C. (See Friedlander, G.)
- Perlman, M.L. (See Miskel, J.A.)
- Perlman, M.L. (See Bigeleisen, J.)

- Perlman, M.L., Bigeleisen, J. and Elliott, N.
Equilibrium in the exchange of deuterium between ammonia and hydrogen
J. Chem. Phys. (In press.)
- Prosser, H.C. (See Bigeleisen, J.)
- Rubinson, W. and Bernstein, W.
The emission of L X-rays of lead in Po^{210} decay
Phys. Rev. 86, 545 (1952)
- Sancier, K.M. (See Freed, S.)
- Sancier, K.M. and Freed, S.
Comparison of absorption spectrum of uranium tetrachloride with that of praseodymium trichloride and of uranium trichloride with that of neodymium trichloride
J. Chem. Phys. 20, 349-51 (1952)
- Sancier, K.M.
The infrared absorption spectra of solutions of methanol in carbon trichloride in the second harmonic region
J. Chem. Phys.
- Sancier, K.M.
Vapor-liquid equilibria of methanol-carbon tetrachloride in solutions of low methanol concentration
J. Phys. Chem.
- Silverman, J. and Dodson, R.W.
The exchange reaction between the two oxidation states of iron in acid solution
J. Phys. Chem. (In press.)
- Slavin, M. (See Bernstein, W., Electronics)
- Thompson, S.O., Schissler, D.O. and Turkevich, J.
Behavior of paraffin hydrocarbons on electron impact: Synthesis and mass spectra of some deuterated paraffin hydrocarbons
Discussions of the Faraday Soc. (Hydrocarbons), # 10, 46 (1952)
- 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. 73, 5213 (1951)
- Thompson, S.O., Turkevich, J. and Irsa, A.P.
Study of the Fischer-Tropsch reaction using deuterium gas
J. Phys. Chem. 56, 243-50 (1952)
- Turkevich, J. (See Cohen, V.W., Physics)
- Turkevich, J. (See Kikuchi, C., Physics)
- Turkevich, J. (See Thompson, S.O.)
- Turkevich, J. (See Friedman, L.)
- Vaughan, C.W., Jr. (See Bothner-By, A.A.)
- Weston, R.E., Jr. and Bigeleisen, J.
Equilibrium in the exchange of hydrogen between phosphine and water
J. Chem. Phys. 20, 1400 (1952)
- Wilson, E. (See Bainbridge, K.T., Physics)
- Wolfgang, R.L. and Dodson, R.W.
Isotopic exchange between the valence states of mercury
J. Phys. Chem. (In press.)

Electronics and Instrumentation Division

- Bernstein, W. and Schardt, A.W.
Activation of LiI crystal phosphors (L)
Phys. Rev. 85, 919-20 (1952)
- Bernstein, W. (See Rubinson, W., Chemistry)
- Bernstein, W. (See Schardt, A.W.)
- Bernstein, W., Foster, E.H. and Floyd, J.J.
Neutron flux scanner
AECU 1621
- Bernstein, W., Chase, R.L., Slavin, M., Garfield, J. and Schardt, A.W.
Photographic gray wedge pulse height analysis (A)
Bull. Am. Phys. Soc. 27, 9 (1952)
- Bernstein, W. and Schardt, A.W.
Resolution of the scintillation spectrometer (L)
Rev. Sci. Inst. 22, 1020-1 (1951)
- Bernstein, W. and Schardt, A.W.
Scintillation neutron detector (A)
Bull. Am. Phys. Soc. 26, 15 (1951)
- Chase, R.L. (See Higinbotham, W.A.)

- Chase, R.L. (See Bernstein, W.)
 Foster, E.H. (See Bernstein, W.)
 Higinbotham, W.A. and Chase, R.L.
 A flexible pulse amplifier with good overload properties
 Rev. Sci. Inst. 23, 34-6 (1952)
 Kuper, J.B.H.
 Radiological monitoring for civil defense
 Bull. of Atomic Scientists 7, 313 (1951)
 Schardt, A.W. (See Bernstein, W.)
 Schardt, A.W. and Bernstein, W.
 Lithium iodide neutron detector
 BNL-1156
 Schardt, A.W. and Bernstein, W.
 Mixed NaI-LiI crystal for a neutron spectrometer (A)
 Bull. Am. Phys. Soc. 27, 8 (1952)
 Schardt, A.W. and Bernstein, W.
 Performance of 5819 photomultipliers in scintillation spectrometers (A)
 Bull. Am. Phys. Soc. 26, 16 (1951)

Health Physics Department

- Cowan, F.P. and Weiss, J.
 Analysis of urine for gross radioactivity
 Nucleonics 10, 33-5 (1952)
 Cowan, F.P.
 Everyday radiation
 Physics Today 5, 10-6 (1952)
 Cowan, F.P., Farabee, L.B. and Love, R.A.
 Health physics and medical aspects of a strontium-90 inhalation incident
 Am. J. Roentgenol. 67, 805-9 (1952)
 Cowan, F.P.
 Plans for radiation survey at the Cosmotron (A)
 Presented at Industrial Hygiene Assoc. Meetings, Cincinnati
 DelDuca, A. (See Harris, S.J.)
 Gemmell, L.
 The Brookhaven National Laboratory emergency radiological monitoring team
 BNL-1189
 Gemmell, L.
 Engineering studies of filter bed efficiency for the treatment of radioactive wastes
 Nucleonics (In press.)
 Harris, S.J. (See Reinig, W.C.)
 Harris, S.J. and DelDuca, A.
 A new type automatic radioassayer
 Nucleonics 9, 60-4 (1951)
 Herman, W.C.
 A new film packet for radiation dosimetry
 Nucleonics (In press.)
 Reinig, W.C. and Harris, S.J.
 The integrity of the biological shield of the Brookhaven reactor
 BNL 119 (T-25)
 Rosenzweig, W.
 Dosimetry problems connected with a kilocurie source (A)
 Presented at Industrial Hygiene Assoc. Meetings, Cincinnati
 Sanders, A.P.
 A monitor for low intensity beta-radiations (A)
 Bull. Am. Phys. Soc. 27, 8 (1952)
 Weiss, J. (See Cowan, F.P.)
 Weiss, J.
 Chemical dosimetry using ferrous sulfate and ceric sulfate solutions
 Nucleonics 10, 28-31 (1952)
 Weiss, M.M.
 Area survey manual
 BNL 167 (T-28)
 Weiss, M.M.
 Radioactivity detected in precipitation and settled dust*
 BNL 116 (I-13)

*For official use only.

Medical Department

- Drew, R.M.
The utilization of ammonium nitrogen for growth and toxin production by a strain of corynebacterium diphtheriae
Proc. Soc. Exp. Biol. Med. 78, 571 (1951)
- Farr, L.E.
Therapeutic goals in the nephrotic syndrome
Delaware State Med. J. (In press.)
- Hale, W.M. (See Stoner, R.D.)
- Hastings, A.B. (See Sinex, F.M.)
- Love, R.A. (See Cowan, F.P., Health Physics)
- Love, R.A.
Lung carcinoma in an industrial population at an atomic pile site
AECU-1620
- Lutwak, L. and Sacks, J.
On the determination of fructose in fructose phosphate
Arch. Biochem. Biophys. 39, 240 (1952)
- Lutwak, L.
The preparation of radioactive iodinated serum albumin
Proc. Soc. Exp. Biol. Med. (In press.)
- Lutwak, L. (See Sacks, J., Biology)
- MacMullen, J. (See Sinex, F.M.)
- Plazin, J. (See Steele, R., Biology)
- Sinex, F.M. and Van Slyke, D.D.
Determination of polyglucose in blood and urine
Proc. Soc. Exp. Biol. Med. 79, 163-9 (1952)
- Sinex, F.M. (See Sacks, J., Biology)
- Sinex, F.M., MacMullen, J. and Hastings, A.B.
The effect of insulin on the incorporation of carbon-14 into the protein of rat diaphragm
J. Biol. Chem. (In press.)
- Stoner, R.D. and Hale, W.M.
The effect of cobalt⁶⁰ gamma radiation on susceptibility and immunity to trichinosis
Proc. Soc. Exp. Biol. Med. 80, 510-2 (1952)
- Tosteson, D.C.
Red cell potassium exchange in sickle cell anemia (A)
Federation Proc. 11, Part 1, 163 (1952)
- Van Slyke, D.D. (See Sinex, F.M.)
- Van Slyke, D.D. (See Steele, R., Biology)

Photography and Duplicating Division

- Garfield, J. (See Bernstein, W., Electronics)

Physics Department

- Alburger, D.E. (See Motz, H.T.)
- Alburger, D.E.
The decay of Rh^{106}
Phys. Rev. (In press.)
- Alburger, D.E. and Kraushaar, J.J.
The decay scheme and angular correlation of Pr^{144}
Phys. Rev. 87, 448-51 (1952)
- Alburger, D.E. (See Friedlander, G., Chemistry)
- Alburger, D.E.
Pair measurement of gamma-rays with a lens spectrometer
Rev. Sci. Inst. (In press.)
- Bainbridge, K.T., Goldhaber, M. and Wilson, E.
Influence of the chemical state on the lifetime of an isomer (L)
Phys. Rev. 84, 1260-1 (1951)
- Blau, M. and Oliver, A.R.
Stars induced by high energy neutrons in the light elements of the photographic emulsion (A)
Bull. Am. Phys. Soc. 27, 3 (1952)
- Chew, G.J. and Wick, G.C.
The impulse approximation
Phys. Rev. 85, 636-42 (1952)
- Chew, G.F. and Lewis, H.W.
A phenomenological treatment of photomeson production from deuterons
Phys. Rev. 84, 779-85 (1951)

- Church, E.L. (See Hill, R.D.)
 Church, E.L. (See Mihelich, J.W.)
 Clark, J.R. (See Weiss, R.J.)
 Cohen, V.W. (See Kikuchi, C.)
 Cohen, V.W., Kikuchi, C. and Turkevich, J.
 Anisotropy in paramagnetic resonance absorption of picryl-n-amino carbazyl (L)
 Phys. Rev. **85**, 379-80 (1952)
 Cohen, V.W. (See Hawkins, N.J.)
 Cohen, V.W.
 Spectroscopy of radioactive molecules
 N.Y. Acad. Sci. (In press.)
 Cool, R.L. and Piccioni, O.
 Interaction of pions originating in penetrating showers (L)
 Phys. Rev. **87**, 531 (1952)
 Coor, T. (See Hafner, E.M.)
 der Mateosian, E. (See Scharff-Goldhaber, G.)
 der Mateosian, E. and Smith, A.
 The "impregnated" scintillating crystal as a tool for the study of radioactive decay (A)
 Bull. Am. Phys. Soc. **27**, 3 (1952)
 der Mateosian, E. (See Thornton, W.A., Jr.)
 der Mateosian, E. and Goldhaber, M.
 Two-step isomeric transition in $\text{Hf}^{179\text{m}}$ (L)
 Phys. Rev. **83**, 843 (1951)
 Deutsch, M. (See Sunyar, A.W.)
 Deutsch, M. and Scharff-Goldhaber, G.
 Decay of 10.7 min $\text{Co}^{60\text{m}}$ (L)
 Phys. Rev. **83**, 1059 (1951)
 Falk, C.E. and Poss, H.L.
 Liquid scintillation counters
 Am. J. Phys. (In press.)
 Falk, C.E. (See Hafner, E.M.)
 Fowler, E.C., Fowler, W.B., Shutt, R.P., Thorndike, A.M. and Whittemore, W.L.
 Angular distribution of 53 Mev positive pions scattered by protons (L)
 Phys. Rev. **86**, 1053-4 (1952)
 Fowler, E.C. (See Shutt, R.P.)
 Fowler, E.C. (See Thorndike, A.M.)
 Fowler, W.B. (See Fowler, E.C.)
 Fowler, W.B. (See Shutt, R.P.)
 Fowler, W.B. (See Thorndike, A.M.)
 Frisch, D.H. (See Hafner, E.M.)
 Garth, R.C., Hughes, D.J. and Levin, J.S.
 Level densities from fast neutron capture (A)
 Bull. Am. Phys. Soc. **27**, 46 (1952)
 Goldberg, M.D. (See Hughes, D.J.)
 Goldberg, M.D. (See Harvey, J.)
 Goldhaber, M. (See Sunyar, A.W.)
 Goldhaber, M. (See Bainbridge, K.T.)
 Goldhaber, M. and Hill, R.D.
 Nuclear isomers and shell structure
 Revs. Modern Phys. (In press.)
 Goldhaber, M.
 Nuclear isomers and shell theory (A)
 Science **114**, 480 (1951)
 Goldhaber, M. (See Thornton, W.A., Jr.)
 Goldhaber, M. (See der Mateosian, E.)
 Goudsmit, S.A. (See Hays, E.E.)
 Goudsmit, S.A. (See Richards, P.I.)
 Hafner, E.M., Frisch, D.H., Falk, C.E., Coor, T. and Hornyak, W.F.
 Neutron-proton total cross section (A)
 Bull. Am. Phys. Soc. **27**, 18 (1952)
 Harvey, J.A. (See Hughes, D.J.)
 Harvey, J., Hughes, D.J. and Goldberg, M.D.
 The neutron-electron interaction (A)
 Bull. Am. Phys. Soc. **27**, 44 (1952)
 Harvey, J.A., Goldberg, M.D. and Hughes, D.J.
 Reflection and refraction of neutrons from a beryllium mirror (A)
 Bull. Am. Phys. Soc. **27**, 29 (1952)

- Hawkins, N.J., Cohen, V.W. and Koski, W.S.
The microwave spectra of POF_3 and PSF_3 (L)
J. Chem. Phys. 20, 528 (1952)
- Hays, E.E., Richards, P.I. and Goudsmit, S.A.
Mass measurements with a magnetic time of flight mass spectrometer
Phys. Rev. 84, 824-9 (1951)
- Hays, E.E. (See Richards, P.I.)
- Hays, E.E., Richards, P.I. and Goudsmit, S.A.
Time-of-flight mass spectrometer
Symposium on Mass Spectroscopy, Nat. Bur. Standards, 9/6 - 8/51
- Hill, R.D., Church, E.L. and Mihelich, J.W.
The determination of gamma-ray energies from beta-ray spectroscopy and a table of critical X-ray absorption energies
Rev. Sci. Inst. (In press.)
- Hill, R.D. (See Goldhaber, M.)
- Hill, R.D., Scharff-Goldhaber, G. and McKeown, M.
Two-step isomeric transition in $\text{Ba}^{133\text{m}}$ (39 hr) (L)
Phys. Rev. 84, 382-3 (1951)
- Hornyak, W.F.
A fast neutron detector
Rev. Sci. Inst. 23, 264-7 (1952)
- Hornyak, W.F. (See Hafner, E.M.)
- Hughes, D.J. (See Palevsky, H.)
- Hughes, D.J. (See Garth, R.C.)
- Hughes, D.J., Harvey, J.A. and Goldberg, M.D.
Mirror measurement of the neutron-electron interaction (A)
Bull. Am. Phys. Soc. 27, 12 (1952)
- Hughes, D.J. (See Harvey, J.)
- Kikuchi, C. and Cohen, V.W.
Anisotropy in paramagnetic resonance absorption in organic free radicals (A)
Symposium on Molecular Structure and Spectroscopy, Ohio State University, Columbus, Ohio, June, 1952
- Kikuchi, C. (See Cohen, V.W.)
- Kikuchi, C., Cohen, V.W. and Turkevich, J.
Anisotropy in paramagnetic resonance in free radicals (A)
Bull. Am. Phys. Soc. 27, 33 (1952)
- Kleinman, D.A.
The diffuse scattering of neutrons and X-rays (A)
Bull. Am. Phys. Soc. 27, 47 (1952)
- Koski, W.S. (See Hawkins, N.J.)
- Kraushaar, J.J.
Angular correlation of Rh^{106} (A)
Bull. Am. Phys. Soc. 26, 31 (1951)
- Kraushaar, J.J. (See Alburger, D.E.)
- Levin, J.S. (See Garth, R.C.)
- Lindenbaum, S.J. and Bernardini, G.
Interactions of 150 Mev protons with the nucleus $A = 100$ (A)
Bull. Am. Phys. Soc. 27, 31 (1952)
- McKeown, M. (See Hill, R.D.)
- McReynolds, A.W.
Inelastic thermal neutron scattering in lead (A)
Bull. Am. Phys. Soc. 27, 19 (1952)
- McReynolds, A.W.
Neutron refraction in O_2 , N_2 , He, A gases
Phys. Rev. 84, 969-72 (1951)
- Mihelich, J.W. (See Sunyar, A.W.)
- Mihelich, J.W. (See Hill, R.D.)
- Mihelich, J.W. (See Scharff-Goldhaber, G.)
- Mihelich, J.W.
Internal conversion of gamma-ray transitions in the L sub-shells
Phys. Rev. 87, 646-51 (1952)
- Mihelich, J.W. and Church, E.L.
Low energy γ -transition in some rare earth isotopes (L)
Phys. Rev. 85, 690 (1952)
- Mihelich, J.W. and Church, E.L.
Relative internal conversion in the L sub-shells (A)
Bull. Am. Phys. Soc. 26, 37 (1951)
- Miller, D.H. (See Shutt, R.P.)

- Motz, H.T.
Beta activity of Si^{31} and the masses of the Al and Si isotopes (L)
Phys. Rev. 85, 501 (1952)
- Motz, H.T. and Alburger, D.E.
Beta and gamma radiation of Al^{28}
Phys. Rev. 86, 165-7 (1952)
- Motz, H.T. (See Thornton, W.A., Jr.)
- Neuman, M.
Fredholm structures in positron theory (L)
Phys. Rev. 83, 1258 (1951)
- Neuman, M.
A note on the U operator (L)
Phys. Rev. 83, 671 (1951)
- Neuman, M.
On the eigenvalue problem in quantum electrodynamics
Phys. Rev. 85, 129-33 (1952)
- Oliver, A.R. (See Blau, M.)
- Palevsky, H., Hughes, D.J. and Smith, R.R.
Cross section of Fe for cold neutrons (A)
Bull. Am. Phys. Soc. 27, 45 (1952)
- Palevsky, H. and Smith, R.R.
Low energy cross section measurements of Be with the Brookhaven slow neutron chopper (A)
Bull. Am. Phys. Soc. 27, 29 (1952)
- Piccioni, O. (See Cool, R.L.)
- Poss, H.L. (See Falk, C.E.)
- Poss, H.L. (See Yuan, L.C.L., Accelerator)
- Poss, H.L., Salant, E.O., Snow, G.A. and Yuan, L.C.L.
Total cross sections for 14-Mev neutrons
Phys. Rev. 87, 11-20 (1952)
- Ramsey, N.F.
Long range proton-proton tensor force (L)
Phys. Rev. 85, 937-8 (1952)
- Reilly, E.G. (See Golian, S.E., Accelerator)
- Richards, P.I. (See Hays, E.E.)
- Richards, P.I., Hays, E.E. and Goudsmit, S.A.
Masses of lead and bismuth
Phys. Rev. 85, 630 (1952)
- Richards, P.I. and Tuthill, W.A.
A simple ion-gauge regulator (L)
Rev. Sci. Inst. 22, 841-2 (1951)
- Salant, E.O. (See Poss, H.L.)
- Scharff-Goldhaber, G. (See Sunyar, A.W.)
- Scharff-Goldhaber, G. (See Deutsch, M.)
- Scharff-Goldhaber, G., der Mateosian, E. and Mihelich, J.W.
Disintegration schemes of Lu^{176m} (A)
Bull. Am. Phys. Soc. 26, 38 (1951)
- Scharff-Goldhaber, G.
Excited states of even-even nuclei (A)
Bull. Am. Phys. Soc. 27, 42 (1952)
- Scharff-Goldhaber, G. (See Hill, R.D.)
- Scott, W.T.
Summary calculations for projected multiple scattering
Phys. Rev. 85, 245-8 (1952)
- Serber, R. and Snyder, H.S.
The effect of atomic binding on nuclear reaction energies (L)
Phys. Rev. 87, 152 (1952)
- Serber, R.
Meson theory (Lectures)
BNL 153 (T-29)
- Shutt, R.P. (See Fowler, E.C.)
- Shutt, R.P. (See Whittemore, W.L.)
- Shutt, R.P., Fowler, E.C., Miller, D.H., Thorndike, A.M. and Fowler, W.B.
 n^- -p Scattering observed in a diffusion cloud chamber (L)
Phys. Rev. 84, 1247 (1951)
- Shutt, R.P. (See Thorndike, A.M.)

- Shutt, R.P.
A theory of diffusion cloud chambers
Rev. Sci. Inst. 22, 730-6 (1951)
- Sirvetz, M.H.
The microwave spectrum of furan (L)
J. Chem. Phys. 19, 1609-10 (1951)
- Slater, J.C.
The effect of chemical combination on the internal conversion (L)
Phys. Rev. 84, 1261-2 (1951)
- Slater, J.C.
A soluble problem in energy bands
Phys. Rev. 87, 807-35 (1952)
- Smith, A. (See der Mateosian, E.)
- Smith, L.G.
The mass synchrometer (A)
Symposium on Mass Spectroscopy, Nat. Bur. Standards, September 6-8, 1951
- Smith, L.G.
Recent developments with the mass synchrometer (A)
Bull. Am. Phys. Soc. 26, 19 (1951)
- Smith, R.R. (See Palevsky, H.)
- Snow, G.
Analysis of 14 Mev n-p scattering
Phys. Rev. 87, 21-6 (1952)
- Snow, G.A. (See Poss, H.L.)
- Snyder, H.S.
Calculations concerning the measurement of the energy
of charged particles by small angle scattering (L)
Phys. Rev. 83, 1068 (1951)
- Snyder, H.S. (See Serber, R.)
- Snyder, H.S.
Remarks concerning the adiabatic theorem and the S-matrix
Phys. Rev. 83, 1154-9 (1951)
- Snyder, H.S.
Remarks concerning the existence of the Foldy-Wouthuysen transformation (L)
Phys. Rev. 84, 1052 (1951)
- Sunyar, A.W., Mihelich, J.W., Goldhaber, G.S., Goldhaber, M., Wall, N.S. and Deutsch, M.
Decay of Sr^{85} and Sr^{85m}
Phys. Rev. 86, 1023-7 (1952)
- Sunyar, A.W., Mihelich, J.W., Deutsch, M., Scharff-Goldhaber, G. and Goldhaber, M.
Isomerism of Sr^{85} (A)
Bull. Am. Phys. Soc. 26, 38 (1951)
- Sunyar, A.W.
Measurement of some internal conversion coefficients (L)
Phys. Rev. 83, 864 (1951)
- Thorndike, A.M. (See Fowler, E.C.)
- Thorndike, A.M.
Atomic energy
(Encyclopedia) Americana Annual (1952)
- Thorndike, A.M. (See Shutt, R.P.)
- Thorndike, A.M., Fowler, E.C., Fowler, W.B. and Shutt, R.P.
Scattering of 50 Mev positive pions by helium (L)
Phys. Rev. 85, 929 (1952)
- Thorndike, A.M., Fowler, E.C., Shutt, R.P. and Fowler, W.B.
Scattering of π -mesons by hydrogen and helium (A)
Am. Phys. Soc. Meeting, Chicago, October 24-7, 1951
- Thornton, W.A., Jr., der Mateosian, E., Motz, H.T. and Goldhaber, M.
Slow neutron capture gamma rays (A)
Bull. Am. Phys. Soc. 27, 29 (1952)
- Tuthill, W.A. (See Richards, P.I.)
- Wantuch, E.
The scattering of 4.5 and 5.5 Mev neutrons by deuterons
Phys. Rev. 84, 169-72 (1951)
- Weiss, R.J.
Concerning extinction effects in powders (L)
Proc. Phys. Soc. 65B, 553 (1952)

- Weiss, R.J.
Extinction effects in neutron transmission of polycrystalline media
Phys. Rev. 86, 271-5 (1952)
- Weiss, R.J., Hastings, J. and Corliss, L.
Neutron crystal monochromators (L)
Phys. Rev. 83, 863-4 (1951)
- Weiss, R.J., Clark, J.R., Corliss, L. and Hastings, J.
Neutron diffraction studies of cold worked brass
J. Appl. Phys. (In press.)
- Whittemore, W.L. (See Fowler, E.C.)
- Whittemore, W.L. and Shutt, R.P.
Electric and non-electric scattering of cosmic ray mesons and protons (A)
Bull. Am. Phys. Soc. 27, 65 (1952)
- Whittemore, W.L. and Shutt, R.P.
Momentum spectra of cosmic ray mesons and protons at sea level and 3.4 km altitude
Phys. Rev. 86, 940-6 (1952)
- Wick, G.C. (See Chew, G.J.)

Reactor Science and Engineering Department

- Borst, L.B. and Sailor, V.L.
A crystal spectrometer for neutrons (A)
Bull. Am. Phys. Soc. 26, 15 (1952)
- Borst, L.B. (See Sailor, V.L.)
- Bretton, R.H. (See Manowitz, B.)
- Chernick, J.
The dependence of reactor kinetics on temperature
BNL 173 (T-30)
- Cordovi, M.A.
A method of evaluating corrosion test results
Am. Soc. Testing Materials (In press.)
- Downes, K.W. (See Sher, R.)
- Fireman, E.L. and Schwarzer, D.
A re-investigation of the double beta decay from Sn^{124}
Phys. Rev. 86, 451 (1952)
- Floyd, J.J. (See Bernstein, W., Electronics)
- Fried, H. (See Horrigan, R.V.)
- Gurinsky, D.H.
Properties and requirements of materials in nuclear engineering
J. Eng. Education 42, 90-2 (1951)
- Gurinsky, D.H.
Reactor materials requirements (S)
Presented at A.A.A.S. Meeting
- Hance, P.D., III (See Stang, L.G., Jr.)
- Hatch, L.P. and Isakoff, S.
Fluid dynamics of porous systems
Chem. Eng. Progress
- Horrigan, R.V.
Cooking with hot atoms
Research Reviews, 32-4, March, 1952
- Horrigan, R.V. and Fried, H.
Progress report on waste concentration studies. Engineering results on the BNL semi-works vapor filtration vapor compression evaporator
BNL 121 (T-24)
- Horrigan, R.V. (See Manowitz, B.)
- Isakoff, S. (See Hatch, L.P.)
- Kammerer, O.F. (See Teitel, R.J.)
- Kouts, H.J. (See Sher, R.)
- Kouts, H.J. and Yuan, L.C.L.
The production rate of cosmic ray neutrons and C^{14} (L)
Phys. Rev. 86, 128-9 (1952)
- Landon, H.H. and Sailor, V.L.
Slow neutron resonances in Cs and Pd (A)
Bull. Am. Phys. Soc. 27, 30 (1952)
- Manowitz, B.
Current experimental program on fission product utilization
Proceedings of the N.C.A. Technical Sessions at the 45th Annual Convention, January 20, 1952.
Convention Issue, Information Letter No. 1371, January 30, 1952

- Manowitz, B., Horrigan, R.V. and Bretton, R.H.
Progress report on fission products utilization. 1. (Unclassified Section) Preliminary studies on industrial applications of intense gamma radiation. BNL 141 (T-27)
- Manowitz, B.
Use of kilocurie radiation sources
Nucleonics 9, 10-3 (1951)
- Mazzarella, D.A.
An all-weather, remote-recording bivane (A)
Bull. Amer. Meteorological Soc. 33, 60-6 (1952)
- Mazzarella, D.A.
Operational and research facilities in meteorology at Brookhaven (A)
Presented at Am. Meteor. Soc. Meeting, July, 1952
- Mazzarella, D.A.
Wind tunnel tests on seven aerovanes
Rev. Sci. Inst. (In press.)
- Meteorology Group
Ground-level measurements of oil-fog emitted from a hundred meter chimney
Meteorological Monographs 1, 30-5 (1951)
- Rand, A.C., Jr.
Mechanical features of the Brookhaven shielding facility
BNL 139 (T-26)
- Sailor, V.L. (See Borst, L.B.)
- Sailor, V.L. (See Landon, H.H.)
- Sailor, V.L. and Borst, L.B.
Slow neutron resonances in In^{113} and In^{115} (L)
Phys. Rev. 87, 161 (1952)
- Schwarzer, D. (See Fireman, E.L.)
- Selvin, G.J.
Small corrosion resistant valves for remote chemical service
BNL 186 (T-31)
- Sher, R., Kouts, H.J. and Downes, K.W.
Half-life of 139 min Dy^{165} (L)
Phys. Rev. 87, 523 (1952)
- Singer, I.A. and Smith, M.E.
Microclimatology of wind and temperature at Brookhaven (A)
Presented at Am. Meteor. Soc. Meeting, 1952
- Smith, M.E.
The forecasting of micrometeorological variables (A)
Meteorological Monographs 1, 50-5 (1951)
- Smith, M.E.
Meteorological factors in atmospheric pollution problems (A)
Am. Ind. Hyg. Assoc. Quart. 12:4, December, 1951
- Smith, M.E. (See Singer, I.A.)
- Southworth, R.W. (See Thomas, H.C.)
- Stang, L.G., Jr. and Hance, P.D., III
Nomogram for calculating fission-product activities
Nucleonics 10, 48-9 (1952)
- Teitel, R.J. and Kammerer, O.F.
The measurement of spatial particle size by the "line-area" method
J. Metals
- Teitel, R.J.
The uranium-lead system
J. Metals
- Thomas, H.C., Southworth, R.W. and Faucher, J.A., Jr.
Absorption studies on clay minerals. I. Chromatography on clays
J. Chem. Phys. 20, 157-60 (1952)

Technical Information Division

- Puleston, D.
Technical information services at atomic energy laboratories
J. Eng. Education 42, 93-6 (1951)

B. OFFICERS AND SCIENTIFIC STAFF

Leland J. Haworth, Director
Gerald F. Tape, Deputy Director

Robert A. Patterson, Assistant Director,
University Liaison

Maxwell M. Small

George B. Collins, Chairman, Accelerator Project
Howard J. Curtis, Chairman, Biology Department
Richard W. Dodson, Chairman, Chemistry Department
J.B.H. Kuper, Chairman, Instrumentation and Health Physics Department
Lee E. Farr, Chairman, Medical Department
Thomas H. Johnson, Chairman, Physics Department (on leave of absence since 12/1/51)
Samuel A. Goudsmit, Acting Chairman, Physics Department†
Lyle B. Borst, Chairman, Reactor Science and Engineering Department*
Marvin Fox, Associate Chairman, Reactor Science and Engineering Department
Clarke Williams, Associate Chairman, Reactor Science and Engineering Department
J. Georges Peter, Manager, Architectural Planning & Plant Maintenance Department
H. Russell Cort, Budget Officer
Lewis R. Burchill, Controller
Charles F. Dunbar, Legal Counsel
Laurence R. Swart, Personnel Officer
Frederick H. Williams, Security Officer

Accelerator Department

George B. Collins, Chairman
John P. Blewett
M. Hildred Blewett
Ernest M. Bolze
James G. Cottingham
Ernest D. Courant
Edward W. Dexter
H. Edel Dietrich, Jr.*
Salvatore C. Giordano
G. Norris Glasoe*
(on leave from RPI)
George K. Green
William M. Harris
Edward L. Healey
David D. Jacobus
David A. Kassner
Ralph R. Kassner

Calman Lasky
John J. Mede
Walter W. Merkle
William H. Moore, Jr.
Martin Plotkin
Irving J. Polk
Edwin Rogers
Anatole Shapiro
Edward E. Shelton
Lyle W. Smith
Rudi Sternheimer
(on leave from Los Alamos)
Lincoln D. Stoughton
Clifford E. Swartz
Clarence M. Turner
James L. Walsh*
Luke Chia-Liu Yuan

Biology Department

Howard J. Curtis, Chairman
Jesse M. Berkowitz
(on leave from Cornell)
Vaughan T. Bowen
Margaret R. Bubeck*
Richard S. Caldecott
(on leave from U. of Nebraska)
Margaret Clements
Ralph De Moss*
(AEC postdoctoral fellowship)
Elwood J. Dollinger
(graduate student from Columbia)

Rosalind J. DuBow*
Abraham Edelmann
Frederick Forro, Jr.
Martin Gibbs
Irene P. Goldring
(graduate student from NYU)
Seymour Katsh*
(on leave from U. of Massachusetts)
Leroy G. Kavaljian
(on leave from Brooklyn Botanical Garden)
Robert C. King
J. Raymond Klein

†Chairman, July 1, 1952.

*Terminated before June 30, 1952.

Calvin F. Konzak
 Daniel E. Koshland, Jr.
 Gladys M. Mateyko*
 (graduate student from NYU)
 Knut Mikailson*
 (graduate student from Cornell)
 Montrose J. Moses
 Chizue S. Nagareda
 (AEC postdoctoral fellowship)
 Leslie F. Nims
 Lynn M. Paegle
 (assigned from Frankford Arsenal)
 Mary Frances Perry*
 Elizabeth A. Pieczur
 (graduate student from U. of Michigan)

Eugene M. Renkin
 Benjamin A. Rubin*
 Jacob Sacks
 Leon A. Saunders
 Leon M. Sharpe*
 W. Ralph Singleton
 Arnold H. Sparrow
 Robert Steele
 Robert Van Reen*
 Harold H. Williams
 (on leave from Cornell)
 George Yerganian*
 (AEC postdoctoral fellowship)

Chemistry Department

Richard W. Dodson, Chairman
 Augustine O. Allen
 R. Christian Anderson
 Jacob Bigeleisen
 Aksel A. Bothner-By
 Edward Cerwonka*
 (graduate student from Fordham)
 David R. Christman
 Lester M. Corliss
 Raymond Davis, Jr.
 Ray F. Dawson
 (on leave from Columbia)
 Yvette J. Delabarre
 Lois J. Eimer*
 Norman Elliott
 Simon Freed
 Gerhart Friedlander
 Lewis Friedman
 Garman Harbottle
 (on leave of absence)
 Julius Hastings
 Virginia D. Hogan
 Jerome J. Howland, Jr.
 Jerome Hudis
 Adolph P. Irsa

Everett R. Johnson
 Arthur Kant
 Seymour Katcoff
 Avrom I. Medalia
 John A. Miskel
 Eleanor F. Norton
 Morris L. Perlman
 William Robinson
 Stanley Ruby*
 (graduate student from Columbia)
 Jerome Saldick
 Kenneth M. Sancier
 Edward V. Sayre
 Oliver A. Schaeffer
 Harold A. Schwarz
 Morris Slavin
 Raymond W. Stoenner
 Sydney O. Thompson
 Joan Welker
 Ralph E. Weston, Jr.
 Elizabeth D. Wilson
 Alfred P. Wolf
 Richard L. Wolfgang
 Max Wolfsberg

Instrumentation and Health Physics Department

J.B.H. Kuper, Chairman
 William Bernstein
 Seymour Block
 Herbert Booth*
 (assigned from American Cyanamid Co.)
 Richard Bull*
 (assigned from American Cyanamid Co.)
 William F. Burditt
 Irvin A. Butler*
 (assigned from American Cyanamid Co.)
 Robert L. Chase
 Donald W. Connor*
 Frederick P. Cowan
 Anthony Del Duca*
 Edward H. Foster
 Lee Gemmell

Martin Graham
 John S. Handloser
 Bryant L. Hanson
 (assigned from American Cyanamid Co.)
 Saul J. Harris*
 Richard Hede*
 William A. Higinbotham
 Byron E. Keene
 Stanley I. Kramer*
 Richard P. Lawler
 Cornelius F. Murphy
 Casimir Z. Nawrocki
 John V. Nehemias*
 Lloyd A. Nevala
 Frederick B. Oleson
 Seymour Rankowitz

*Terminated before June 30, 1952.

Walter Rosenzweig
 Aaron P. Sanders
 Alois W. Schardt
 W. David Small
 George Sponsler

Charles F. Stearns
 Jerome Weiss
 Max M. Weiss
 Mildred Widgoff

Medical Department

Lee E. Farr, Chairman
 George C. Blanchard*
 (on leave from Massachusetts General Hospital)
 Leonard V. dos Remedios*
 (on leave from New York Hospital)
 Ruth M. Drew
 James A. Fancher, Jr.
 Charles G. Foster
 James L. Gamble
 Lewis I. Gidez
 Arvin S. Glicksman
 (AEC postdoctoral fellowship)
 John R. Godwin
 William M. Hale
 Lawrence V. Hankes
 Charles A. Hannigan*
 (on leave from Memorial Hospital)
 David L. Jellinger
 Herbert B. Locksley
 (on leave from Massachusetts General Hospital)
 Robert A. Love

Leo Lutwak
 Sidney C. Madden*
 Klaus Mayer*
 (postdoctoral appointment)
 Mortimer L. Mendelsohn*
 (on leave from Memorial Hospital)
 James S. Robertson
 Wilma C. Sacks
 F. Marrott Sinex
 George M. Sisson
 (postdoctoral appointment)
 Winton Steinfield
 Elmer E. Stickley
 (postdoctoral appointment)
 Richard D. Stoner
 Daniel L. Sutherland
 (on leave from Massachusetts General Hospital)
 Daniel C. Tosteson
 Donald D. Van Slyke
 Robert N. Watman

Physics Department

Thomas H. Johnson, Chairman (until Dec. 1, 1951)
 Samuel A. Goudsmit, Acting Chairman (Dec. 1, 1951)
 David Alburger
 Charles P. Baker
 (on leave from Cornell University to Nov. 1, 1951)
 Kenneth T. Bainbridge*
 (on leave from Harvard)
 Marietta E. Blau
 Eugene L. Church
 (graduate student from Harvard)
 Victor W. Cohen
 Rodney L. Cool
 Thomas Coor
 Noel R. Corngold
 (graduate student from Harvard)
 Nancy W. Curtis*
 Charles C. Damm
 (assigned from Picatinny Arsenal)
 Theresa Danielson*
 Edward der Mateosian
 George J. Dienes
 Charles E. Falk
 Earl C. Fowler
 William B. Fowler
 Morton Fuchs
 (postdoctoral appointment)
 Donald A. Gilbert
 (postdoctoral appointment)
 Murrey D. Goldberg
 Gertrude Goldhaber

Maurice Goldhaber
 Everett M. Hafner
 John A. Harvey
 Norval J. Hawkins*
 (graduate student from Johns Hopkins)
 Earl E. Hays*
 Clifford J. Heindl
 (graduate student from Columbia)
 John Hornbostel
 William F. Hornyak
 Donald J. Hughes
 John E. Iwersen*
 (graduate student from Johns Hopkins)
 Allen L. Johnson
 Gerald W. Johnson
 (on leave of absence)
 Walter Y. Kato
 (graduate student from Penn. State College)
 Edward J. Kelly
 (postdoctoral appointment)
 Vincent P. Kenny*
 (graduate student from Fordham)
 Chihiro Kikuchi
 (on leave from Michigan State College)
 Walter H. Kleiner
 (on leave from MIT)
 David A. Kleinman
 (postdoctoral appointment)
 George F. Koster*
 (on leave from MIT)

*Terminated before June 30, 1952.

Jack J. Kraushaar
(postdoctoral appointment)
Jane S. Levin
Jules S. Levin
(graduate student from Cornell)
Seymour J. Lindenbaum
Marilyn H. McKeown
Andrew W. McReynolds
John W. Mihelich
Henry T. Motz
Maurice Neuman
(postdoctoral appointment)
Harry Palevsky
Robert H. Parmenter*
(on leave from MIT)
Simon Pasternack
(Assistant Editor of The Physical Review)
Oreste Piccioni
Howard L. Poss*
Paul I. Richards
David B. Rosenblatt
(assigned from Frankford Arsenal)
Stanley L. Ruby
(graduate student from Columbia)
Edward O. Salant

Frederick G.P. Seidl
Ralph P. Shutt
Marshall H. Sirvetz
(postdoctoral appointment)
Joseph E. Smith
Lincoln G. Smith
Richard R. Smith
(graduate student from Columbia)
Jean H. Snover
George A. Snow
Hartland D. Snyder
Marilyn J. Stafne
Andrew W. Sunyar
Alan Thorndike
William A. Thornton*
(graduate student from Yale)
Bert J. Toppel
Richard J. Weiss
(assigned from Watertown Arsenal)
Joseph Weneser
(postdoctoral appointment)
William L. Whittemore
Stephen E. Wiberly
(on leave from RPI)

Reactor Science and Engineering Department

Lyle B. Borst, Chairman†
Marvin Fox, Associate Chairman
Clarke Williams, Associate Chairman
James E. Atherton, Jr.
David S. Ballantine
Hampton O. Banks, Jr.
David W. Bareis
William C. Bartels
(assigned from H.K. Ferguson Co.)
Joseph Berkowitz
John E. Binns
Joseph S. Bryner
David Burgreen
(assigned from H.K. Ferguson Co.)
Frank V. Caccavo
Jack Chernick
Melville Clark, Jr.
Shirley N. Connor*
Marcel A. Cordovi*
(on leave from Babcock & Wilcox)
Wallace De Laguna
(assigned from U.S. Geological Survey)
Kenneth W. Downes
Orrington E. Dwyer
Harmon L. Finston
Edward L. Fireman
John J. Floyd
Hughie L. Foote
(graduate student from U. of Utah)
Herbert M. Fried*
William S. Ginell
Althea Glines

Walter W. Godsin
(assigned from Westinghouse Corp.)
Lionel S. Goldring
Eli Y. Goodman
David H. Gurinsky
Loranus P. Hatch
Franklin A. Heasley*
Raymond J. Heus
Robert J. Hoe
(graduate student from Cornell)
Paul Hogroian
Robert V. Horrigan*
Robert Isler
Otto F. Kammerer
Irving Kaplan
Justin Karp*
Carl J. Klamut
Herbert J.C. Kouts
Harry H. Landon
Theodore M. Littman
Walter Lones
Philip H. Lowry*
Bernard Manowitz
Daniel A. Mazzearella
Robert H. McCormick
(assigned from U.S. Weather Bureau)
Lowell McLean
Francis T. Miles
Sophie Oleksa
(on leave of absence)
Charles L. Osborne
William R. Page

†Terminated August 1st. As of that date, Marvin Fox, Associate Chairman, assumed responsibility for reactor and hot laboratory operations and Clarke Williams, Associate Chairman, assumed responsibility for the research program of the Department.

*Terminated before June 30, 1952.

Jack E. Phillips
DePuyster G. Pitcher
Robert W. Powell
William W. Pratt
Glenn A. Price
Alonzo C. Rand
Chad J. Raseman
William H. Regan, Jr.
Melvin Reier
Leslie G. Ritner
Jerome Sadofsky
Vance L. Sailor
Robert D. Schamberger
Robert J. Schomer
 (on leave from Gibbs & Cox)
William F. Scully*
Gerald J. Selvin*
Thomas V. Sheehan
 (on leave from Standard Oil Co. of Indiana)
Rudolph Sher
Ferdinand Shore

Joseph Silverman
 (assigned from H.K. Ferguson Co.)
Irving A. Singer
Maynard E. Smith
Louis G. Stang
Gerald Strickland
Herbert Susskind
Robert J. Teitel
Walter D. Tucker
Robert L. Turner*
Edward J. Vanderman*
Allen H. Vort
Charles H. Waide
Raymond C. Wanta
 (assigned from U.S. Weather Bureau)
William T. Warner
Alfred M. Warren
 (assigned from U.S. Geological Survey)
Joel Weisman
Warren Winsche*
Edward Wirsing, Jr.
Richard Wiswall

*Terminated before June 30, 1952.