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BROOKHAVEN NATIONAL LABORATORY

Annual Report

July 1, 1953

Associated Universities, Inc.

under contract with the

United States Atomic Energy Commission

Annual Report
July 1, 1953

BROOKHAVEN NATIONAL LABORATORY

Associated Universities, Inc.

Upton, New York

Brookhaven National Laboratory is operated under a contract between the United States Atomic Energy Commission and Associated Universities, Inc. This, the fourth in a series of unclassified Annual Reports, gives an account of the progress of the Laboratory during the interval July 1, 1952 - June 30, 1953, and its plans for the future. It is submitted under the terms of Contract #AT-30-2-GEN-16 between Associated Universities, Inc and the Atomic Energy Commission. Previous reports in this series are

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A report by Associated Universities, Inc, covering the period from January, 1952 - July, 1953 is being issued separately. It contains a resumé of the corporate organization, a statement by the President, a brief account of the actions and discussions of the Board of Trustees, a summary review of the Brookhaven program and, in more detail, a review of the PROJECT EAST RIVER study on civil defense.

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September, 1953

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The first picture of a neutral V particle produced under laboratory conditions by the BNL Cosmotron. This cloud chamber photograph shows the disintegration of the neutral particle into a proton and meson.

INTRODUCTION

This annual report of Brookhaven National Laboratory describes its program and activities for the fiscal year 1953. 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 research and development activities are covered more fully in scientific and technical periodicals and in the quarterly scientific progress reports and other special reports of the Laboratory. Hence, the activities of the Laboratory service organizations are treated more fully in this report, whereas the details of the research program are covered in summary.

Brookhaven National Laboratory is operated by Associated Universities, Inc, under contract with the US Atomic Energy Commission. The annual report of the Corporation contains summaries of the corporate activities and policies relating to the operation of Brookhaven National Laboratory as well as a report on its other activities. The nine northeastern universities which sponsor the corporation and the two representatives of each which form the Board of Trustees are as follows: George B. Pegram, I.I. Rabi of Columbia; Franklin A. Long, Theodore P. Wright of Cornell; Norman F. Ramsey, Edward Reynolds of Harvard; H. Keffer Hartline, P. Stewart Macaulay of Johns Hopkins; Edward L. Cochrane, Jerrold R. Zacharias of Massachusetts Institute of Technology; William H. DuBarry, Charles W. MacGregor of Pennsylvania; William S. McCann, LaRoy B. Thompson of Rochester; C. Hamilton Sanford Jr., William W. Watson of Yale. AUI has appointed five Visiting Committees to Brookhaven National Laboratory to provide a continuing independent evaluation of the research program. These Visiting Committees cover the fields of Physics, Chemistry, Biology, Medicine and Engineering and report annually to the Board of Trustees. Their reports are on file with the Corporation and summary statements are included in the Corporation's Annual Report.

The fiscal year 1953 witnessed an active research program in progress at the Laboratory in all areas of investigation. The nuclear reactor continued to support a large and varied research program; the accelerator construction program was essentially completed a year ago, and such construction work in progress at the several machines this year was in the nature of modifications and refinements. As noted last year, the last large facility to be completed was the proton synchrotron or Cosmotron; its formal construction was completed in the spring of 1952. Operational tests proceeded rapidly and a proton energy of 2.3 Bev was obtained for the first time on June 10th of that year. Soon thereafter operations were suspended for an extended period while modifications and refinements were made. A shielding wall was placed around the east half of the machine to isolate it from the experimental area. Operation was resumed in the fall and a rapidly expanding research program is now under way.

The successful operation of the Cosmotron was a milestone for the Laboratory. This significant stage in the Laboratory's development was noted in a formal manner by the Corporation and by the US Atomic Energy Commission when they jointly sponsored dedication ceremonies at the Cosmotron on December 15, 1952. Although the ceremonies were formally centered about the Cosmotron, the day was significant in that it marked the turning point in the Laboratory's history, when the Laboratory was recognized as a full-fledged research organization which had demonstrated its capabilities in carrying out major scientific achievements. Both national and international representatives of scientific and governmental units were present. The Cosmotron was formally dedicated in an address by AEC Commissioner Henry D. Smyth who concluded his remarks with, "I am proud and happy to dedicate this Cosmotron to the enlightenment and service of mankind."

ASSOCIATED UNIVERSITIES, INC.

ORGANIZATION CHART
JULY, 1953

Exhaustive studies have been made on the operational characteristics of the Cosmotron and the behavior of the beam under varying injection and accelerating conditions. Two factors have contributed to the success of these studies: first, the development and present availability of extremely fast detection and recording devices, and second, the longer time cycle of acceleration in the Cosmotron compared with that of lower energy accelerators. For the first time it has been possible to locate the beam orbits continuously in space during the acceleration cycle and to record their position and behavior accurately as a function of the many parameters which control them. As a result, much information has been gained and its application has resulted in improved operation; approximately 10^{10} protons are accelerated to full energy in every pulse. In parallel with the operational studies, a full program of research has been implemented with techniques developed in connection with earlier cosmic ray studies. These include exhaustive use of counters, cloud chambers, and photographic emulsions. However, considerable modification of these techniques has been made to adapt them to controlled beams of high energy mesons, protons, and neutrons. The scintillation counter is playing a constantly more important role.

One of the major difficulties has been the support of a large number of research activities at the same time by the single beam from the machine. Great ingenuity has been exhibited in the use of targets at different locations and the simultaneous use of various beams by different experimenters during the same period of operation. The research demands on the machine very early required the activation of a second shift, and the normal schedule now calls for two shifts per day of operation. Experience has shown that a periodic extended shutdown time is more desirable than occasional short periods. Therefore, one week in four is devoted to extended overhaul and to the provision of sufficient time for the experimenters to adapt their equipment to their own changing requirements.

One of the major purposes in the extensive analysis of the operation of the Cosmotron was to obtain sufficient information that the design of even higher energy accelerators could be better formulated. During the summer of 1952, some consideration was given to the next stage of accelerator development. This interest was stimulated by questions from the sponsors of the European Nuclear Laboratory (CERN) who were considering their own program for the provision of high energy accelerators. A new concept of focusing called the alternating gradient principle was developed at Brookhaven by Courant, Livingston, Snyder and Blewett. In brief, a magnetic accelerator employing this principle would be composed of many magnet sectors each having a sharply changing magnetic field across its aperture but of opposite sense in successive sectors around the circular orbit. The sharp field gradient combined with the alternation provides strong focusing and allows for an extensive reduction in the size of the vacuum chamber in which the particles move; it thereby requires a smaller magnet in comparison with conventional synchrotrons such as the Cosmotron.

The application of the alternating gradient principle can therefore make economically feasible the construction of higher energy machines. Groups of scientists at several institutions have become interested in this problem. In addition to increased effort at Brookhaven, coordinated studies of problems associated with the design, development and construction of 10 to 20 Bev machines are in progress at Princeton University and jointly at Harvard and MIT. The development studies are coordinated through subcontracts of the Laboratory. A group of Midwestern scientists has exhibited considerable interest in a similar high energy machine for possible location in the Midwest. Active participation by this group commenced in the spring of 1953, and a study project was initiated by them in July which, in its early stages, is taking place at Brookhaven.

After publication of the original paper on the alternating gradient principle, the Laboratory's attention was called to the existence of private papers written by

Nicholas C. Christofilos, an American citizen residing in Greece, who had described an application of similar principles to the design of a high energy accelerator. The paper by Mr. Christofilos was dated several years ago and his prior discovery has been acknowledged. Mr. Christofilos joined the Accelerator Development Division of the Laboratory in the spring of 1953 and is now actively engaged in the Laboratory's accelerator development program.

The general problem of design, development, and construction of more energetic accelerators is considered to be of sufficient significance to warrant the establishment of a separate Laboratory Division. The Accelerator Development Division reporting to the Director was set up in July 1953 for this purpose.

The nuclear reactor continues to play a vital role in the Brookhaven program. The volume of research carried out with this facility during the past year has continued to increase. The number of research projects is essentially at capacity with about 40 separate and distinct experimental arrays in use at the three faces of the reactor. Several in-pile facilities have been completed and installed during the year. These include a very fast pneumatic rabbit now in operation on the west face; a large volume irradiation facility in the central core hole to handle physically larger samples than could be accommodated previously; and a liquid nitrogen cooled facility on the east face to provide low temperatures for solid state investigations. The reactor operated about 90 percent of the total time throughout the year, the accumulated annual output being 7500 megawatt days as contrasted with 6370 megawatt days accumulated during the preceding year.

In the early days of the Laboratory it was decided that two adjunct programs, namely meteorological studies and ground-water studies, should be carried out in support of reactor operations. The first program was directed at problems associated with the dispersal of activity carried into the air by the reactor stack effluent. The information and data collected over a period of years by the Meteorology group have demonstrated that the activity carried by the stack effluent under routine operations is not a problem. Before any operating experience had been gained, it was thought that continuous meteorological forecasting might be required to provide advance information on local meteorological conditions for the proper control of reactor operations; this would permit curtailment of operating levels to prevent excessive stack activity from reaching off-site locations. It is now obvious from the knowledge gained of actual meteorological conditions and from measurements of stack activity in the vicinity that curtailment of reactor operations due to meteorological conditions is not necessary. Therefore, support of the meteorological studies as an adjunct to reactor operations is no longer required. Several meteorological research studies, however, have grown out of the study of the behavior of the stack effluent. Some of these, especially those related to the atmospheric turbulence at low elevations, are now being directly studied by the Meteorology group. The extensive facilities and equipment which exist are admirably suited for just such studies. In addition, the reactor operations staff will continue to have consulting service immediately available.

The second study carried out in support of reactor operations, namely ground-water studies, was directed at assessing the seriousness of possible contamination of the ground water in case of accident. The information provided by members of the US Geological Survey, who carried out this phase of the work, indicates that considerable time will be available for action should any serious spill occur. A final comprehensive report covering their findings and recommendations is now in preparation. Laboratory support of this study will be discontinued as of July 1, 1953; however, it is anticipated that the US Geological Survey will maintain some research work at the Laboratory on problems associated with Commission work.

The 60-inch cyclotron, the 18-inch cyclotron, and the electrostatic accelerator have been used in support of research and have also undergone programs of modification

and reconstruction. An extensive program of overhaul, realignment of the magnetic field, and the incorporation of several mechanical changes took place with the 60-inch cyclotron during the winter. Since the completion of those changes, the machine has been alternately used for activation of targets, neutron cross-sections work, and further de-bugging and modification. Significant alpha particle beams, 10 to 20 microamperes at 44 Mev, have also been used for the production of special radioisotopes. The remaining serious mechanical difficulties will be corrected in the near future by the installation of new dees. The 18-inch cyclotron has undergone a period of component modification in the interest of providing a high intensity beam for special neutron physics work. This beam has been obtained, and the work now in progress involves the leading of the beam to external locations for the particular experimental work to be undertaken. The electrostatic accelerator was used during the early part of the year for research and development of neutron detection equipment and is now undergoing an extensive modification in order to increase the energy of the beam, improve the reliability of operation, and provide an expanded experimental work area by relocation of the machine itself. This modification program, which was planned at the time the accelerator was taken over from the manufacturer, was postponed to suit the convenience of the research program. It is expected that the machine will be ready for trial operations in the late summer.

Fiscal year 1953 saw the completion of two major buildings whose construction was carried out by the Atomic Energy Commission and the completion and inauguration of minor plant improvements and additions under the supervision of the Laboratory staff. The addition to the Biology building was finished and was occupied early in 1953. This new addition which now completes the Biology unit provides extensive laboratory space and animal rooms and rounds out the complement of facilities for animal and plant work. The Atomic Energy Commission also contracted for the design study and the ultimate construction of a Waste Concentration Plant for the concentration of dilute liquid radioactive wastes. The plant was turned over to the Laboratory staff for operation at the end of the fiscal year.

A large number of smaller projects was carried out by the Laboratory with most of the actual work done by subcontract. Additions to the steam distribution system during the year resulted in the connection of the high pressure steam plant with the old low pressure central station. This system achieves the tying of the new Biology building to the high pressure plant and also permits the central plant to be closed during the summer months, which thus allows reduction in the heating costs through rescheduling of plant operations. A second greenhouse has been added to the old Biology unit, which provides increased capacity for handling plant specimens required to accommodate increased radiation facilities at the reactor (slow neutrons and fast neutrons) and in the gamma irradiation field where the source strength was increased to over 2000 curies. A micro-biochemical laboratory was added to the medical research complex by the alteration to existing space. The use of high intensity radiocobalt and other sources had been confined to a classified area prior to the completion of a water-irradiation pit in the Hot Laboratory. This modification now permits the irradiation of materials for both on-site and off-site users in an unclassified area; at the same time it has removed this type of work from the reactor canal which is required for the day-to-day handling of reactor fuel elements and for the discharge and transfer of high intensity irradiated materials.

The full activation of the Cosmotron research program requires the addition of a separate structure for the housing of the several motor-generator equipments necessary to power research magnets used in conjunction with the accelerator. The details of the motor-generator house and the electrical installation have been under design for a considerable period of time, and construction was initiated in the spring of 1953. Completion of this unit and installation of all electrical equipment is not anticipated

before the fall of 1953. The successful production of significant amounts of activity as measured by radiochemical means from targets bombarded within the Cosmotron has required expansion of counting facilities for the Chemistry program. An additional counting room for this purpose is now under construction with completion expected in the late summer of 1953.

The increase in Laboratory reports resulting from the maturing of the research program has necessitated an enlargement of facilities for duplication. Rather than expand in personnel, off-set press equipment with a greater production capacity was installed. This installation required some modification of the building space to house the equipment. A larger than normal program of these general plant projects was in progress during this past fiscal year since a sizeable part of the work financed from FY 1952 funds was deliberately delayed until FY 1953. Typical of these projects were the steam line and the Cosmotron motor-generator house.

Laboratory operations are carried out in permanent, semi-permanent and temporary structures. The major facilities such as the reactor and accelerators are housed in structures of permanent type, designed and built specifically to house them. The only research laboratory so housed is the recently completed Biology Laboratory mentioned above. Several semi-permanent type structures inherited from the Army are occupied by research units and service units. However, most of the research laboratory space is still found in temporary wooden structures which were modified from their former Army use. The Laboratory has reached the point at which major decisions must be made concerning future permanent quarters. The long-range development of the Laboratory has been under study by the Laboratory, the Board of Trustees and the Commission. In the fall of 1952 the Commission contracted with Skidmore, Owings and Merrill to study and to recommend a long-range plan for the development of the Laboratory plant and site. This cooperative study has resulted in the submission to the Commission of an analysis of the future plans and program for the Laboratory by AUI, and of a Master Plan report by this firm of architect engineers. These documents are now under study by the Commission and it is expected that formal action will be forthcoming in fiscal year 1954. Briefly, the recommendations call for the ultimate construction of permanent structures to house the research laboratories and the service and administrative units with construction occupying a 12- to 15-year period. The location of the new units will provide for consolidation of the site and a redistribution of research laboratories in order that the physics, chemistry, electronics, and engineering units will be in close proximity to the accelerators and the reactor, and that biology and medicine will be in close proximity to each other. The permanent physics laboratory and the medical research center with its research hospital are the first priority units. It is hoped that these first units can be started in fiscal year 1955.

The business and administrative procedures of the Laboratory are undergoing continuing analysis in order to provide better service to the scientific and technical program at a smaller cost to the Laboratory. The changes instituted in the previous fiscal year have demonstrated their worth. The existence of an Inventory Management Group to coordinate the requirements of the Laboratory inventory and at the same time to streamline the inventory holdings has resulted in a net increase of items stocked, while the total dollar value has been reduced from \$864,000 to \$573,000 within the fiscal year. A reduction in paper work through the implementation of new purchase orders, reductions of requirements on official records by the Government, and the institution of new procedures in materials handling have resulted in improved service at lesser costs. During the last part of this fiscal year an extensive study of punched card systems for accounting and for stores control and for the handling of statistical information was in progress. It was demonstrated that the installation of a punched card system would result in lower operating cost to the Laboratory while at the same time a greater amount

of information could be made available for management purposes. The installation of this equipment was authorized at the end of the year and it is to be completed by January 1, 1954. Immediate application to payroll, inventory records and stores control, and personnel records will be made. A computer with greater flexibility than normally required for accounting purposes is being included so that many scientific problems can be accommodated in addition to the regular fiscal operations.

The research of the Laboratory is carried out within the framework of eight departments. In addition, an Accelerator Development Division reporting to the Director was added on July 1, 1953 which is devoting its entire effort to the study of accelerator development in the energy region of 10 Bev and above. Basic studies in the physical sciences are carried out primarily in the Physics, Cosmotron and Chemistry Departments, and research in the life sciences is conducted in the Biology and Medical Departments. Although the major portion of applied research is found in the Nuclear Engineering Department and in the Reactor Department, some applied work is 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.

Personnel trends for the report year have been similar to those in the past in that there was an increase in the scientific staff, an increase in the technical supporting staff and a decrease in the staff of the general and administrative service units. These changes, however, were not as marked as in previous years. In the case of the scientific and technical supporting staff, a personnel freeze during the spring and summer of 1952, due to budget uncertainties for the fiscal year 1953, forced the Laboratory to pass the normal recruiting period without substantial increases in new scientific personnel. It was not until the winter and spring of 1953 that significant numbers of new scientists were added to the staff. In the case of the administrative and service personnel, further reductions were made during the report year. However, it is felt that the numbers of employees in the administrative and service areas are now at about the lowest level compatible with the present work requirements of the Laboratory. Further reductions are possible only through the elimination of functions which are now considered necessary to continued efficient operations.

It is gratifying to report that the number of scientific visitors at the Laboratory continues to increase. A significant fraction of these visitors, who spend periods of from one month to several years away from their home institutions and participate in the program of the Laboratory, come without salary compensation. Of a total of 327 man-years of scientific effort in the report period, some 75 man-years were contributed by salaried visitors, guests, temporary employees and consultants. The results of the failure to recruit scientific personnel in the spring of 1952 were so costly that a decision was made not to pass the spring recruiting period without making offers to promising new Ph.D.'s. This decision was made without firm knowledge of the budget levels which might be imposed by the Commission for the ensuing fiscal year. It is felt that this procedure is necessary to guarantee continued vitality of the Laboratory's research program through the maintenance of an exceptional group of active younger scientists.

The actual growth of the scientific staff from July 1948 can be seen in Figure 2 on page 12. 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

Figure 2.

Figure 3.

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; however, during the fiscal year 1953, over 24 man-months of service were rendered by these consultants.

The composition of the scientific staff, including the regular research staff of the Laboratory and the visiting scientific staff, is shown in Table 1. It is recognized that the definition of a scientist will vary from discipline to discipline, and such differences are obvious in the table. For example, the scientific staff in Biology and in Medicine is composed 100 percent of those holding Ph.D. or M.D. degrees, whereas in the Physical Sciences certain individuals holding bachelor's or master's degrees are included, depending upon their particular contributions to the research program. The number of such individuals is largest in the engineering field in which equipment design and machine operations are also involved. However, of the research staff total, approximately 75 percent hold doctor's degrees. The large fraction of visiting scientists not holding doctoral degrees is due to students pursuing thesis work. Of the total full-time staff, 62 percent hold doctoral degrees. The part-time visitors who participate in the research program of the Laboratory on an intermittent basis are, in general, professors from nearby institutions. The statistics quoted and used in Table 1 were selected for the staff at the Laboratory on May 1, 1953. In the report year, 186 persons from educational institutions and 53 from other organizations participated in the Brookhaven research program for a period of one month or longer. This is to be contrasted with approximately 152 and 35, respectively, who were engaged in the previous year's work. These numbers have been derived for a period from June to June in each fiscal year in order to include within the report year one complete summer program. The summer program continues to attract a large number of visiting scientists. The demands have been sufficiently large to warrant the scheduling of on-site housing for periods of four, six or twelve weeks and the use of additional off-site housing.

Table 1			
Scientific Staff			
May 1, 1953			
	Doctors	Others	Total
Physics and Chemistry Research	78	15	93
Biology and Medicine Research	41	--	41
Engineering Research	19	31	50
Research Total	138 (75%)	46 (25%)	184
Equipment Design	12	17	29
Operations-Reactor, Acc. and H.P.	2	26	28
Total Staff	152 (63%)	89 (37%)	241
Paid Visitors	17	14*	31
Unpaid Visitors	16	11	27
Full Time Visitors	33	25	58
Total Full Time Staff	185 (62%)	114 (38%)	299
Part Time Visitors	28	3	31
*Thesis Students			

The formal program of participation by undergraduate and graduate students from universities and colleges during the summer period was initiated in 1952. The great success of the first year's program warranted a continuation for the summer of 1953. The circulation of formal announcements to colleges and universities resulted in a response by 276 students. Selections were made on a competitive basis, and acceptances were received from 38 undergraduates and 33 graduates who will be at the Laboratory during the full three months. In addition to their participation in the Laboratory's activities, the students are given a complete briefing on all phases of the research activities in progress.

The trend in nonscientific staff for the Laboratory is shown in Figure 4. This staff has been divided into two groups, namely technical helpers and others. It must be noted

Figure 4.

that included in "others" are those non-technical helpers who work directly in the scientific departments but whose particular skills are not classed as technical. It is interesting to note that since 1950 the total number of nonscientists has remained essentially constant. However, technical help has increased while a corresponding decrease has occurred in the nontechnical help. In terms of scientists present at the end of the fiscal year, there were approximately 3.8 nonscientists per scientist. If the total scientific man-years contributed by all scientists during the

fiscal year are compared with the man-years contributed by the nonscientific staff, this same ratio becomes 3.5 per scientific man-year.

Relatively few organizational changes took place during the report period. As previously noted, an Accelerator Development Division with Dr. L.J. Haworth as Acting Division Head was set up on July 1, 1953. The Metals Warehouse, which previously was a responsibility of the Central Shops Group, was transferred to the Receiving Warehousing and Distribution Group in November 1952.

Drs. Marvin Fox and Clarke Williams, who served as cochairmen of the Reactor Science and Engineering Department, were appointed Chairman of the Reactor Department and Chairman of the Nuclear Engineering Department, respectively, on August 1, 1952.

Three program divisions of the Atomic Energy Commission finance the research program at the Laboratory. These three divisions, namely the Reactor Development Division, the Research Division, and the Biology and Medicine Division, each separately finance research activities at the Laboratory. However, to carry out these activities it is necessary for the Laboratory to provide for the general operation and administrations of the Laboratory and for the support of the technical activities as well as the direct research involved in each activity. The operating costs of the Laboratory for the past three fiscal years are shown in Figure 5. These costs have been distributed by the programs supporting the work and also by major categories of expenditures. It is interesting to note that almost 75 percent of all expenditures are accounted for by salaries and wages.

Figure 6 shows the operational costs of the Laboratory for the past four fiscal years in which the general and administrative costs are contrasted with the direct research costs. Note that in spite of a rising economy the absolute cost of general and administrative work has remained essentially constant. The percentage of these costs to the entire operation has shown a steady decrease from 42.6 percent in 1950 to

COST DISTRIBUTION BY PROGRAMS

YEAR	PHYSICAL SCIENCES	REACTOR DEVELOPMENT	LIFE SCIENCES	OTHER	TOTAL COST
1951	62.9 %	6.4 %	22.4 %	8.3 %	7,995,884
1952	57.8 %	12.3 %	24.0 %	5.9 %	9,234,209
1953	57.2 %	17.7 %	23.2 %	1.9 %	9,568,244

MAJOR CATEGORIES OF EXPENDITURES

YEAR	LABORATORY SALARIES AND WAGES	MATERIALS AND SUPPLIES	SPECIAL POWER	ALL OTHERS	TOTAL COST
1951	73.6 %	18.2 %	3.5 %	4.7 %	7,995,884
1952	74.1 %	17.9 %	5.1 %	2.9 %	9,234,209
1953	74.9 %	19.1 %	4.9 %	1.1 %	9,568,244

Figure 5.

Figure 6. Laboratory operational cost including cost per scientist in thousands of dollars. Figures in parentheses are the same costs expressed in 1950 dollars.

35.4 percent in 1953. The operation of the reactor and the various accelerators, as well as health physics and waste control operations, represents a rather fixed operating cost which is relatively independent of the volume of research carried out. The relative magnitudes of these costs are shown for 1953. During the four years shown, research effort has increased and machines have gone into operation with a resultant increase in annual costs. However, the cost per scientist which was \$30,400 in 1950 has decreased to \$28,000 in 1953, and when expressed in equivalent 1950 dollars to compensate for the effects of the rising economy, this figure becomes \$23,700. Additional details covering the organizational expenditures of the Laboratory for the past three fiscal years are shown in Figure 7. Since

the Laboratory organization contributes labor toward the construction of equipment and in some instances for the design and construction of facilities, the total organization expenditures in any one year are made up of the total of the operational costs plus an appropriate share representing such services rendered to Plant and Equipment Projects. In fiscal year 1953, the total organizational costs were \$9,568,244. The delay in personnel recruiting, which occurred during the early part of the fiscal year, and the subsequent personnel additions which took place in the spring have resulted in a "going rate" of approximately \$10,000,000 for fiscal 1954.

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 divided into four categories:

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 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.

Studies of atomic nuclei, the particles which constitute them and the forces involved in their structure are carried out in the Physics Department, the Cosmotron Department, and the Chemistry Department. The most significant advance during the past year has been the use of the Cosmotron to provide controlled beams of high energy particles. The majority of this high energy research has revolved about the study of interactions between mesons and matter and the observation of new events resulting from the interaction of high energy particles with matter. An expansion chamber is being used in a search for heavy mesons produced by high energy mesons. Diffusion cloud chambers are used to investigate the interactions of neutrons and mesons with hydrogen and other materials in the study of the production of heavy mesons. Photographic emulsions,

ORGANIZATIONAL EXPENDITURES - FISCAL 1951, 1952, 1953 (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 (Total Expense)
Physical Sciences	1953	1,144,834	63,121	78,964	37,021	325,991	73,497	34,319	(122)	1,757,625	18.4	155,363
	1952	1,111,460	52,389	73,191	48,752	268,419	(12)	22,655	(243)	1,576,611	17.1	107,166
	1951	1,156,135	54,400	59,594	47,611	325,993	1,393	37,778	14,511	1,697,415	21.2	146,765
Life Sciences	1953	763,932	27,949	51,673	32,190	178,230	-	-	(8,802)	1,045,172	10.9	47,151
	1952	702,077	15,713	45,417	26,888	211,359	-	-	(8,483)	992,971	10.8	42,301
	1951	526,747	10,310	27,026	16,973	172,806	7,225	-	9,883	770,970	9.7	89,727
Applied Research	1953	724,401	26,481	47,998	29,292	348,184	25,926	-	(12,869)	1,189,413	12.4	92,435
	1952	540,047	21,472	33,931	24,542	304,225	24,970	-	(10,366)	938,821	10.1	140,231
	1951	245,056	10,692	12,056	11,748	102,149	27,526	-	23,250	432,477	5.4	123,026
Radiation Protection	1953	208,735	1,844	13,663	3,058	50,758	-	2,145	(1,028)	279,175	2.9	6,090
	1952	223,659	2,244	14,344	5,362	26,665	18,300	3,478	-	294,052	3.2	9,295
	1951	181,563	738	9,450	3,696	35,101	16,840	4,306	4,748	256,442	3.2	7,495
Supporting Scientific & Technical Services	1953	1,438,589	4,448	93,845	6,003	221,085	-	439,881	(173,119)	2,030,732	21.2	102,443
	1952	1,293,794	2,608	82,496	5,915	201,288	-	439,825	(53,914)	1,972,012	21.4	65,697
	1951	1,136,806	1,452	58,643	9,042	264,926	-	237,947	4,336	1,713,152	21.4	48,535
Security, Police and Fire Protection	1953	504,537	-	32,690	52	6,358	-	-	-	543,637	5.7	457
	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)	1953	-	-	-	-	32,513	-	-	202,277	234,790	2.4	59,973
	1952	-	-	-	32	17,681	-	-	181,525	199,238	2.2	54,691
	1951	-	-	-	276	64,049	-	-	180,080	244,405	3.1	96,071
General & Administrative	1953	1,812,284	2,507	118,638	12,856	475,645	-	-	(98,684)	2,323,246	24.3	3,421
	1952	1,978,153	672	125,957	14,426	444,940	-	-	(95,778)	2,468,370	26.7	-
	1951	1,838,159	1,556	94,913	14,624	422,841	-	-	(106,004)	2,266,089	28.4	-
Laboratory Total	1953	6,597,312	126,350	437,471	120,472	1,638,764	99,423	476,345	(92,347)	9,403,790(1)	98.2	467,333
	1952	6,341,073	95,098	406,691	125,949	1,487,732	43,258	465,958	12,741	8,978,500(2)	97.3	419,431
	1951	5,522,650	79,148	284,581	104,156	1,397,268	52,984	280,031	130,804	7,851,622(3)	98.3	511,620
AUI Administration and Public Education	1953	-	-	-	-	-	-	-	150,000	150,000	1.6	-
	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	1953	6,597,312	126,350	437,471	120,472	1,638,764	99,423	476,345	57,653	9,553,790(1)	99.8	467,333
	1952	6,353,493	95,098	407,483	126,996	1,491,134	43,258	465,958	164,959	9,148,379(2)	99.1	419,431
	1951	5,543,409	79,148	285,657	105,690	1,402,614	52,984	280,031	226,804	7,976,337(3)	99.8	511,620
Work for Others, Direct Costs Only	1953	7,677	-	560	181	1,958	4,078	-	-	14,454	0.2	-
	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	1953	6,604,989	126,350	438,031	120,653	1,640,722	103,501	476,345	57,653	9,568,244(1)	100.0	467,333
	1952	6,394,331	101,417	410,148	139,119	1,515,019	43,258	465,958	164,959	9,234,209(2)	100.0	419,431
	1951	5,547,312	79,148	285,598	105,833	1,410,558	52,984	280,031	234,420	7,995,884(3)	100.0	511,620

(1) \$ 79,667 of this total is also included in Capital Equipment Expense.

(2) \$ 96,094 of this total also is included in Capital Equipment Expense.

(3) \$ 169,719 of this total also is included in Capital Equipment Expense.

Figure 7.

placed in the proton, neutron, and meson beams, provide information on the interaction of these various particles with the nuclei which make up the emulsion. Fast counting equipments are used to study the absorption of mesons at energies up to 1.5 Bev.

It is interesting to note that neutral V-particles are being produced by high energy particles from the Cosmotron. A number of such V-particles has been observed in the diffusion cloud chamber. Recently, photographs have been obtained which represent the absorption of a π -meson by a proton with the creation of a neutral V-particle and a still unknown neutral component. Other diffusion cloud chamber observations have yielded events in which the collision of high energy neutrons with protons produce one or two pions. In addition to the work in high energy physics being carried out directly by BNL staff, a number of cooperative programs are in progress with scientists from the northeast region. Equipment is already in operation at the Cosmotron, and experiments are under way by physicists from MIT, Harvard, and Yale.

The uses of neutrons in the studies of atomic nuclei range from conventional cross-sections measurements to measurement of the neutron-electron interaction. The measurement of neutron cross sections is a continuing program and measurements are being made at all energies. The most significant advance of the year was the continuous successful operation of the "fast neutron chopper" at the reactor. The development of an improved detector, and the mechanical refinement of the rotor will provide for still improved resolution over the present model. However, the experimental resolution is sufficiently high to permit measurement of the resonance level parameters directly from the observed levels at energies less than 10 electron volts. The results to date indicate that the fast chopper is able to resolve many resonances over a wide energy range, and in fact, has brought to light resonances not previously known to exist. This instrument utilizes extremely small samples thereby allowing measurements to be made on separated isotopes which are available in small quantity.

It was found that substantial quantities of radioactivity could be induced in targets bombarded by protons from the Cosmotron. It was gratifying to find that the amounts of activity so produced were easily detectable and that radiochemical means of identifying the products of bombardment could be used. An extensive program in nuclear chemistry whereby the products of high energy bombardment are studied has been undertaken. Yields from fission and from spallation with particles of several hundred Mev energy are now being compared with the spallation yields from bombardment with 2.3 Bev protons. It is of interest to note that a greater variety of isotopes and larger fractions of isotopes having lower atomic number are found when a target is bombarded with these very energetic particles. For example, beryllium-7 (atomic number 4) is easily separated from a bombarded copper (atomic number 29) target.

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 otherwise possible. For example, radiation damage of a cell may give rise to information on radiation effects, but 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 radiation and for their engineering application as suitable materials for use in high neutron and gamma radiation fields. Metallurgical studies are devised to satisfy the requirements of nuclear engineering reactor designs. Extensive studies of the behavior of graphite and of various alloy materials when exposed to radiations are under way. The program of fundamental studies of the solid state has been stimulated by an increase in the number of scientific investigators at the Laboratory both in BNL staff and in visiting staff.

Radiation chemistry studies are concerned with chemical changes produced in water and aqueous solutions when they are exposed to ionizing radiation. To date,

exposures have been made with high energy electrons, x-rays and gamma rays. Significant progress has been made in the field of dosimetry in which more and more attention is being given to the use of chemical changes as a measure of radiation dosage.

The study of biological effects of radiation ranges from the study of simple cells to applications to humans. Facilities used by the biologists provide x-rays, gamma rays both from a small cobalt source in the greenhouse and from a 2200 curie cobalt source in the six-acre growing field, and neutrons from a thermal column on top of the reactor which can provide either thermal neutron exposures or fast neutron exposures by the addition of a U^{235} fission plate. The gamma field continues to be extremely valuable, and a number of interesting phenomena have been observed. Continuous radiation upsets normal growth of the plant, and at the present time it appears that each plant responds in a different way. At certain dosage rates, some plants will grow much faster than normal, in others flowering may be induced much earlier. These are but a few of the effects noted. The study of mutation production in plants has shown that thermal neutrons are much more effective in producing mutations for a given amount of damage than are other forms of radiation. It is also becoming clear that thermal neutrons produce radiation damage in biological material by a quite different mechanism than do x-rays. The use of fast neutrons in comparable studies is yet to be explored.

In medicine, radiation is used both externally, with neutrons from the reactor and gamma rays from cobalt sources, and from internal sources such as internally administered isotopes or in vivo induced disintegrations. A large share of the medical effort is centered on the utilization of thermal neutrons from the reactor to determine their biological effects, their application to medical therapy, and their effects on biological, biochemical, cytological and physiological systems. Representative of this effort is the treatment of glioblastoma multiforme, in which the tumor area is irradiated with thermal neutrons from the reactor after the patient has received an injection of a material containing boron-10. Some ten patients have received a total of 19 treatments, with a maximum of four treatments being received by one patient. Although none of the patients is now living, the results of the treatments were promising in that in several instances relief was provided and the remaining lives of the patients were considerably more pleasant. Pathological examinations also showed that in several instances, satisfactory destruction of the tumor tissue was achieved. An extensive program involving modification of the facility at the reactor and the investigation of new techniques is now in progress. The use of short-lived isotopes also has received considerable attention in both research and therapy and is a significant feature of the Brookhaven medical program.

The tools of nuclear and atomic science are in use by all research workers at the Laboratory and generally take the form of tracers or of radiation, neutron, beta or gamma. The major portion of this research effort is in solid state physics, chemistry and the life sciences. Neutron diffraction studies of structure, the kinetics of chemical reactions, photosynthesis, metabolism, protein synthesis, and the application of gamma irradiation in the catalysis of chemical reactions, are but a few examples of the application of tracers or radiation to general scientific problems. Gamma sources equivalent to several thousand curies, produced by irradiation of cobalt in the nuclear reactor, are being used at Brookhaven and are being provided for use elsewhere in the study of sterilization of foods and pharmaceuticals and in the activation of chemical reactions. The use of radioisotopes and the application of radiation as a tool has its greatest use in the hands of the life scientists. This year, a program designed to test the feasibility of producing useful mutations in plants by means of ionizing radiation was initiated. Some 17 institutions have supplied material to be grown in the Brookhaven gamma field. The exposed specimens will then be returned to the cooperating institutions for study, which will include examination for useful mutations. Agricultural experiment stations are among the participants in this program.

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, are carried out primarily by the engineering departments. A wide range of studies is pursued: for example, basic chemical studies of those elements associated with fission processes, metallurgy or reactor fuels and container materials, heat transfer and instrumentation. Many of these studies are related to reactor components and the design of complete reactor systems. Their results appear in the classified reports of the Laboratory. Other studies involve the concentration of liquid radioactive waste materials in order that the bulk of liquid material may be disposed of by ordinary means and a concentrated radioactive residue can then be fixed in concrete for ultimate disposal at sea. Other studies are directed at devising a more satisfactory solution for the ultimate disposal of radioactive wastes: for example, the use of clays and the fixation in these clays by absorption and baking. Satisfactory results have been obtained and a pilot plant process is now under design. The field of electronics is vital to the further development of atomic energy. The understanding of nuclear processes requires the provision of higher speed circuits and detection devices. Research and the development of improved radiation detection equipment sensitive to the lowest energy radiations and on up to the billion volt range is a continuing process.

Extensive technical conferences were held in support of the individual research programs, in addition to regularly scheduled seminars and colloquia. The dedication of the Cosmotron on December 15, 1952 was attended by 241 representatives of 111 institutions and was followed by a two-day conference on high energy accelerators at which 95 physicists, representing 45 institutions in this country and abroad, were in attendance. In addition to being host to several AEC sponsored information meetings, such as the AEC Metallurgical Conference and the Shielding group, a major conference was held by the Biology Department on the subject of "Utilization of the Major Metabolic Fuels."

The past year showed a marked change in the request for group visits by technical societies in that a large number of requests were from groups who had already visited the Laboratory and desired another visit for additional information on some particular phase of the program. Out of 37 groups numbering almost 2000 individuals who visited the Laboratory during the year, roughly 10 groups totaling almost 800 individuals could be classed in this category. The visits of these technical groups generally included an introductory talk outlining the broad policies and research program of the Laboratory, followed by a visit to the major facilities.

An Employees' Open House and a Visitors' Day were held on two successive Saturdays in May. Some 800 individuals, Laboratory employees or members of their immediate families, attended a Laboratory Open House in which all except the exclusion areas were open for inspection. The controlled area of the reactor (west face) was included among the facilities shown to the employees on that day. The annual Visitors' Day of the Laboratory was attended by some 3500 individuals. The Visitors' Day exhibits and inspection of certain of the Laboratory's facilities form an important part of the continuing program directed at acquainting Long Island and the New York neighbors with the program of the Laboratory. In addition, speakers from the Laboratory continued to acquaint neighbors with the Laboratory program in more or less detail depending on the special interests of the listeners. The Public Information Office has continued to serve the press, the radio, television, and newsreel interests, and has coordinated with the scientists the provision of information and material for those media.

Brookhaven National Laboratory

Balance Sheet, June 30, 1953

ASSETS

Cash	\$ 375,280
Accounts Receivable	36,552
Inventories	604,119
Advances, Deposits and Prepaid Items	40,139
Fixed Assets (less reserves of \$14,632,399)	42,010,233
Construction in Progress	<u>226,516</u>
Total Assets	\$43,292,839

LIABILITIES

Accounts Payable	\$ 335,243
Accrued Payroll	94,101
Atomic Energy Commission	<u>42,863,495</u>
Total Liabilities	\$43,292,839

PHYSICAL SCIENCES AND ENGINEERING

PHYSICS

The physics program of the Laboratory may be divided roughly into four major fields: nuclear particles, stable and excited nuclei, neutron physics, and solid state physics.

The physics program is carried out primarily in the Physics Department. However, because of the nature of the facilities for which they are responsible, research with high energy particles is also carried out by the Cosmotron Department and research with neutrons from the reactor is carried out in the Reactor Department. Summaries of all work without regard to the department in which it is done are contained in sections below.

The study of nuclear particles is now almost entirely concentrated on investigations with the Cosmotron. The successful completion and remarkably reliable operation of this unique machine by the Cosmotron Department* has shifted much of the physics effort onto this new research facility.

The most gratifying result obtained during these initial Cosmotron experiments is the evidence that neutral V-particles are being produced by the high energy particles of the Cosmotron. A number of such V-particles has been observed in a diffusion cloud chamber. Just recently, two photographs were obtained which seem to represent the absorption of a negative π -meson by a proton to create a neutral V-particle and a still unknown neutral component. Moreover, the diffusion cloud chamber observations have yielded several events in which the collision of high energy neutrons with protons produces one or two pions.

The research in nuclear properties comprises primarily the study of stable and excited atomic 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 important contributions to this wide field.

Under neutron physics may be listed the study of the interaction of neutrons with matter. The continuous successful operation of the "fast neutron chopper" has made it possible to measure the neutron cross sections of several atomic nuclei with higher precision and resolution than was attainable before. Crystal spectrometer techniques are also being successfully applied to the measurement of total cross sections and to resonance scattering cross sections.

Solid state physics has expanded its activity considerably during the last year. Its two major fields of research are the study of the structure of materials by means of neutron diffraction and the investigation of changes produced under intense bombardment by neutrons and other radiations.

Cooperative programs of research involving scientists from other institutions are well under way. At the Cosmotron this cooperative work tends to become an integral part of the whole Laboratory program, with the visiting researchers working for the most part directly with Brookhaven scientists. The large capacity of the nuclear reactor, on the other hand, permits visiting scientists to carry out individual experiments with greater independence. Examples of these experiments are the electron neutrino angular correlation investigation by Columbia University, the cross section studies by Columbia and the solid state studies by the General Electric Company.

*Up until July 1, 1953, the Accelerator Department.

Nuclear Particles

Cloud Chamber Experiments

Pions from the Columbia University Nevis cyclotron have been studied in their interaction with helium nuclei with the aid of a diffusion cloud chamber. Total cross sections of 89 ± 18 and 207 ± 27 mb were found at pion energies of 60 and 105 Mev, respectively. The cross sections for elastic scattering alone are 37 ± 12 and 72 ± 14 , and for charge exchange scattering the cross sections are about 20 and 60 mb. A calculation shows that these results, as well as the observed angular distributions for elastic scattering, are fairly consistent with the expectations from the known pion scattering on hydrogen.

At the Cosmotron, a 16-in. diameter diffusion cloud chamber filled with about 20 atmos of hydrogen has been set up in a magnetic field of 11,000 gauss. It has been exposed to a beam of neutrons with energies ranging from 1 to 2.2 Bev, to a beam of 1.5 Bev negative pions and to a beam of 1.5 Bev protons. A 6-ft long diffusion cloud chamber filled with 20 atmos of hydrogen has been exposed to 230 Mev and 550 Mev positive pions.

About 150 three-prong events have been found to originate in the hydrogen filling of the 16-in. chamber when exposed to the neutron beam. These events represent neutron-proton interactions resulting in the production of one or two pions. So far, 40

Figure 1. Diffusion cloud chamber photograph of a neutron-proton collision in hydrogen which results in multiple production of pions. The incident high energy neutron was produced in a carbon target by the 2.2-Bev circulating proton beam in the Cosmotron. Three tracks, a proton and a positive and negative pion pair, originate from the point of collision.

Figure 2. A Cosmotron-produced pion of 1.5 Bev produces a neutral V-particle in a collision with a proton in a hydrogen-filled diffusion cloud chamber. The track of the pion ends abruptly in the gas. A few millimeters away the decay products of the V-particle, identified as a proton and a negative pion, can be seen. A heavy neutral meson may have been produced in addition.

cases have been analyzed. Half of them show with certainty the production of a positive-negative pion pair. In one case, the creation of a neutral and negative pion has been definitely established and in three cases only a single negative pion was produced. In the remaining cases, the identification of the particles is less certain but it appears that only one or two pions and no more are produced, even though there is enough energy available to produce at least four mesons.

Approximately five neutral V-particles were found. These were produced by the neutron beam in the wall of the chamber or in lead absorbers placed outside. Most of these are probably V_1^0 -particles decaying into a proton and a negative pion, but in one case a V_2^0 may be decaying into a positive and a negative pion.

For 230 Mev positive pions, a preliminary determination of the scattering cross section in hydrogen gives a value of 125 ± 25 mb. Of 31 pion-proton scattering events, 19 appear to show pions scattered through angles $< 90^\circ$ and 12 through angles $> 90^\circ$; there is no indication of appreciable preference for either backward or forward scattering.

A separate experiment is being carried out to determine the momentum distributions of the different particles produced by 2.2 Bev protons in carbon, aluminum, and lead at different angles to the incident proton beam. At energies above 200 Mev, 85 percent of the particles emerging from lead at 57° to the proton beam appear to be protons. The ratio of the number of positive pions to the number of negative pions, in the remaining 15 percent, is found to be 1.7 ± 0.3 . Broad maxima are found in the momentum distributions near 900 Mev for the protons and near 350 Mev for the mesons.

Counter Measurements

Several measurements were taken with scintillation counter telescopes in pion beams of various energies emerging from the Cosmotron. Absorbers, deflection magnets and proper time delays in the coincidence circuits ensure that only pions of the required charge and energy are being recorded. The beams do contain some muons from the decay of pions in flight, about 10 percent at 500 Mev, and 4 percent at 1.5 Bev.

Total cross sections of pions at different energies were determined for carbon and for hydrogen. The latter was obtained by noting the difference between the carbon measurements and those for polyethylene or paraffin.

The carbon cross section lies between about 0.6 and 0.8 of the geometric nuclear cross section for negative pions of 500 Mev and 1.5 Bev. For positive pions, there is a drop in cross section from about geometric at 210 Mev down to 0.7 geometric at 500 Mev.

The results for the pion-proton cross section are only preliminary. For negative pions it is about 24 ± 5 mb at 475 Mev and 35 ± 4 mb at 1.5 Bev. These results are lower than a known value of 60 mb measured at the University of Chicago for 160 Mev negative pions. For positive pions, the cross section drops from about 90 mb at 200 Mev to 35 mb at 1.5 Bev. At 160 Mev the cross section is 110 mb according to the Chicago measurements.

By observation of the difference between the cross sections for heavy water and ordinary water, the cross section of the deuteron was measured for negative pions of 1.5 Bev. On the assumption that this cross section is merely the sum of the proton and neutron cross sections (neglecting double scattering and interference effects), the results give a value of 32 mb for the neutron. According to the principle of charge symmetry, this value should be the same as that for positive pions on protons; within the error of about 10 percent, it is equal to that for negative pions on protons mentioned above. It is known, however, that at lower energies, 120 Mev, the proton cross section for positive pions is about three times larger than that for negative, whereas at 1.5 Bev the above deductions seem to make them equal.

Nuclear Emulsions

Emulsions were bombarded directly by the 2.2 Bev protons of the internal beam of the Cosmotron. The features of the observed "stars" were examined and found to be in accord with those of stars caused by cosmic rays of the same energy. The angular distributions of the emitted fast and slow particles were measured and found to show a strong forward preference, the ratio of forward-to-backward particles being 10 for relativistic particles, and 1.7 for slow particles. In addition, "along-the-track" scanning established that the cross section for nuclear interaction of the 2.2 Bev protons with emulsion nuclei amounts to 0.7 ± 0.2 of the nuclei's geometric cross section and that the cross section for diffraction scattering is about 0.4 of the geometrical cross section.

About 500 stars were found after exposure of emulsions in the 500 Mev negative pion beam. In about 40 percent of them, a single scattered meson leaves the nucleus; most of these scatterings are inelastic and there is no apparent correlation between angle and energy of the scattered particles. The fraction of events showing this type of scattering is higher than that observed at lower incident meson energies. This effect is thought to be due to a smaller capture probability at higher energy.

The angular distribution of the scattered mesons is nearly symmetrical, about 90° in the laboratory system; the ratio of the numbers of backward to forward scattered mesons is about 1, as compared to a ratio of 2 for negative pions at 135 Mev. Six definite and six very probable cases of two mesons among the star fragments have been observed, which show the creation of charged mesons by charged mesons colliding with nuclei. Two hundred and sixty of the stars show no emitted meson track, and hence represent capture or charge exchange processes; however, their analysis is not yet completed.

All negative particles in the 310-420 Mev/c momentum range emitted from a target bombarded by the Cosmotron's 2.2 Bev protons, after deflection by the machine's magnetic field, pass through a short channel next to the machine, which is surrounded by a 4-ft thick lead shield, and impinge on nuclear emulsions surrounded by scattering material. The energy of pions in this beam is such that the particles pass through the emulsion without stopping; particles of 3 to 6 times the mass of the pions would, however, end in the emulsion and might be identified both by some characteristic event at the end of their range and by their masses measured by the grain count, range and scattering of their tracks. Over 500 stars produced by pions in flight have been noticed, but so far no heavy mesons have been observed.

High Energy Neutrons

A preliminary survey has been made of the forward neutron beam coming from a beryllium target in the Cosmotron. The flux of neutrons of energies above 1.5 Bev is about 10^9 per steradian per pulse. The beam drops off to half its intensity at an angle of 7° with the forward direction and at 13° it is down to about 10 percent. This distribution is in agreement with the assumption that most of the neutrons in the forward direction arise from charge-exchange scattering.

The neutron detector consists of a scintillation counter, then an aluminum block, and an anti-coincidence counter with a following fourfold counter telescope. Charged particles produced in the aluminum by the neutrons enter the coincidence telescope which contains 6 in. of lead to absorb radiations produced by low energy neutrons. The efficiency of this system is about 0.3 percent. The neutron flux was also determined by studying the number and prong distribution of stars produced in photographic emulsion.

Nuclear Properties

Nuclear Energy Levels

Continuation of the research program on nuclear excitations has this year again contributed a large amount of new data, which have led to refinements of the nuclear shell model. Interesting regularities have been found for the lowest excited states of nuclei with an even number of protons and neutrons.

Among the many results obtained is a case of complex isomerism in $\text{Mo}^{93\text{m}}$. The study of families of isomeric nuclei among the isotopes of odd atomic weight of Hg and Au and the study of isomers of very short half-lives, of microseconds' duration, yield examples of low energy electric dipole transitions.

The gamma-ray spectrum produced when Be^9 is bombarded with protons from the Van de Graaff generator has been determined with a NaI scintillation counter. Gamma rays of Na^{23} resulting from the capture of slow neutrons in the reactor have been examined by means of photoelectrons which these rays produce in thorium and uranium converters. The energy of the conversion electrons is measured with a thin lens beta-ray spectrometer. Suitable coincidence counter schemes eliminate background from the reactor. The electrons arising from internal conversion of capture gamma rays have also been studied for a number of strong neutron absorbers, such as Cd and Gd.

During the investigation of a design for a gas-filled neutron counter, it was discovered that the argon isotope A^{36} emits alpha particles under fast neutron bombardment. The reaction $\text{A}^{36}(\text{n}, \alpha)\text{S}^{33}$ was studied in detail. The cross section increased from about 40 to 210 mb when the neutron energy varied from 2.15 Mev to 4.4 Mev. The Q-value of the reaction was 2.0 Mev to the ground state and 1.1 Mev to an excited state of S^{33} . The cross sections for the reaction going to the excited state were much smaller, namely less than 5 mb at 2.15 Mev and 40 mb at 4.4 Mev.

Of special interest was the observation that pile neutrons produce a considerable amount of Ta^{183} from successive capture of two neutrons by Ta^{181} . The capture cross section of Ta^{182} has been estimated to be at least 50,000 b.

A study of the correlation between the emitted electron and the recoil nucleus in the He^6 decay has given valuable information about nuclear forces. The He^6 , which has a half-life of only 0.8 sec, is produced in the pile by the bombardment of a beryllium compound and is introduced into the experiment chamber. The energy and direction of the electrons are measured by means of a scintillation counter and the recoil nuclei are detected by a multiplier. The variation of the coincidence rate with the angle between electron and recoil, as well as with the energy of the beta particles, agrees best with the assumption of so-called tensor forces for nuclear interaction. This study is being carried out by Columbia University scientists at Brookhaven.

The Production of Tritium

The cross section for the production of tritium from the bombardment of nitrogen with fission neutrons was measured and found to be about 10 mb. The tritium was detected by introducing the gas into a diffusion cloud chamber after bombardment and observing the short tracks produced when it decays. Another method giving the same result was to introduce the gas into a counter. These results, combined with cosmic ray data, give information about the tritium production in the atmosphere, its average abundance in rain and ocean water, the mean escape time of He^3 from the atmosphere and the temperature near the top of the atmosphere.

These phases of nuclear research are very prolific and have in the past year led to more than 30 papers.

Nuclear Moments and Masses

The nuclear moment program comprises the study of nuclear spins by various techniques, such as microwave gas spectroscopy, microwave paramagnetic resonance, radiofrequency nuclear resonance, and atomic beam resonance. Some of the work is done in cooperation with similar researches at Columbia University and the Massachusetts Institute of Technology.

Figure 3. Atomic beam apparatus for determination of nuclear spins of radioactive materials.

The magnetic moment of the S^{35} nucleus was found to be 1.00 ± 0.05 nuclear magneton, a value predicted by the shell theory of nuclear structure.

A study has been made of the paramagnetic resonance and nuclear hyperfine structure of free organic radicals, picryl-*n*-amino carbazyl and α, α -diphenyl- β -picrylhydrazyl. The crystalline anisotropy was found to be proportional to the applied magnetic field and was best explained as the result of molecular diamagnetism. In this work the unpaired electron can be viewed as a probe for exploring the magnetic field within the molecule.

The hyperfine structure measurements of carbazyl in dilute solutions showed that the unpaired electron spent twice as much time near one of the nitrogen nuclei as near the other. In hydrazyl, as shown by earlier measurements made elsewhere, the electron spends equal times in the vicinity of the two nitrogen nuclei.

Reflection from magnetized mirrors can be used to produce and detect beams of highly polarized neutrons. Depolarization by a high frequency field of neutrons moving in a homogeneous magnetic field can thus be observed with precision. With this technique the magnetic moment of neutrons has been measured by a method analogous to that used in atomic beam resonance experiments. The result obtained so far agrees with the neutron moment found by other methods.

Nuclear Masses

The radiofrequency mass spectrometer, which measures masses of ions in terms of high harmonics of their cyclotron frequency, has yielded very promising results. To date, measurement of nine mass "doublets," which have involved stable isotopes of oxygen, carbon, hydrogen, nitrogen and sulfur, have been made with an accuracy, in some cases, several times higher than obtained by other mass spectrometers. New values determined in this way for the masses of C, H, N and S are in good agreement with those derived from energy relations observed in nuclear disintegrations.

Neutron Cross Sections

The Fast Chopper

The fast chopper, which is a fast-acting neutron shutter used as a means of velocity selection, has now been in operation about one year and has performed without mechanical difficulty during this period. At the present time, it is running 24 hours a day, 7 days a week, completely unattended except for periodic changing of samples and recording of data. A set of controls incorporated in the equipment is so arranged that

Figure 4. Total cross section of hafnium measured with Brookhaven fast chopper.

any change in operating conditions, e.g. in the vacuum, motor current, line voltage, etc., stops the rotor. The rotor is being run at 6,000 rpm, to give 1 μ sec neutron burst. One of the principal factors in the attainment of unattended operation has been the trouble-free performance of the timing circuits, designed and built by the Brookhaven Electronics Division.

The remaining development problem concerning the fast chopper is that of a suitable detector. At the present time, a bank of some 40 BF_3 proportional counters is in use, but the time variation in collection of pulses from these counters is 4 μ sec, much longer than the burst itself.

The chopper is now being used on a routine basis for measurement of nuclear level densities and the properties of individual nuclear levels. The experimental resolution is sufficiently high to enable measurement of the resonance level parameters (width and peak cross section) directly from the observed level shape for energies less than 10 ev. This method, as well as alternative techniques of analysis, has been applied to several elements. The ability of the fast chopper to resolve many resonances over a wide energy range is demonstrated in Figure 4, which shows the cross section curve for normal hafnium. In order to obtain information of value for basic nuclear theory, it is essential to know the properties of levels in individual isotopes rather than in the normal element. As the fast chopper can utilize extremely small samples (0.1 g or less), measurements can be made on the available amounts of separated isotopes. The separated isotopes of hafnium, for instance, have been run and all the resonances shown in Figure 4 have been assigned to particular isotopes. It is interesting that only one resonance is found in Hf^{180} and one in Hf^{178} , all the others being in the odd isotopes Hf^{177} and Hf^{179} . Similar measurements have been made for several other elements and the results are available for comparison with various nuclear models and with the experimental values of level densities measured at 1 Mev neutron energy.

The Slow Chopper

The use of extremely "cold" or slow neutrons available with the slow chopper for investigations of lattice vibrations has continued, with special emphasis on the magnetic inelastic scattering observed in iron. It has been found that this magnetic inelastic scattering, or spin-wave scattering, is present both above and below the Curie temperature and the quantitative results are now being compared with theory.

The slow chopper has also been used for very careful measurements of the absorption cross sections of boron and gold, important as cross section standards. The final values for the cross section for neutron speeds of 2200 meters per second for boron and gold are 749 ± 4 and 98 ± 1 b; these are somewhat higher than values reported in the past few years. The incoherent scattering of iron and nickel, again measured for very cold neutrons with the chopper, has been combined with total cross section measurements to obtain the coherent scattering of these materials. These particular coherent cross sections are important standards for magnetic diffraction from magnetic materials.

Mirror Experiments

Final measurements were made at the beginning of the year on the mirror experiment for determination of the neutron-electron interaction. A number of small sources of error were investigated in an attempt to improve the accuracy as much as possible. The final result for the well depth, 3860 ± 370 ev, is, within experimental error, equal to the magnetic interaction between electron and neutron (the Foldy effect), with no

residual interaction corresponding to that arising from a finite extension of the meson cloud. At present, there is no theoretical explanation for the smallness of the meson interaction. Techniques developed in connection with the neutron-electron experiment have been applied to the measurement of the nickel and iron coherent cross sections; these results, which are consistent with others obtained with the slow chopper, give coherent cross sections of improved accuracy for these important materials.

Crystal Spectrometer Experiments

Three crystal spectrometers are in use at the reactor for neutron physics experiments. One of these is now being aligned by Columbia University scientists in order to perform high precision cross section measurement in the low energy region where high intensity and stability are required. Their first experiment will be a study of the neutron-electron interaction and will be a repeat of a former Columbia experiment which measured the change in cross section of liquid bismuth at short wavelengths.

The two other spectrometers are used by Brookhaven scientists, one for the measurement of total cross sections, especially for the rare earth elements in an energy range from .1 to 30 ev, and the second especially arranged to study resonance scattering. A number of total cross sections have been measured and at present attention is being given to the problem of analyzing neutron resonances to obtain the Breit-Wigner parameters. Resonance scattering and (n, γ) cross sections are being measured with the new facility employing a crystal spectrometer located at the end of a large evacuated pipe passing through the reactor and extending some 40 ft beyond. With this arrangement, background is an order of magnitude smaller and the geometry for collimation is greatly simplified. Two methods have been used for the preliminary runs. In the first, a scattering sample is placed at the center of the reactor and scattered neutrons emerge through the collimating system to the spectrometer for analysis. This is essentially a "bright line" experiment. The second arrangement employs a "white" neutron radiator at the center of the pile, and monochromatic neutrons are selected by the spectrometer. The scattering sample is placed in the monochromatic beam. This same scattering spectrometer has been used to demonstrate the feasibility of the measurement of (n, γ) cross sections as a function of neutron energy.

60-Inch Cyclotron Experiments

The time-of-flight analyzer for the 60-in. cyclotron has been modified for more stable operation with minor changes of power supplies and trigger circuits. Conversion has been made to a double modulation system which affords more constant and stable detector gate widths and doubles the number of channels from 32 to 64. The shielding and collimation between cyclotron vault and detector room have been considerably improved. An (n, γ) detector which employs three NaI crystals in fast coincidence has been built to view an (n, γ) radiator of the element of interest (e.g., silver). It is planned to use this for (n, γ) cross section measurements, measurements of multiplicity of gamma production from various resonances, and measurements of gamma energies involved in the (n, γ) cascade. Preliminary measurements at 4 m with 1 μ sec pulses of deuterons on the cyclotron target indicate adequate resolution and intensity and a sufficiently low background for this work.

Cross Section Compilation and Evaluation

The compilation and evaluation of cross sections for the Neutron Cross Section Advisory Group has proceeded at a high level of activity. Two men have served as

members of the Group, one as its Chairman. Several supplements to the large cross section compilation, AECU-2040, have been issued and many requests from individuals for cross section information have been handled.

Neutron Detector Development

Several experiments have been performed on different types of neutron detectors for use in the neutron energy range from a few electron volts to the Mev region. In these experiments the particular characteristics investigated were: 1) sensitivity to neutrons, 2) insensitivity to gamma rays and charged particles, 3) speed of the detection process, and 4) discrimination for neutrons at different energies.

There are two approaches to detector development in connection with the fast chopper. The first makes use of multiple BF_3 counters; the objective of small time variation is attained by means of small counters within a common container. The other method utilizes scintillation detectors, the most encouraging form of which consists of an intimate mixture of fused B_2O_3 and ZnS crystals. This detector has small size and extremely short time delays, both properties essential for high resolution. In addition to these two methods, some experiments were carried out by means of experimental photomultipliers with 5-in. diameter photocathodes in the hope that such tubes could be used with solid scintillators to cover the area of the beam at the fast chopper. The tests showed that the photocathode surface was about twice as sensitive at the center as at the edge. With the bias set to discriminate against gamma rays, the effective counter area was less than one-half of its geometric area.

Another type of scintillation counter tried for neutron detection consisted of a series of parallel cadmium plates (30 mils thick) immersed in a hydrogenous scintillation medium of toluene and 2.5 diphenyloxazole. The plates were separated by 3-4 mm and were coplanar with the axis of a 5819 photomultiplier. An epithermal neutron would be rapidly slowed down to the cadmium absorption limit (0.5 ev) and absorbed in the cadmium within 0.5 μsec . Several gamma rays of about 9 Mev energy would be liberated. The metal plates assisted in degrading the gamma rays but were also responsible for absorbing much of the Compton electron recoil energy. The pulse height distribution, therefore, extended from 0 to 9 Mev. Good neutron efficiency was obtained in an open beam at the reactor but not in the chopper beam where the ratio of gamma rays to neutrons is much higher.

Preliminary work has been done on a large liquid scintillation counter for the detection of fast neutrons. A suitable mixture of organic liquids and a boron-containing compound must be chosen. A fast neutron will then give a characteristic double scintillation pulse: the first pulse is due to the recoil of a hit proton; about 2-3 μsec later a second pulse is caused by the slowed-down neutron being captured by boron. The scintillations are detected by photomultipliers; 25 tubes are required for a counter of this size (16-in. diameter, 16-in. length).

The disintegration of He^3 under neutron bombardment has been applied in the design of a proportional counter for neutron detection; the pulse height is a measure for the neutron energy. In this investigation it was found that argon cannot be used with He^3 as gas filler for the counter. The isotope A^{36} produces itself a pulse from the $\text{A}^{36}(\text{n}, \alpha)\text{S}^{33}$ reaction which completely masks the pulses due to the small amount of He^3 . Krypton shows no such effect and thus can be used successfully.

Solid State Physics

Structure of Solids and Liquids

Considerable improvement has been achieved in neutron diffraction and transmission techniques. Design improvements in the double crystal spectrometer have given

finer adjustment, higher resolution, lower background, wider variation in reflection angle and an increase of the useful upper limit to neutrons of 12 Å wavelength.

Studies of ferroelectrics have shown that neutron diffraction is a very powerful tool for determining hydrogen positions in these crystals. A detailed study of Rochelle salt is nearing completion. Structural change at the ferroelectric Curie point was demonstrated by the observation of certain reflections in the ferroelectric range and their disappearance at the transition points. These reflections are not observed with x-rays and are presumably the result of reorientations in the hydrogen bond network.

Other studies with neutron diffraction techniques to investigate structure and related properties of ferrites are being carried out by members of the Chemistry Department. A description of this work is included in the Chemistry section of this report. Personnel of the General Electric Company are carrying out a similar series of studies with a double crystal spectrometer which they have constructed and are using at the reactor as part of the Laboratory's industrial cooperation program. They have already reported results of studies on MnBi, Cr₂, O₃, and on various mixtures of nickel and zinc ferrites. Their interests center about the basic properties, especially with regard to magnetic structures.

Further studies have been made on severely cold worked α -brass. It has been concluded that the change in the shape of the Bragg "cut-off" is caused entirely by distortion broadening. A shift in the positions of the (111) and (200) cut-offs, attributable to stacking-fault broadening, has also been resolved. Neutron diffraction techniques constitute an important complement to x-rays in understanding the nature of cold-work. Long wavelength neutron transmission techniques have also been refined and are being used successfully in the study of the nature of lattice imperfections.

Neutron diffraction measurements have been applied to liquid lead and mercury. Results so far are in agreement with simple scattering theory in which energy changes are neglected. An attempt to determine the energy spectrum of the diffracted neutrons yielded inconclusive results.

Theoretical work in this field has been concerned with the following problems:

1. Refined calculations of the inelastic scattering of slow neutrons have been done with emphasis on the total 1 phonon cross section as a function of temperature and wavelength; the energy distribution of scattered neutrons has also been studied.
2. The theory of the scattering by an "Einstein" model of a liquid has been worked out. The results so far indicate that departure from x-ray theory of scattering by liquid elements is unimportant above an atomic mass of about 10.
3. Multiple scattering has been calculated for some geometries of interest in neutron diffraction studies. Multiple scattering is generally found to be more important in the case of neutrons than in the case of x-rays. As long as the second order term is small compared to first order, the second order term is a good estimate of all multiple scattering.

Radiation Effects

Most of the work during the last year has been concerned with the effect of radiation in metallic materials. The change in resistivity and critical shear stress of copper and aluminum as a function of irradiation at low temperature and subsequent annealing has been studied. The experimental work is largely finished but the correlation and interpretation of the data are not complete. One interesting observation was that the change in the critical shear stress of irradiated Cu showed no annealing between liquid nitrogen and room temperatures but about 75 percent of the resistivity change annealed out below room temperature. Recently some experiments were started on α -copper-zinc alloys. It was found that, contrary to the pure metals, the resistivity of these

samples decreased upon irradiation, at least for low exposures. Further experiments are required before an interpretation can be suggested.

Fast neutron irradiation may influence nucleation and growth processes in solids by means of the formation of lattice defects. In order to investigate this question, super-cooled metallic tin was irradiated and maintained at liquid nitrogen temperature. An appreciable amount of transformation to grey tin was observed. The x-ray lines corresponding to grey tin appeared in the irradiated samples and typical grey tin "pimples" were observed on the surface.

Some experiments have been done on a covalent crystal, black phosphorus, in cooperation with work performed at the Massachusetts Institute of Technology. Broadening of x-ray lines and increase in the c-axis were observed in this anisotropic crystal at a level of irradiation (rather low) where close packed metallic crystals show no observable change in the x-ray pattern. It is suggested that large distortions can occur in an anisotropic crystal in the direction of low elastic modulus. Extra lines, not belonging to the pattern of black phosphorous and not seen in the pattern of the undamaged material, were also observed. This may well indicate a phase change. It is definite that the material is changing under irradiation but the nature of the change is still uncertain.

In cooperation with the Reactor Department, a study was made concerning the effects of ionizing radiations (primarily gamma rays) in organic crystals. The possibility of bringing about chemical reactions in solids by means of irradiation was investigated. One very interesting observation was made: it was found that polymerization of a crystalline monomer (acrylamide in this particular experiment) can be accomplished by gamma irradiation at room temperature.

Theoretical work has continued on the nature and properties of lattice imperfections.

1. In a detailed calculation for copper, it has been shown that vacancies in metals tend to combine into stable pairs of vacancies. The activation energy for the motion of a pair is appreciably less than that for an isolated vacancy. Consequently, the existence and motion of combined vacancies is expected to be of importance in many annealing and diffusion processes.
2. The theory of the concentration of vacancies in a crystal lattice has been re-examined. Attention was focused on the entropy terms appearing in the free energy to create lattice defects. A rather general thermodynamic analysis has established the nature of these contributions to the free energy.
3. The nature of radiation damage in diamond and similar covalent crystals has been investigated theoretically. Indications are that in these systems energetic recoil atoms may rupture the covalent single bonds which then reform into a system of double and single bonds. The calculations suggest that each fast neutron collision produces an isolated disordered region which is quite large and is mechanically weak. Experiments are in progress to test these ideas by means of elastic constant measurements.

ACCELERATORS

Since the early days of the Laboratory, accelerator development, design, construction, and operation have been the responsibility of first the Accelerator Project and later the Accelerator Department. The machines included have been the Cosmotron, the 60-inch cyclotron, the 18-inch cyclotron, and the electrostatic generator. The two cyclotrons are now operating reasonably well and are available for research. Consequently, as of July 1, 1953, both machines, along with the research electrostatic accelerator, were transferred to the Physics Department, their prime user, which will now

have responsibility for their operation. This transfer was effected since, for machines of this size, operational problems are not sufficiently extensive to prohibit effective integration of operations with research.

Recently, design considerations of even higher energy accelerators have led to a formulation for the use of alternating gradient fields to provide strong focusing, which makes the construction of accelerators in the multi-billion-volt region both technically and economically feasible. The development and exploitation of this new concept will require an extensive and long range program, and a separate organization to accomplish these aims has been established. This group operated as the AGS (Alternating Gradient Synchrotron) Project until July 1, 1953, at which time it became the Accelerator Development Division with L.J. Haworth as Acting Head.

Because these two changes would leave the Accelerator Department with responsibility for the operation and maintenance of the Cosmotron, as well as for the research program centered about it, the name of the department has been changed to the Cosmotron Department, effective July 1, 1953.

The Cosmotron

On December 15, 1952, the Cosmotron was dedicated to scientific research by Commissioner Henry D. Smyth, of the Atomic Energy Commission, in a ceremony attended by 240 visitors. This event, in fact, marked the stage at which the performance of the Cosmotron became sufficiently reliable to permit the beginning of research experiments. Since then there has been a steady decrease in the time devoted to improvement of the Cosmotron's performance and a steady increase in the time assigned to experiments.

By the middle of April the Cosmotron was running fairly well, and its performance for the most part was understood. This seemed to be the proper time to record the very large amount of information gained during the construction and bringing into operation of the accelerator. After a month of concentrated writing and editing by almost every member of the staff, a series of 27 articles was prepared which will constitute the entire September 1953 issue of the Review of Scientific Instruments. These articles should be of value to those concerned with high energy accelerators and, because of the wide range of special techniques described, they should be of general interest as well.

Since about March 1953, research at the Cosmotron has been carried on by members of both the Cosmotron and the Physics Departments. It was decided, for the sake of simplicity, to report the over-all research program in this section and to give the results of experiments in the Physics section.

Operations

During the last six months, there has been a steady improvement in the reliability of operation, an increase in beam intensity, and a large increase in the use of the beam for research purposes. On March 2, a second shift was started and since then, operation has been five days per week from 8:30 A.M. to midnight. Saturdays are frequently used to make repairs which cannot be made during operation. In addition, every fifth week is scheduled for shutdown to permit necessary major alterations to be made in Cosmotron components, to do preventive maintenance, and to relocate shielding blocks and analyzing magnets.

During the past three months, beam time has averaged 53 percent of the total number of 75 operating hours in a week with a maximum of 69 percent for the week of May 25. Causes of lost time are about equally distributed among component failure, starting and stopping, and time off requested by experimenters.

Figure 1. View of experimental area outside the concrete shield in which counters and analyzing magnets are set up in the meson and neutron beams.

Six technicians are assigned as console operators, two for the day shift, two for the night, and two alternates. These men make all target changes, start, stop, and operate the machine, and make the adjustments of control parameters required for good beam acceleration and experimental needs. The motor generator room has three men assigned for each shift, with at least one of the three being present at all times, while the other two inspect and control the operation of 64 other pieces of rotating machinery. The number of operators required per shift to run the Cosmotron is thus five. A total of 18 technicians is assigned to all phases of operation, which include electronics and mechanical maintenance, repair and modification, as well as direct operation.

Shielding of personnel and experiments from the various forms of radiation produced by the Cosmotron constituted a problem with many unknown aspects at the time operation started. Before experience was gained from actual operation, it was not known what the intensity, or the composition or the distribution in space of the stray radiations would be; nor was there agreement as to biological effectiveness of radiations in the billion-volt range. Consequently, the first shield was experimental in nature and so designed that it could be altered and extended with relative ease. As a result of nearly six months' experience with the Cosmotron, enough was learned to justify an addition to the present shield; however, many uncertainties still remain.

This additional shielding was designed in the light of three factors: a) The intensity in the control room since June has been close to tolerance levels, and an increase in beam intensity by a factor of 5 is expected because of increased efficiency of operation. b) The major source of radiation was found to be the target, and little radiation comes from other portions of the machine under normal operating conditions. c) The nature of the experiments to be performed in the future is so unpredictable that a highly versatile shield is a necessity.

Accordingly, it was decided to box in the straight section containing the target with walls of 36-in. thick concrete blocks and a roof of 30-in. thick reinforced concrete beams. This addition to the present shield is expected to be complete in a few months and should reduce the intensity of stray radiation in the control room and experimental areas by a factor of 10.

A generator house, which will form an addition to the Cosmotron building, is now under construction. When complete, it will house a 1200 kw, a 300 kw, and three 100 kw dc generators, together with controls, distribution panels, and safety devices. At present the only dc power available is from two 100 kw machines located on temporary mountings on the main floor of the Cosmotron.

Figure 2 (Left). A liquid hydrogen target to be used for meson scattering experiments. The mesons to be scattered pass through thin stainless steel windows near the bottom of the tank and through an internal vessel containing liquid hydrogen.

Figure 3 (Right). Targets to be bombarded are inserted into the proton beam of the Cosmotron by means of an air lock. It is also possible to inject the target into the beam near the end of the acceleration cycle by means of a pneumatic ram. This is a view of the air lock and ram mechanism seen through the array of magnet cooling water tubes.

The two electromagnets with pole faces 18 in. x 36 in. which were started last year are now in almost continual use for analysis of the π^+ and π^- meson beams. The other major pieces of experimental equipment started last year are two liquid hydrogen targets now in the final stages of testing.

Research

At present, protons are being accelerated to a maximum energy of approximately 2.3 Bev; this energy is limited by magnetic field distortion due to saturation which occurs at about 9 kilogauss. Design and installation of controls for the motor-generator power supplies for the pole face windings are in progress to correct the magnetic field shape and permit acceleration to 3 Bev.

Rough measurements indicate that approximately 10^{10} protons per pulse are accelerated to the maximum energy, but under present conditions, 70 to 80 percent of the initially captured protons are lost during acceleration. Possible causes contributing to this large loss include errors and rapid phase shifts in the frequency of the accelerating voltage, sudden changes in its amplitude, and possible resonances of synchrotron oscillations with the magnet ripple voltage. Efforts are being made to improve this situation without interference with the research use of the machine.

The Cosmotron is the only accelerator which permits exploration with artificially produced particles of phenomena lying in the range above a billion electron volts, and thus considerable effort has been made to use this machine as effectively as possible. Whenever possible, operations have been scheduled so that several experiments can be performed simultaneously, and on occasion, as many as five groups of experimenters have been able to collect significant data at the same time. The large floor area next to the magnet ring, through which various beams from the Cosmotron pass, makes this possible.

The method of running several experiments simultaneously is best illustrated by the counter experiments. On days assigned to this type of activity, one group may use a set of counters in the 1.5 Bev π^- beam to perform a total absorption experiment. At the same time, an electromagnet may be located at the end of a channel through which pass

lower energy π^+ and π^- mesons coming directly from the target. Since these oppositely charged mesons are deflected in opposite directions by the electromagnet, one group may work with the π^+ mesons while another group works with the π^- beam. An entirely separate group may use the high energy neutron beams for neutron spectrum studies. Thus, four counter experiments can proceed simultaneously with radiations from the same target. Obviously, it is not possible for all four groups to have operating conditions exactly to their liking, but careful planning of experiments has reduced conflicts of interest to a considerable extent.

All experiments are being done at the Cosmotron with one of three methods of detection: cloud chambers, photographic emulsions, or scintillation counters. For purposes of this report, it is convenient

Figure 4. Targets used vary in the size and the material of which they are made. The target shown here is a 2-in cube of graphite. After a single transit through the strip of metal screwed to the face of the target support, the protons spiral in, and on the next trip around they pass through the carbon target at some distance from the surface.

Figure 5. This is a setup to study the characteristics of the neutron beam emerging from the small hole in the shield. The white cylinder of paraffin converts some of the neutrons into protons, which are then detected by scintillation counters. The cubical block of lead between the counters is an absorber used to determine the energy of the protons.

lower energies. The fourth group is using its counting equipment to study the spectrum of neutrons produced in the target by proton bombardment. The results of this study will be of value to all experiments which use the high energy neutron beam. The fifth group is concerned with the study of the γ -ray spectrum emitted from the target of the Cosmotron; π^0 mesons are known to decay in about 10^{-14} sec into two γ -rays, and a study of these γ -rays will reveal characteristics of π^0 meson production. The sixth set of counting equipment is used to study the characteristics of the Cosmotron's proton beam and to improve the methods of inserting the target into these proton beams.

Alternating Gradient Synchrotron

The field of nuclear physics has been greatly influenced by the construction of successively higher and higher energy particle accelerators. The resulting availability of progressively higher energy protons, deuterons, alpha particles, and electrons has always made it possible to obtain new information about nuclear forces and the composition of nucleons. It is curious to note that since the initial construction of electrostatic generators in 1931, an idea for a new, successful method of particle acceleration has appeared about every 5 years. Each one of these new methods increased the maximum available energy by an order of magnitude. Exactly along this pattern, the

to separate the experiments into these three categories.

Two BNL diffusion cloud chambers are used to study the interactions of neutrons and mesons with hydrogen and to study the production of heavy mesons. A BNL expansion chamber is used in a search for heavy mesons produced by high energy mesons. A group from Yale University is operating an expansion-type cloud chamber in a search for heavy mesons produced by the high energy neutron beam.

Particle emulsions are explored regularly in the proton, neutron, and meson beams for members of the Brookhaven staff and for scientists from other institutions. These emulsions are being used to study the interactions of these various particles with the nuclei which make up the emulsion and in addition, a search is being made for events which yield unusual types of particles.

Six sets of fast counting equipment are in operation. Three are used to find the total absorption of π^+ and π^- mesons in the range .10 to 1.5 Bev. (One of these sets will soon be diverted to another type of experiment.) The emphasis on this type of experiment is a consequence of the current interest in the relation of the total absorption data being obtained here to similar data obtained elsewhere at

alternating gradient ("strong") focusing principle was discovered at Brookhaven in the summer of 1952.

This discovery of what is sometimes called "strong focusing" resulted directly from an exploratory study of the possibility of scaling up the Cosmotron design in order to produce protons of considerably higher energy than those available with the present machine. It was soon, of course, obvious that costs would mount very rapidly with energy, and the extreme practicable limit was felt to be no higher than, say, 20 Bev. Fortunately, studies of magnet configurations required by this investigation led directly to the discovery of the strong focusing principle, which seemed capable of reducing greatly the probable costs. Subsequent analyses of the new focusing principle showed that it was applicable to linear accelerators as well as to circular magnetic machines.

More detailed theoretical investigations and component studies were carried on during the autumn of 1952 by a group assembled from the Cosmotron project. These studies revealed several complications, such as possible instabilities due to resonances and to lack of phase stability at one point in the cycle. However, although these complications made the designs more difficult, they did not affect the feasibility of the new scheme. By the end of 1952, it was decided to proceed with a very detailed design and development study of a new multi-billion-volt accelerator. For this purpose a separate group was formed, named the AGS (Alternating Gradient Synchrotron) Project. Three barracks buildings were reopened to house the new group. At about the same time, study groups were formed at Princeton University and at Cambridge (a joint venture of MIT and Harvard) to investigate possible high energy accelerator designs. Both of these groups operated under subcontracts with BNL.

The initial efforts of the AGS group were mainly concentrated on detailed analyses to evaluate costs and relative ease of construction for 20, 50, and 100 Bev proton

Table 1

Proposed Possible Design Parameters for a 50 Bev
Alternating Gradient Synchrotron

Orbit radius of curvature	400 ft
Total length of orbit	3280 ft
Aperture at centerline of orbit	5-1/2 x 3-1/2 in.
Maximum field at centerline of orbit	14,000 gauss
n value	685
Total number of magnet sectors	264
Number of correcting magnets	66
Total weight of steel in main magnet	2650 tons
Total weight of copper in main magnet	700 tons
Length of straight sections	4 ft 9 in.
Length of straight magnet section	9 ft 6 in.
Peak load of magnet generator	23,000 kva
Rise time	2 sec
Repetition rate	5 sec
Injection energy	50 Mev
Frequency ratio	3/1
Number of accelerating units	88
Applied frequency at maximum energy	9.9 Mc
Peak rf v/rf cavity	2600 v
Total rf power	140 kw
Peak circulating rf power	700 kva
Estimated average power use for entire installation	6000 kw

synchrotrons. As a result of these design evaluations, it was decided that a 50 Bev machine would be the most appropriate goal for the Laboratory from the point of view of both economy and practicability. Consequently, all further efforts were concentrated on obtaining a working design for an accelerator of this size. The table given below shows some of the parameters initially determined for a 50 Bev proton synchrotron. It should be remembered that all these parameters are the results of theoretical calculations and experience gained from the construction of the Cosmotron; consequently, it is expected that the model studies now in progress will alter many of them.

After the decisions on the size of the proposed machine had been made, the group settled down to a careful model and design study of a 50 Bev accelerator. These investigations branched out along four main lines: magnet, radiofrequency accelerating system, linac injector, and theoretical orbit dynamics study.

During the year the group worked in close cooperation with other multi-billion-volt accelerator design organizations. Thus, two joint meetings were held with the Cambridge and Princeton design groups; AGS staff members acted as consultants to the European Council for Nuclear Research and to the Midwestern Accelerator Group; and eleven members of the latter organization will visit Brookhaven for three weeks in July 1953 to exchange ideas on accelerator design.

The project has grown from an initial staff of nine scientists, most of whom were contributing only part of their time, to a total of 24, of which 17 are on the scientific staff. Of the scientists and engineers, five are on loan from the Mechanical Engineering Division, three are on loan from the Cosmotron, one is on loan from the Physics Department, and two are summer visitors. At the end of the fiscal year, the group was made into a separate division, the Accelerator Development Division, which reports directly to the Director's Office.

Theory

The initial papers on alternating gradient focusing showed that a system of alternating focusing and defocusing lenses can give a net focusing effect if the number, size, and strength of the lenses are properly chosen. Alternating gradient focusing makes it feasible to obtain stable particle orbits with field indices n which are much larger than unity, where n is defined as

$$n = \frac{R}{B} \frac{dB}{dR},$$

R = radius of orbit

B = magnetic field

In previous accelerators only the condition $0 < n < 1$ made stable operation possible. As the focusing forces are proportional to n , it is thus evident that the AGS machines provide means for much stronger focusing. The result of this is that smaller magnet apertures, and consequently smaller magnets, can be used in AGS machines. This is essentially the feature which makes it possible to extend the size of accelerators into the multi-billion-volt range.

Subsequent analyses of the orbit dynamics of such a machine revealed two difficulties. Studies of betatron and synchrotron oscillations showed that strong resonances exist whenever the vertical, horizontal, or phase oscillation frequencies are integral or half-integral multiples or sub-multiples of the frequency of revolution. This fact places rather severe limitations on the constancy of n in the whole magnet. A good idea of the magnitude of these limitations can be obtained from Figure 6 which shows the range of n values usable for stable operations and also indicates all possible resonances.

Figure 6. Resonance lines in alternating-gradient synchrotron. Solid lines are integral resonances, dashed lines half-integral resonances, and dotted lines resonance between horizontal and vertical modes.

The second point brought out by further investigation was the existence of a phase transition point. It was shown that at a particle energy E_T the equilibrium phase angle shifts from the rising to the falling side of the voltage curve. Here E_T is defined as

$$E_T = (Mc^2) \frac{(\Delta p/p)}{(\Delta C/C)},$$

where M is the rest mass of the particle, c is the velocity of light, ΔC is the change in orbit circumference C associated with a change Δp in the momentum p . In order to retain an accelerated beam beyond energy E_T , it will be necessary to shift the phase of the applied radio-frequency voltage by the appropriate amount at the appropriate time. This will involve going through a point where no phase focusing takes place at all and where, indeed, there is a slight instability. Consequently, it is of importance to go through this point as rapidly as possible.

Present plans are to traverse this critical point by changing n swiftly with the help of pole face windings.

A considerable amount of time was invested in the studies of the effects of non-linearities in the magnetic field. It was fairly soon realized that this problem could be handled only by extensive and lengthy computations. Consequently, the problem was set up and programmed for the AEC's Univac installation at NYU. This computing program was started early in 1953 and will probably continue for one or two more years. Up until now, the results have revealed that relatively large non-linearities can be tolerated and that, as a matter of fact, a certain amount of these non-linearities might be tailored into the design of the machine in order to smear out the resonances.

Much time is being spent in actual theoretical design investigations involving such problems as mode of alternation of magnet sectors, shape of magnet sector, effects of magnet inhomogeneities, effects of straight sections, and determination of maximum mechanical tolerances.

The theory of the application of strong focusing in linear accelerators has been developed and has been extended into the relativistic range.

Magnet

Experience has shown that most accelerators are as good as their magnets. This is especially true for the type of fields desired for an AGS machine. Early in 1953, therefore, designs for a model magnet (dc) were completed and the magnet was erected a month later. The model is made of 2 in. laminations in such a way as to make it easy to add or subtract iron from any part of the model. The cross section is full-scale, and the 2 ft long positive and negative n sections are energized by a single set of coils. Figure 7 is a photograph of the model.

Figure 7. Front view of the dc model magnet. Magnet cross section is full scale but the length is smaller than the planned magnet sector lengths. Both 2-ft long positive and negative gradient sections are energized by the same coils. Equipment in front of the magnet is the precision flip coil slide used in magnet measurements.

Figure 8a. Graph of magnetic field strength versus position in central plane of magnet gap. R_0 is the assumed position of central orbit. The shaded outline shows the location of the actual magnet pole face. It is noticeable that the field is falling off very linearly over the central region of the gap.

Figure 8b. Normalized representation of Figure 8a demonstrating the constancy of the field gradients at various field strengths.

Preliminary measurements have been made with a GE fluxmeter and a flip coil. The results are extremely encouraging. In the first place, it is relatively easy to obtain fields as high as 14.4 kilogauss in the center of the gap; the only limiting factor is the heat dissipating ability of the coil. Furthermore, the field gradient appears to be very constant over 2.5 - 3 in. of central gap. The n -values themselves stay constant as a function of field up to 13.4 kilogauss. Above this field value, n starts to decrease and at 14.4 kilogauss it has dropped by 5 percent. These general features of the field can be seen in Figure 8, which shows B as a function of radius for several field strengths.

A precision carriage and slide for final field measurements has been constructed and is now being tested. With this device, it is expected that it will be possible to measure fields and gradients to an accuracy of $1/2$ percent.

A second set of pole faces has been designed. Basically this design is similar to the first one. Changes have been incorporated at the narrow end of the gap to reduce saturation at this point. Furthermore, the shape of the hyperbolic surfaces has been adjusted to give an n -value of 685, on the basis of $R_0 = 400$ ft. These figures represent approximately the present design parameters for the 50 Bev machine magnet. A first attempt has been made to design a dynamic magnet model. However, the determination of some of the final dimensions of this design will have to wait until more precise measurements have been made on the static model.

Linear Accelerator

A rather complete design study of a 50 Mev linear accelerator has been made. It is felt that such high injection energy is desirable for several reasons. At these energies, the guide field is still only ~ 80 gauss. To go to any lower values would invite serious eddy current and remanent field difficulties. Furthermore, the frequency swing of the rf will be only 3:1 with 50 Mev injection; this factor will simplify the rf design considerably.

Since it is planned to have a rather low energy gradient of $1/2$ Mev per ft on a relatively long linac, (200-300 ft), the injector should prove to be a comparatively easy problem. It is planned at this time to inject the ions directly into the linac from a 60 kv ion source. The initial frequency of the rf on the drift tubes is 30 Mc, and this frequency will be repeatedly doubled as the particles move down the accelerator.

A 9 drift tube injection section is now being built for model testing. Electrical properties, especially coupling between adjacent drift tube sections, are being studied in a sheet copper mock-up.

Radiofrequency

A rough rf accelerating design has been made which assumes a maximum magnetic field of 14,000 gauss and approximately 80 rf stations located at regular intervals around the 3200 ft circumference of the machine. The frequencies required would be from 4 to 12 Mc. If an accelerating period of two sec and an equilibrium phase of 150° are assumed, the voltage across each accelerating gap would be about 2100 v. Over-all output power is estimated at 4 kw per accelerating station. The frequency swing for this accelerating period differs markedly from that of the Cosmotron in that the rf rises to almost its maximum frequency in $1/20$ th of a sec. Ferrite properties in these frequencies were determined for the Laboratory by the Philips Research Laboratory in Holland. Two new ferrites, L-516 and P-1133, have been developed especially for this purpose. These ferrites have permeabilities varying from 200 to 400 between the frequency ranges of 1 to 12 Mc. Their unsaturated Q is about 60 at 1 Mc and goes down to ~ 2.5 at 10 Mc. Modeling of a ferrite loaded cavity will start as soon as some more information can be obtained on the availability of ferrite rings.

Building Complex

With the help of the Architectural Planning and Plant Maintenance Department, a study of the building complex to house the machine has been started. This complex consists of an experimental area of 42,000 sq ft, which will hold a heavy, permanently shielded cave for the target area, a 10,000 sq ft linac tunnel, a 75,000 sq ft magnet tunnel, and a laboratory, office and shop area of 60,000 sq ft. Shielding problems are being investigated.

60-Inch Cyclotron

The difficulties experienced in trying to get a consistently good deflected beam with this cyclotron led to an extensive program to improve and stabilize the cyclotron's magnetic field. After fairly extensive mechanical adjustments were made, a detailed survey was made of the magnetic field in the acceleration region. The radial field fall-off was increased slightly, and the first harmonic in azimuthal asymmetry was reduced to less than 1 gauss at all radii by means of properly placed spot shims.

While the cyclotron was dismantled for the magnetic measurements, a set of measurements was taken on the oscillator-amplifier system. As a result of these measurements, the rf system was cleaned up to reduce parasitic oscillations which had probably been the cause of numerous tube failures previously. Since reassembly of the cyclotron, the oscillator-amplifier system has been operating satisfactorily, with good stability and complete freedom from tube failure.

Since reassembly it has been possible to obtain a consistent beam of 30 to 50 μ a on the external target at a deflection efficiency of 25 to 50 percent. A number of target irradiations have been performed with integrated beam ranging from a few to several hundred μ a-hr. The mechanical distortion of the dee carrying the septum and deflector, that results from thermal expansion of an uncooled portion of the dee stem, continues to be a major source of difficulty and annoyance when a large circulating beam exists in the chamber. Because of this, a decision was made to limit the magnitude of the circulating beam to a value at which the deflected beam can be maintained steady for extended periods of time. A new set of dees designed to correct this difficulty is being fabricated and should be incorporated into the cyclotron before the end of the year.

A considerable amount of cyclotron operating time has been spent with a pulsed beam of deuterons on an external Be target for neutron time-of-flight experiments. One μ sec pulses at 0.25 percent duty cycle are obtained with peak target currents of 70 to 100 μ a. The operation under pulsed beam conditions is much steadier than that with continuous beam since the amount of dee heating is less and hence also the amount of dee distortion. The pulsed beam has also been used to make measurements of the acceleration time for the deuterons and to find the best combination of the adjustable parameters to obtain good deflection efficiency.

18-Inch Cyclotron

The construction and preliminary testing of the 18-inch cyclotron has been completed, and its performance now justifies the use of this machine for experimental purposes. Deflected proton beams of over 400- μ a have been obtained, and operation is possible between the energy limits of 1 and 2.7 Mev. Although the deflected beam must be increased to meet the original objective of 1 ma out, the operating range of energy is consistent with design specifications. At this time, attention is being given to focusing the external beam of protons into a small area in preparation for experiments.

As is frequently the case, a faulty magnetic field proved to be the main source of difficulty in obtaining a good accelerated beam. Reduction of the azimuthal variations

of the magnetic field and centering of the median plane of the magnetic field by magnetic shims made a very marked difference in the performance of the machine. An improved cold trap for the high vacuum pumps and a new set of dees with greater aperture also bettered operating conditions.

Plans are being made to study the character of the neutron beam that this machine can produce.

Research Electrostatic Generator

The electrostatic generator was completely dismantled early in 1953 in preparation for carrying out the program of revision and reconstruction described in last year's report. Prior to the dismantling of the machine, tests of the column structure indicated that the ultimate voltage limit can be expected to lie between 3.0 and 3.5 Mev. The numerous modifications which are being made will make the machine operation much more reliable and versatile for experimental use. The program is progressing according to schedule and the generator should be ready for tests and adjustments this fall.

ELECTRONICS

The Electronics and Instrumentation Division, which, together with the Health Physics Division, forms the Instrumentation and Health Physics Department, carries out research on electronic devices and provides technical service to the research departments by designing and constructing special electronic instruments. In the past year activity has been about equally divided among four categories of work: research, development of new instruments, construction of more or less conventional circuits, and maintenance operations. Activities related to research and development of new instruments are reported below. A brief statistical summary of construction and maintenance work is included later under the Technical Operations section of this report.

Research activities relate principally to the design and use of scintillation counter equipment. The "gray wedge" technique of pulse height analysis, developed in this Division last year, has been applied to the analysis of nuclear decay schemes and to a study of the degradation of gamma radiation.

In the gray wedge analyzer, scintillation counter pulses are amplified, shaped, and displayed on a cathode-ray tube. A camera views the tube face through a gray wedge. The arrangement is such that a time exposure produces a plot of the number of pulses as a function of pulse height (energy). This comparatively simple equipment provides data rapidly, in convenient form, and with accuracy compatible with the needs of many problems. The instrument has been improved this year and circuits added so that it will record only that part of the pulse height spectrum which is in coincidence with certain other selected events. Operation was checked by analysis of iodine-131, whose radiation is known. The system has since been used to analyze the radiation and hence the nuclear structure of several isotopes, including rubidium-86, silver-108, and arsenic-73. These measurements have been made in cooperation with members of the Chemistry Department.

In a cooperative project with the Health Physics Division, the gray wedge analyzer has been used to study the degradation of cobalt-60 gamma rays as they spread out from a source. Measurements have been made with the source in a large water tank (which was, in effect, an infinite homogeneous medium), with the source at the surface

of the ground, and with the source suspended in air. The intensity, distribution in energy, and directionality are measured at many points. Near the source, the radiation consists primarily of high energy gamma rays emitted from the source. As these interact with matter many are degraded, so that at larger distances there is a larger proportion of low energy secondary radiation. Because of the degradation, and because photons of different energy have different specific ionizations, the biological effectiveness is a function of the distance. The results of these measurements, which agree with a theory by Fano of the National Bureau of Standards, are important for the evaluation of many shielding problems.

Apparatus has been designed to measure the time for emission of secondary electrons because it is significant in determining whether the speed of photomultiplier tubes can be improved. The times involved are a few millionths of a microsecond.

New developments include fast amplifiers for use at the Cosmotron, a 100-channel neutron velocity selector, and data storage and handling devices.

Radiation is produced by the Cosmotron in a series of short bursts spaced about 0.2- μ sec apart. There are a few hundred bursts and then a long dead time. For efficient data taking, it was necessary to design circuits capable of operating on successive bursts. These include a linear amplifier with a rise time of about 3×10^{-8} sec, a fast discriminator or trigger to couple to a scaler, and fast scaling stages. The amplifier and discriminator were developed here, and the scaler is a copy of a Chalk River design.

The neutron velocity selector is used with the Brookhaven fast chopper. It consists of electronic circuits which sort neutron detector pulses into 100 successive time channels. Each channel may be 1, 2, or 4- μ sec wide, and the set of 100 channels may start at zero time or be delayed to a maximum of 900 channel widths. The system has been in operation for six months and has performed very reliably.

At present the velocity selector data are presented on 100 telephone type message registers. Reading, recording, and handling the quantity of data obtained by this and similar machines is laborious, and mistakes in reading may be costly. Various devices are under study to mechanize the data handling and to provide automatic recording or plotting of the data. In some cases the data may be recorded in a form suitable for mathematical treatment in an electronic calculator.

The new glow counter tubes have been incorporated in a number of scaling and counting circuits. Non-overload amplifiers and pulse stretching circuits have been improved. Programmed count integration systems have been designed for physics and biology experiments. One device has been built to count kernels of corn and another to deposit single seeds at regularly spaced intervals in a strip of gummed paper in preparation for planting.

CHEMISTRY

The research program in the Chemistry Department has continued along lines previously established. These are discussed below under the headings: Nuclear Chemistry; Isotope Chemistry and Applications; Chemical Effects of Radiation; Magnetism, Spectra, and Neutron Diffraction; and Other Researches. The last heading is used simply to avoid the proliferation of topics. It includes theoretical chemistry, development of analytical methods, mass spectrometry, and hot atom chemistry.

A classified project involving about two man-years of research effort has been completed and the results communicated to the Atomic Energy Commission.

Nuclear Chemistry

One of the main developments in nuclear chemistry during the past year has been the study of nuclear reactions in the billion-volt energy region. Since determination of the yields of radioactive end products is a valuable technique for the study of nuclear interactions, complementary to cloud chamber, counter, and photographic emulsion measurements, radiochemical work was started at the Cosmotron as soon as the machine became available for research use, at about the beginning of 1953.

The lead and copper targets used during start-up and initial operation of the Cosmotron were each found to contain many microcuries of radioactivity, and a number of well-known radioactive species were isolated radiochemically from each of these targets. It was found that the geometrical distribution of radioactivity could be used as a convenient indicator of where the target had been struck by the proton beam.

Up until now, the radiochemical work with the Cosmotron has proceeded primarily along two lines. The main effort has been directed toward learning whether the radioactive products resulting from the bombardment of some representative target elements with 2.3 Bev protons differ markedly in kind and in relative yields from those observed with protons in the 200 - 400 Mev range. Also, a good deal of time has been spent in the study of beam behavior and the establishment of appropriate targeting procedures. In the latter category may be mentioned investigations of the number of beam traversals as a function of target thickness, studies of radial and vertical distributions of activity in various targets, attempts to establish techniques for monitoring beam intensity by means of induced activity, and measurements of the loss of radioactive products from target foils by reason of the momenta imparted to them in the course of their formation. Table 1 summarizes the data on percentage losses due to recoil of C^{11} , F^{18} , and Na^{24} from 0.00025 in. aluminum foil. In the case of a 0.001 in. copper foil, the over-all loss of activity by recoil was found to be only about 1.5 percent, but there is evidence that larger fractions of some products of low atomic number, notably Be^7 , are lost from copper foils.

Thus, for relative yield measurements, some caution is required in the choice of target thickness: thin targets are desirable because high specific activities can be attained with multiple beam traversals and because secondary reactions are minimized; but recoil losses of certain products may be appreciable. In practice, target thicknesses between 0.002 and 0.060 in. have been used in most of the yield work. All targets are introduced into the beam from the inside of the Cosmotron ring by an air-operated ram which is actuated toward the end of the acceleration cycle. Thus, the targets are not exposed to the lower energy protons lost from the circulating beam during the early part of the acceleration.

No complete study of reaction yields produced in a given target element with Cosmotron protons is yet available, but the relative yield measurements which have

been taken show some very striking differences from the results at lower energies. For example, when the results of a 2.3 Bev proton bombardment of lead were compared with those of a 385 Mev bombardment at the Nevis cyclotron, a substantial difference in yield distributions was found. Of the total long-lived gamma activity in the target (as measured three months after irradiation), the rare earth fraction contained about 70 percent in the 2.3 Bev and only about 1 percent in the 385 Mev experiment. This

Table 1		
Percentage Recoil Loss of C^{11} , F^{18} , and Na^{24} Activity from 0.00025 in. Aluminum Foil		
	1 Bev Proton Energy %	2.3 Bev Proton Energy %
C^{11}	45	36
F^{18}	25	32
Na^{24}	15.2	13.7

Figure 1. Approximate yield curve for Pb + 385 Mev protons.

may be taken as an indication that the deep valley in the yield curve, observed between the "fission" and "spallation" regions when elements of high Z are irradiated with particles in the 100 to 400 Mev range, may have disappeared at the higher bombarding energy. In the case of a lead target, this valley just covers the rare earth region (A about 130 to 180), as is shown in the idealized yield curve of Figure 1. It was also found that products in the fission region tend to be more neutron-deficient in the 2.3 Bev than in the 385 Mev bombardment. This may be illustrated by the fact that the long-lived strontium isolated from the Cosmotron lead target was mostly Sr^{85} , whereas at the lower energy Sr^{89} is the most prominent isotope.

In the case of aluminum bombardments, the relative yields of Na^{24} , F^{18} , and C^{11} , which can be deduced directly from the gross decay curve of an irradiated aluminum foil, were found to be 1.0, 0.64, and 0.50 at 2.3 Bev proton energy, compared with 1.0, 0.55, and 0.19 at 335 Mev (Marquez and Perlman, Phys. Rev. **81**, 953 (1951)). A more striking result is the very high yield of Be^7 . If the Be^7 and Na^{22} yields from aluminum by scintillation spectrometer measurements of the gamma-ray intensities are compared, a lower limit of 5 could be set for the $\text{Be}^7/\text{Na}^{22}$ atom ratio, whereas Marquez and Perlman found a value of 0.12 for this ratio. The reason the value quoted is only a lower limit is that the target used in this experiment was stationary and therefore exposed to a considerable flux of lower energy protons which produce more Na^{22} than Be^7 . Indications are that the true ratio is still much higher.

In the bombardment of copper targets, the very high relative yield of Be^7 is again the outstanding feature. The relative yield data so far obtained in copper bombardments are summarized in Table 2. Since absolute cross sections have not yet been measured, all yields are arbitrarily normalized to the yield of Mn^{52} taken as unity. Many of the values given are rough, but all should be accurate

Table 2		
Yields of Some Nuclides Produced in the Bombardment of Copper with Protons (Normalized to Mn ⁵² Yield)		
Product	Relative Yield at	
	2.3 Bev	340 Mev
Zinc-62	0.3	0.11
Copper-64	2	3.2
Copper-62	4	6.8
Copper-61	2	3.2
Copper-60	0.5	
Nickel-65	0.02	
Nickel-57	0.06	0.25
Cobalt-55	0.2	0.32
Iron-59	0.03	0.11
Iron-52	0.03	0.025
Manganese-56	0.5	0.16
Manganese-52	1.0	1.0
Manganese-52m	0.3	
Manganese-51	0.3	0.23
Chromium-51	0.4	1.0
Chromium-49	0.3	0.13
Potassium-43	0.1	
Potassium-42	0.2	0.004
Phosphorus-32	0.1	0.017
Sodium-24	0.1	0.004
Beryllium-7	29	0.077

within a factor of 2. For comparison, Batzel, Miller, and Seaborg's values (Phys. Rev. 84, 671 (1951)) for 340 Mev protons are listed, also normalized to $Mn^{52} = 1.0$. It is seen that the relative yields at the two energies show no very marked discrepancies from the target region down to about $A = 50$; from potassium down, the yields relative to Mn^{52} are substantially higher at 2.3 Bev, and the Be^7/Mn^{52} ratio at 2.3 Bev is about 400 times that at 340 Mev bombarding energy.

Investigation continues on the modes of decay of radioactive isotopes. The 19.5 day Rb^{86} decays by beta emission to stable Sr^{86} . Positron decay of this isotope has not been observed. A search has been made for electron capture decay by looking for characteristic x-rays of krypton with the x-ray proportional counter equipment, which has been extensively used in this Laboratory. None were found, and an upper limit of 1×10^{-3} is set for the ratio of K capture to negative beta emission in 19.5 day Rb^{86} . The 1.02 min period formed along with the 19.5 day period by neutron capture was also proved to belong to Rb^{86} by experiments with separated rubidium isotopes. This isomeric state was shown to decay by the emission of 560 kev gamma rays, largely unconverted, probably by E4 transition.

The decay of As^{73} to Ge^{73} has been studied with scintillation counters. The two transitions of 54 and 13.5 kev which were reported to follow the electron capture were confirmed by scintillation counter pulse height analysis. The 13.5 kev transition is so highly converted that it could be observed only with a crystal (NaI) which had been grown with As^{73} incorporated in it. This transition was shown to follow the 54 kev transition, with a half-life of 4.6 μ sec. The technique was to trigger an oscilloscope sweep with the 54 kev pulses and photograph the time distribution of 13.5 kev pulses on the oscilloscope screen (Figure 2). By similar experiments in which the germanium x-rays accompanying electron capture in As^{73} were used to trigger the sweep and the 54 kev pulses displayed on the screen, the half-life of the 54 kev transition was shown to be greater than 900 μ sec. An upper limit of 10 sec was placed on this half-life by rapid chemical separations of germanium from arsenic. (It is now known from work elsewhere that the half-life is 0.33 sec.) The decay scheme of As^{73} and Ge^{73} is shown in Figure 3.

The assignment of the 0.8 sec lead isomer to mass 207 has been confirmed by its chemical separation from Bi^{207} . Chemical separations were carried out in about 1 sec, and the half-life of the separated Pb^{207m} was measured to be 0.88 ± 0.10 sec. The radiations have also been studied.

As mentioned in the last Annual Report (BNL 196(AS-6)), an investigation of the electric charge of daughter atoms produced in radioactive transitions is being made. The quantities measured are the current resulting from the collection of the primary positive ions produced in a sample of radioactive gas and the absolute disintegration rate of the gas sample. The quotient of the quantities is the average charge per disintegration. By this method it was found that the average charge on the Cl^{37} formed by electron capture in A^{37} is $+3.41 \pm 0.14$. For the Xe^{131} daughter of the isomeric transition in Xe^{131m} , the average charge is $+8.5 \pm 0.3$. Estimates of the average charges which might be expected have been calculated from Auger transition probabilities and fluorescence yields to be +2.30 and +6.41, respectively. These numbers may be increased somewhat if the energetically allowed Coster-Kronig transitions occur; however, data for the probabilities of these transitions are not available. Other processes, such as electron "shake off" caused by the abrupt change in electrostatic potential, are doubtless contributing somewhat to the ionization.

Several investigations have been made of nuclear reactions caused by neutrons in the reactor. Most commonly, radioisotopes are made in the reactor by the n, γ capture reaction. However, sufficient fluxes of fast neutrons are present to be useful for fast

Figure 2. Decay of the 13.5 keV level in Ge^{73} as observed on the gray wedge time-delay analyzer.

Figure 3. Decay scheme of As^{73} and Ga^{73} .

neutron reactions. It has been found that Fe^{59} can be prepared by the $\text{Co}^{59}(n,p)$ reaction in the pneumatic tube of the reactor and that this method for producing carrier-free Fe^{59} is comparable economically to cyclotron production. The yield of Fe^{59} per gram of cobalt at a total neutron flux of 3×10^{12} is 1.2 μc per day.

A study was made of short-lived cerium isotopes produced by the fission of uranium to confirm, or disprove, the existence of reported 1.8 hr Ce^{145} and 4.5 hr Pr^{145} . It was conclusively shown that Ce and Pr isotopes of these half-lives are not formed with fission yields greater than 0.1 percent. The previously reported Ce^{145} - Pr^{145} chain was probably due to contamination, perhaps by 2.0 hr Nd^{149} and 3.7 hr La^{141} . The Ce^{146} - Pr^{146} chain was observed and investigated further with respect to half-lives and beta energies.

Until recently it was felt by those who had measured fission yields radiochemically that the accuracy of such measurements was not better than ± 10 percent, most of the error arising from the estimate of absolute disintegration rate of the radioactive sample. The advances in beta counting techniques during recent years have made it possible to improve the accuracy of these measurements. The yield of 5.27 day Xe^{133} was remeasured by determination of the fission rate of a sample of uranium in a double chamber fission counter and meas-

urement of the disintegration rate of the chemically separated xenon by gas-phase proportional counting. Five separate determinations gave a mean value of 6.62 ± 0.15 percent, where the indicated error is the 99 to 1 probable error. A considerable number of possible sources of error were investigated. It is felt that this measurement is accurate within 3 percent of the value given. Xe^{133} can be used as a convenient standard in future radiochemical relative fission yield determinations.

Isotope Chemistry and Applications

The program of investigation of electron transfer exchange reactions (exchanges between different oxidation states) has been continued. Isotopic tracer studies have also been made on other inorganic, organic, and biochemical reactions.

The rate of the thallos-thallic exchange reaction was measured at 50°C in perchloric acid-sodium perchlorate mixtures. The results are in good qualitative agreement with those of two other investigations, which could not formerly be compared

because of the different ionic strengths employed, and serve to tie together into one consistent picture a body of kinetic data obtained at different laboratories. Further reasons were found for doubting that unhydrolyzed thallic ion participates significantly in the reaction; however, this point is not firmly established. At high ionic strengths and constant acid concentration, the rate decreases as the ionic strength is increased in a way which was shown to be consistent with the assumed mechanism and with the known behavior of the activity coefficients of some electrolytes at high concentrations.

Additional work has been done on the Hg(I)-Hg(II) cyanide system. A previous conclusion that HgCN^+ must not exchange rapidly with Hg^{++} was experimentally confirmed, and the kinetics of several reactions in this system were determined.

The kinetics of the electron exchange reaction between duroquinone and durohydroquinone have been studied at 25°C in buffered methanol solution, and it was found that the rate is independent of the quinone concentration and first order with respect to that of hydroquinone. This rate law is consistent with a proposed mechanism involving slow ionization of the hydroquinone and rapid exchange between the resulting doubly charged durohydroquinone anion and duroquinone. The rapid exchange step may proceed through the equilibrium formation of a semiquinone free radical as an intermediate oxidation state.

The kinetics of the exchange of hydrogen between phosphine and water have been studied further. It was found that the reaction is subject to general acid catalysis and to catalysis by hydroxyl ions. The suggested mechanisms involve the formation of PH_3D^+ and PH_2^- as rate-determining steps for the acid and hydroxyl catalyzed paths, respectively. The acid and base strengths were estimated from the kinetic data, on the basis of these mechanisms, and were found to be very small, 10^{-29} and 10^{-28} , respectively.

The homogeneous gas-phase decomposition of nitrous oxide, a classical reaction in chemical kinetics, has been further investigated with the aid of N^{15} tracer. Experiments on the decomposition of mixtures of $\text{N}^{15}\text{N}^{14}\text{O}$ and $\text{N}^{14}\text{N}^{14}\text{O}$ and also on exchanges involving NO showed there was no equilibration of N^{14} and N^{15} in the product N_2 . The results support the idea that the reaction goes through a unimolecular decomposition mechanism, and argue against the chain mechanism that has been proposed.

The first phase of a tracer study of the OXO reaction has been completed. The reaction was carried out with $\text{C}^{14}\text{H}_3\text{OH}$, and the distribution of C^{14} in carbon atoms of the ethanol and *n*-propanol products was determined. The results show that the addition of carbon to the methanol is quite different from the addition to ethanol. With respect to the latter, the results are quantitatively almost as expected if the formation of propanol proceeds through addition to a symmetrical intermediate; however, until the small systematic variations are studied further, a firm conclusion on this point is not justified.

The processes involved in alkaloid biogenesis by the tobacco plant are being explored with C^{14} labeled materials. Nicotinic acid has been regarded (Winterstein-Trier hypothesis) as a possible precursor of the pyridine part of the alkaloids found in tobacco. To test this hypothesis, C^{14} labeled nicotinic acid and ethyl nicotinate were provided to growing tobacco roots. The nicotine synthesized by the growing plant was found to be inactive; hence this hypothesis must be rejected. Further work is in progress on alkaloid biosynthesis in the genus *Nicotiana*.

The program of isotope chemistry (the effects of isotopic substitution on the equilibrium and kinetic properties of substances) has been continued. With respect to equilibrium properties, functions needed for calculation of the effect of isotopic substitution on the entropy, enthalpy, and heat capacity of ideal gases have been numerically evaluated and tabulated. Future calculations of these thermodynamic quantities will be greatly simplified by the tables which have been prepared and published. Only vibrational data are required.

Two different approaches have been employed in the use of isotopes to elucidate the mechanisms of chemical reactions. The most common approach involves the tracing of an isotope through the course of a reaction. The other consists in determining the effect of isotopic substitution on the rate of the reaction. The latter does not require samples of initially abnormal isotopic composition; the relative rates of reaction of the isotopic species can be determined by measurement of the change in the natural isotopic abundance which occurs during the course of the reaction. This approach has been employed in a study of the mechanism of the pyrolysis of barium adipate to form barium carbonate and cyclopentanone,

Two mechanisms appeared to be consistent with other data on the reaction. One of these was calculated to lead to an isotope effect of several percent. The other (reversible dissociation of a proton from the alpha-carbon followed by a concerted reaction to give barium carbonate and the enolate anion of cyclopentanone) was predicted from the available theory to give no isotope effect. Experimentally, the carbon isotope effect was found to be zero within a few tenths of a percent, and a concerted reaction mechanism is indicated.

The theoretical analysis of carbon isotope effects in decarboxylation reactions has been extended to consider the relative rates of reaction of isotopic isomer malonic acid molecules (-2C^{14} and -1C^{14}). The results have been found to be consistent with those of recent experiments, and also with a C^{14} isotope effect just twice that of the C^{13} . The approximations involved in the descriptions of the motion of the transition state have been examined further. It was found that the theoretical equation for the ratio of the rate constants of isotopic molecules is essentially independent of whether the crossing of the barrier is treated as a translation or a vibration. The temperature-independent factor ("reduced mass factor") has been evaluated for the case of substitution or displacement reactions, and calculations have been made for several cases involving the isotopes of carbon in which there is simultaneous bond rupture and bond formation.

Chemical Effects of Radiation

At the present time, data are appearing from a number of laboratories on the kinetics of radiation-induced reactions in aqueous solution. The observations are treated on the basis of a free radical model, in which water is dissociated by the radiation to form H and OH radicals in groups distributed through the solution. It is thought that a fraction of the radicals undergo initial combination and yield molecules of H_2 and H_2O_2 , which appear as reaction products. The remainder diffuse into the solution and react with solutes to produce observed chemical changes.

A critical survey of existing data was presented at the meeting at the new Radiation Research Society. It was concluded that many reactions are best interpreted on the basis that the amount of molecular peroxide formed initially is greater than the amount of molecular hydrogen, with a corresponding excess of free H atoms over free OH radicals. On this interpretation the yield, per unit energy absorbed, of the different species produced by radiations of varied quality can be calculated. However, in other reactions it appears that the numbers of H and OH are substantially equal; the free radical model in its simple form will probably have to be refined, with more detailed consideration given to the processes in which the radicals are formed.

In this Laboratory a thorough study has been made of the effect of x- and gamma-radiation on potassium nitrite solutions. The net reaction is the formation of nitrate and hydrogen, with a maximum nitrate yield equal to the standard yield of molecular hydrogen generally found in aqueous solutions. The reaction appears to be essentially a radiation-induced reaction between nitrite and peroxide which is formed by the radiation decomposition of water and which gives nitrate. The kinetics have been studied in mixtures of nitrite and peroxide of various concentrations. It is found that the reciprocal of the yield (molecules converted per unit energy input) is a linear function of the ratio of nitrite to peroxide (Figure 4). Such a relation suggests that the rate depends on the competition of two substances for a single intermediate: if some radical (H or OH) reacts with nitrite no net reaction results, whereas if it reacts with peroxide a net reaction occurs. Plausible reaction schemes may be written for either H or OH,

Figure 4. Kinetics of the radiation-induced reaction between potassium nitrite and hydrogen peroxide.

Figure 5. Formation of iodine in irradiated potassium iodide solutions.

and a decision between the possible mechanisms may be obtainable with further work on allied systems, such as solutions of nitrate or nitric oxide. The intercept of the line in Figure 4 gives the total yield of the radical being competed for, since at the limit all radicals will be producing a reaction. This intercept agrees with radical yields proposed on the basis of other reactions.

The x-ray-induced reaction in potassium ferrocyanide solutions has been found to give clean oxidation to ferricyanide, no detectable free cyanide being formed. This contrasts with the action of light on ferrocyanide, which gives hydrolysis to the aquopentacyanoferrate ion with liberation of a free cyanide ion.

The reduction of ceric sulfate in acid solution is a much studied reaction which has played an important role in the development of theories of the radical yield. It has been found that when dissolved carbon monoxide is present carbon dioxide is formed in an amount equivalent to the cerium reduced. The amount of cerium reduced, per unit energy input, is doubled by the presence of carbon monoxide. The yield of CO_2 is the same whether cerium is present or not. A satisfactory explanation of these observations has not been reached.

Potassium iodide solutions have been extensively studied in this Laboratory; at concentrations millimolar or less, the observed products of the action of radiation are H_2 , H_2O_2 , and O_2 , the iodine apparently being oxidized and reduced with no net change except destruction

of the radicals. At higher iodide concentrations a small yield of iodine has been noted; this was assumed to be a result of a secondary reaction between iodide and peroxide. A study of the kinetics of iodine formation now shows unexpectedly that the initial yield of iodine is equal to the yield of molecular hydrogen and that peroxide and oxygen appear only later as the iodine yield falls. The concentration of iodine eventually attains a steady state, which is higher as the iodide concentration becomes higher (Figure 5). Also, contrary to expectation, the steady state concentration of iodine is lowered by the addition of oxygen and raised by the addition of hydrogen. The reaction mechanism is evidently more complicated than was previously suspected, and the system is worthy of further study.

The most convenient and widely used chemical actinometer is a solution of ferrous sulfate in 0.8N sulfuric acid saturated with air. The absolute value of the yield of ferrous oxidation has been measured at a number of different laboratories by ionization chamber and calorimetric methods. The determined values of the yield G , molecules of FeSO_4 oxidized per 100 ev absorbed, fall into two groups, about 20.5 and 15.5. The yield has been determined in this Laboratory by an independent method, in which the energy input was determined by accurate measurement of the current of 2 Mev electrons absorbed by the solutions. The value of G is constant over a wide range of current, as is shown in Table 3, and is found to be 15.7 molecules/100 ev. The disagreement

Table 3		
Absolute Yield of the Ferrous Sulfate Actinometer		
Cathode Ray Current (amp)	Number of Determinations	G (molecules FeSO_4 oxidized/100 ev)
$2 - 5 \times 10^{-7}$	9	15.7 ± 0.5
$1 - 4 \times 10^{-8}$	38	15.7 ± 0.3
7×10^{-10}	5	15.7 ± 0.3
7×10^{-11}	3	16.1 ± 0.8

with ion chamber measurements, which give values close to 20, is quite serious and suggests that unsuspected sources of error may exist in the accepted radiological standards.

Magnetism, Spectra, 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.

The absorption spectra of crystals of rare earth salts, and also of mixed crystals, are being studied at low temperatures. The purpose of this study is to characterize the electronic transitions which give rise to the optical spectrum. The spectra of solutions at low temperatures are also being explored; the main objective here is to find the symmetry of the electric field which is due to the neighboring ions in solutions and thus to approach a knowledge of the structure of fluid solutions of electrolytes.

A detailed investigation has been made of the absorption spectra of praseodymium chloride. Polarization spectra over the range of 2000 to 18,000 Å were taken of single crystals diluted with various amounts of isomorphous lanthanum chloride. It was advantageous to work with the anhydrous salt despite its great hygroscopicity because its crystal structure is known precisely, i.e., it is hexagonal with rare earth ions in sites

Figure 6. Neutron diffraction crystal spectrometer installation.

of C_{3h} point symmetry. The crystals were grown from melts.

When polarized light is sent through these crystals perpendicular to their unique axes, they exhibit a complete dichroism. That is, at temperatures low enough that the absorption spectra are resolved into individual lines, none of these lines is common to both the ordinary and extraordinary spectrum. The number and polarization properties of these lines depend upon the nature of quantum states and the symmetry of the lattice sites of the rare earth ions. Since the nature of the ground states is well understood from magnetic measurements, and the symmetry of the crystal is known, the observations permitted the assignment of terms to excited states. Observations were made with crystals at liquid nitrogen and at liquid helium temperatures. The dependence of line intensities upon temperature served as an additional check upon the quantum assignments.

Comparison of these polarization spectra with the spectrum observed when looking down the unique axis permitted the determination of the nature of the transition. That is, it was possible to differentiate between forced electric dipole, magnetic dipole, or electric quadrupole transitions.

The development of techniques for observation of the absorption spectra of fluid solutions at liquid nitrogen temperatures has led to a number of investigations of solution chemistry in this relatively unexplored temperature region. It was found that various forms of chlorophyll (a, b, and b') which fulfill critical standards of chemical purity at room temperature contain different forms of the substance. This is manifested in the temperature-dependence of their absorption spectra which exhibit reversible changes, explainable as temperature alterations of equilibria between several forms present. There are indications of the formation of solvates of chlorophyll and related substances with polar substances (water, ethers, amines). Equilibria between zerosolvates, monosolvates, and disolvates have been extensively studied in mixtures of hydrocarbons with the polar material.

The program of magnetic susceptibility measurements has emphasized the question of the effect of crystalline fields and exchange interactions on the magnetism of compounds of the transition elements. A study of the magnetic susceptibility of anhydrous CoCl_2 and its isomorphous mixtures with ZnCl_2 and CdCl_2 has shown that the molar susceptibility is very little affected by dilution with isomorphous diamagnetic chlorides. Hence it is concluded that CoCl_2 deviates from Curie's law because of a crystalline field Stark effect rather than Heisenberg spin-spin exchange. This was predicted by analogy with the behavior of manganous ion, which shows little or no evidence of exchange interactions. Work is in progress on the magnetism of solid solutions of NiF_2 and CoF_2 with ZnF_2 to give information on the crystalline fields and exchange interactions in these systems.

The neutron diffraction studies of the chemical and magnetic structures of zinc ferrite and nickel ferrite, mentioned in BNL 196(AS-6), and of magnesium ferrite have been completed. In agreement with previous x-ray investigations, zinc ferrite is found to possess a completely regular spinel structure. The diffraction peaks show no evidence of coherent magnetic scattering, whereas the background exhibits normal paramagnetic diffuse scattering. This eliminates the possibility of an antiferromagnetic

structure at room temperature. In the case of nickel ferrite, calculated intensities based on an inverted structure and the Néel model of ferrimagnetism are in good agreement with the observed intensities. In order to fit the calculated intensities to the observed, it is necessary to assume a form factor describing the angular dependence of the magnetic scattering amplitude; this in turn, by inversion, permits the calculation of a radial distribution for the magnetic 3d electrons in NiFe_2O_4 . The result, shown in Figure 7, indicates a smaller radius of the 3d shell than the theoretical radius. However, only limited significance is to be attached to the derived distribution function, since it requires a rather complicated average involving two ionic species and two different crystallographic sites.

Figure 7. Radial distribution of 3d electrons in NiFe_2O_4 which was obtained by inversion of the magnetic form factor.

Figure 8. Neutron diffraction pattern of polycrystalline MgFe_2O_4 .

The case of magnesium ferrite is somewhat exceptional, in that its structure was originally reported to be inverted, i.e., to have the same number of magnetic atoms in each of the two different lattice sites in which the metal ions are found. Therefore, on the basis of the Néel coupling scheme, it should have zero saturation moment, whereas in fact it has a saturation moment consistent, on the Néel model, with 10 to 15 percent departure from complete inversion. A neutron diffraction study of this material was made to check the Néel theory, not only by a determination of the degree of inversion, but also by direct observation of the coherent scattering from the aligned magnetic moments. Figure 8 shows the neutron diffraction pattern obtained for a sample of polycrystalline magnesium ferrite. This represents the combination of the nuclear and magnetic scattering. Figure 9 shows the pattern due to nuclear scattering alone, the magnetic scattering being eliminated by the application of a suitably oriented strong magnetic field. The calculated and observed peak intensities are compared in Table 4. It is seen that there is excellent agreement, and the Néel model is confirmed.

Additional work on neutron diffraction is reported under "Solid State Physics."

Figure 9. Neutron diffraction pattern of MgFe_2O_4 which is due to nuclear scattering alone. The magnetic scattering has been eliminated by application of a strong magnetic field ($\sim 10,000$ oersteds) parallel to the scattering vector. Lower resolution was employed to enhance the scattered intensity.

Table 4				
Calculated and Observed Integrated Intensities for MgFe_2O_4 Relative to (311)				
Calculated Intensities				Observed Intensity
(hkl)	Nuclear	Magnetic	Total	
(111)	230	3270	3500	3370
(220)	1911	788	2700	2800
(311)	6370		6370	6370
(222)	560	429	990	1000
(400)	4830	720	5550	5500
(331)	11	828	840	634
(422)	1260	334	1590	1470
(511), (333)	4530		4530	4660
(440)	13,250		13,250	13,110
(531)	59	639	700	520
(620)	752		752	771
(533)				
(622)	2184		2180	2230
(444)				
(711), (551)	2534	162	2700	2670
(642)				
(731), (553)	4883		4880	4910

subject of much discussion and study. The mass spectrum shows that in the vapor phase the structure is vinylaceto- β -lactone, the same as that shown by the solid at low temperatures.

Other Researches

A reinvestigation of the relative abundances of ruthenium isotopes has been carried out. The previous data on these abundances involved photographic plate calibrations which used cadmium abundance data which have subsequently been revised. A reinvestigation seemed particularly pertinent since the data led to an atomic weight of 101.1 which was in disagreement with the accepted chemical value of 101.7. One difficulty in the determination of the isotopic abundances of ruthenium has been the scarcity of volatile compounds from which a stable molecular beam for ionization could be obtained. With the discovery and synthesis of ruthenocene, $\text{C}_{10}\text{H}_{10}\text{Ru}$, this difficulty is removed, and isotope abundance measurements can be made easily in a mass range free of background and under circumstances in which errors due to voltage discrimination and isotope fractionation are minimized. The mass spectrum of this compound has been carefully determined with electrical recording. Although significant differences from the earlier data were found at some mass numbers, the calculated atomic weight is 101.08, which is still in disagreement with the accepted chemical value.

Studies have been made of the mass spectra of a number of organic compounds, with particular attention to correlations between the mass spectral patterns and molecular structure. In the mass spectra of six aliphatic lactones (β -propio, γ -butyro, γ -valero, γ -crotono, β -angelica, and α -angelica), it is found that the main peaks result from the splitting of two alternate bonds of the lactone rings. The stability of the parent molecule ion is greater with the unsaturated lactones, and their spectra are characterized by larger intensity of peaks as a result of rearrangement. Mass spectra have also been obtained for ketene and ketene dimer.

The structure of the latter has been the

The structure of phosphine, whose exchange reaction with water has been extensively investigated in this Laboratory, has been studied with isotope, infrared, and microwave techniques. In order to bring the rotational transitions into a conveniently accessible microwave frequency range, the monodeuterated and dideuterated compounds were employed. Analysis of the infrared and microwave transitions leads to the evaluation of structural parameters for the molecule. For PH_2D and PHD_2 , the P-H distance was found to be 1.4177 and 1.4116 Å, and the H-P-H angle was $93^\circ 21.6'$ and $93^\circ 15.4'$.

Theoretical research is being done on the quantum mechanical calculation of molecular energy levels. A method has been found of introducing corrections into the molecular orbital treatment of the ethylene molecule, which brings the results into closer agreement with experiment. The analysis has been applied to *cis*-butadiene, with considerable success, and also to cyclobutadiene. The question of the dissociation energy of the nitrogen molecule has also been examined. This is a matter of considerable interest since, at present, experiment points to two different values. A theoretical treatment which was offered as confirmation of the higher value (9.8 ev) has been carefully examined; unfortunately, it must be concluded that at the present time no quantum theoretical calculation exists which can be the basis for a valid decision between the conflicting theoretical estimates.

In analytical chemistry, the polarographic reduction of tellurium (VI) at the dropping mercury electrode has been investigated in a variety of media. It was found that well defined, though irreversible, waves occur, which are suitable for the analytical determination of this element. It was shown coulometrically that the reduction proceeds to the -2 state. A method has also been developed for the determination of micro-molar amounts of cyanide in the presence of dilute ferrocyanide in the concentration ratio ferrocyanide-cyanide = 100-200.

Finally, it should be mentioned that several investigations in hot atom chemistry (the chemical effects of nuclear transformations) are being continued. A very thorough study of the bond rupture, or lack of bond rupture, caused by C^{14} beta decay is nearing completion. There is strong evidence that a large fraction of the beta decays in C^{14} bonded to carbon fail to cause bond rupture, so that a carbon-nitrogen bond is synthesized by the decay process. The hot atom chemistry of C^{14} , as formed by $\text{N}^{14}(\text{n},\text{p})$, is also under investigation. It has been shown that both radioactive anthracene and acridine are formed when acridine is exposed to neutrons in the reactor. The hot atom chemistry of chromium and cobalt is also being studied, in solid phase and in aqueous solution. Particular attention is being given to the effects of temperature and aging on the yield of the chemical forms taken by the radioactive products of neutron capture. A critical experiment has been performed on the scavenger effect of dissolved chlorine and dissolved allyl chloride on the recoil atom chemistry of carbon tetrachloride exposed to neutrons. The alteration in retention caused by these solutes was found not to be affected by the radiation dose received by the sample. This result rules out a previously advanced radiation decomposition theory of scavenger action in this system and suggests an atom-radical diffusion-recombination mechanism.

ENGINEERING

The engineering activities of the Laboratory are carried out in the Nuclear Engineering and Reactor Departments and in the Mechanical Engineering Division. Both research and service activities are performed with the majority of the service work being carried out by the last organizational unit. A summary of its activities is included in the Technical Operations section of this report. Research activities having

an engineering character are, except for accelerator development, centered around reactors, reactor components and reactor by-products and are basically studies in chemical engineering, metallurgical engineering and reactor physics. On August 1, 1952, the Nuclear Engineering Department with Clarke Williams as chairman and the Reactor Department with Marvin Fox as chairman were organized from the former Reactor Science and Engineering Department. The new Reactor Department has the responsibility for operating the nuclear reactor and for carrying out studies in shielding, reported later in this section, and studies in certain phases of the neutron physics program. These latter studies are reported earlier in the Physics section of this report and include summaries of the cooperative neutron physics work undertaken with individuals from other institutions.

Both Departments are responsible for the operation of certain technical services for the Laboratory, the nuclear reactor in the case of the Reactor Department and the Hot Laboratory and waste control operations in the case of the Nuclear Engineering Department. The work of these service units is described later in the section on Technical Operations.

The Nuclear Engineering Department is directing its attention to research problems which are associated either with the development of economic nuclear power or with the utilization and handling of by-products from reactors. The staff of the Department is directing a considerable fraction of its effort toward the studies of liquid metal fuels and breeder blanket components which lend themselves to continuous processing schemes. These investigations involve metallurgical studies on liquid metal multiphase systems, corrosion of container materials, chemical processing of these fuels and breeder blanket materials, heat transfer studies, as well as the evaluation of various nuclear designs by the reactor theory group. A number of pilot loops have been operated under non-radiative conditions. One circulating loop has been operated successfully in the Brookhaven reactor. Use has been made of the Commission's Univac now being operated by the New York University to extend design calculations for reactor metal fuel systems to more complex arrangements. It is now possible to remove some of the uncertainties introduced by approximations previously made to reduce the mathematical difficulties.

Considerable experimentation has been done on exponential lattices of slightly enriched uranium in water; this work was aimed at measuring parameters needed for predicting the criticality of these fuel-moderating systems. New experimental methods have been developed for some of the parameters, and it is now possible to compare theory and experiment in greater detail than before for these lattices.

In addition to the development of liquid metals and container materials, the Metallurgy Division has been working on some effects of neutron radiation on various properties of materials such as creep and the self-diffusion in iron, change in structure, etc.

Shielding studies carried out by the Reactor Department are directed at measuring and analyzing the effects caused by various materials and configurations on the transmission of neutrons. Both generalized and specific (mock-ups) shapes have been considered. In addition, the construction of a two-crystal scintillation spectrometer, designed to measure neutron capture gamma rays from elements with capture cross sections of at least a few barns, has been completed. It was installed at the reactor in March, 1953. Since that time, a great deal of effort has been spent to reduce the background. The background level is now sufficiently low to permit the detection of a capture gamma ray that is emitted in 10 percent of all neutron captures. Measurements of the low energy spectrum of vanadium have been made. The analysis of these data has not been completed. The measurements of the transmission of gamma rays through slabs of paraffin and lead have also been made; the results for Co^{60} and Cs^{137} gamma rays at angles of incidence of 0° , 50° , and 60° are in agreement with the data reported

by the National Bureau of Standards. The experiment has been redesigned to extend the measurements to larger angles of incidence by use of a Na^{24} source.

Details of many of the preceeding developments can be found in the classified progress reports and other classified publications of the Laboratory. Developments of the Nuclear Engineering Department in the fields of fission products, concentration, utilization and the ultimate disposal of waste products are described below.

Fission Products Utilization Project

The effect of intense fields of gamma radiation on the synthesis of high polymers has been under study. A summary of the data obtained on polymerization reactions is given in Table 1.

The bulk polymerization of styrene and methyl methacrylate has been shown to proceed by a free radical mechanism. The dependence of rate on intensity appears to be first order for styrene and half-order for methyl methacrylate. This effect is being investigated further. Both monomers show a constant rate of polymerization in the initial stages which is followed by a rapid increase similar to a "Trommsdorff effect." Molecular weight increase occurs with increase in ambient temperature. Suspension polymerization and emulsion polymerization of both monomers are now under study. An attempt will also be made to obtain data on the mechanical and physical properties of these radiation-produced polymers.

Table 1					
Polymerization Reactions Initiated by Gamma Irradiation					
Monomer	Gamma Field Intensity r/hr	Temp, °C	Pressure atmos	% Converted per Megaröntgen	Polymer Molecular Weight
Styrene	250,000	-18	1	0.36	20,000
	190,000	30	1	2.2	70,000
	250,000	72	1	10.4	300,000
Methyl methacrylate	250,000	-18	1	10	70,000
	250,000	30	1	32.4	160,000
	250,000	72	1	84	250,000
Perfluoro propylene	235,000	30	1	0.14	600
Perfluoro butadiene	235 000	30	1	0.24	325
Perfluoro acrylonitrile	250,000	30	1	0.10	---
Acrylamide	250,000	30	1	10-20	---

The irradiation of the perfluorinated monomers (supplied and analyzed by Dr. F.A. Bovey of the Minneapolis Mining and Manufacturing Co.) indicated in Table 1 gave polymers of low molecular weight in low yield. It is believed, however, that this is the first time these monomers have been homopolymerized.

The solid state polymerization of acrylamide has been observed and the rate determined by x-ray analysis and chemical separation of monomer and polymer. A joint effort with Dr. R.A. Mesrobian, Dr. H. Morawetz and Mr. P. Ander of the Polymer Institute of Brooklyn Polytechnic Institute will be continued to explore this unique phenomenon. An attempt will be made to determine the molecular weight of the polymer,

the effect of temperature and field intensity on polymerization rate, and the structure of the unit crystal.

The new Gamma Irradiation Laboratory at the Hot Laboratory has been completed. It contains facilities for irradiation work over a wide range of experimental conditions.

An effort has been made to determine reliable curie strengths of Co and Ta sources by pile activation methods, and by two independent dose-geometry calculations. This work is now being prepared for publication.

Table 2				
Use of Gamma Irradiation Facilities in Source Days				
1952	Fission Products Utilization Project	Other BNL Depts	Outside Organizations	Total
July	118	---	5	123
Aug.	45	2	43	90
Sept.	98	---	15	113
Oct.	96	---	3	99
Nov.	15	28	12	55
Dec.	71	36	1	108
1953				
Jan.	95	16	9	120
Feb.	125	35	6	166
Mar.	162	18	24	204
Apr.	97	93	34	224
May	162	84	18	264
June	120	56	5	181

With seven sources in service, wide use has been made of the gamma irradiation facilities (see Table 2).

Ultimate Waste Disposal

During the past year the process of adsorbing fission products on montmorillonite clay for permanent waste disposal has been developed to a point where a full-scale industrial operation seems feasible. Therefore it is now planned that an intermediate-scale pilot plant will be built and operated during the coming year. The designs for such a plant are virtually complete.

Of particular interest in the clay adsorption process is a method of bringing the radioactive ionic solutions into contact with the minute particles of clay and then effecting a clean separation of the two phases, all on a continuous-flow basis. This is accomplished by preparing stable aggregations of the clay particles in the form of small rods which remain intact in assembly as the solution moves freely through them. Multiple unit systems made up of clay-rod columns have been operated with synthetic waste solutions, and the results are very encouraging. The effectiveness of the clay as an ion exchanger is highly dependent on the total ionic strength of the waste solutions, and certain methods of reducing the non-radioactive constituents of the wastes were investigated. For a number of reasons the use of anion exchange resins as a means of neutralizing acidity without the addition of hydroxide is the most desirable. The effect of intense ionizing radiations on the resin is a problem which is currently under study.

Small-scale apparatus has been assembled for testing the clay process with the use of high level activity raw fission wastes. The purpose of such a test is at least twofold: (1) to determine the effect of intense internal radiation on the clay process itself, and (2) to determine the strength of a source of radiation made directly from raw fission wastes by adsorption on clay.

The investigations of the kinetics of ion exchange reactions with clay minerals at Yale University, an activity supported by BNL in connection with this project, have been further reported in the Journal of Chemical Physics by Dr. H.C. Thomas and associates.

Radioisotopes Development (I^{132} Generator)

During the year, this group confined its work to the Te^{132} - I^{132} system. From a technical standpoint, at the present time, both the Te^{132} separation process and the I^{132} milking and purging processes are in satisfactory state and these isotopes are ready to be tried in medical or other applications both on and off site.

The molten $LiCl$ - KCl - TeO_2 milking system described in the last annual report had to be abandoned since no material could be found which would resist the chemical attack of this mixture. The $TeBr_4$ - $NaBr$ and NH_4HSO_4 - TeO_2 alternative systems were tried out, and a $LiCl$ - KCl eutectic mixture containing carrier-free $Te^{*}O_2$; none was completely successful.

However, the present milking system is highly satisfactory, and, in addition to retaining all the advantages of the original system, it is even simpler to use. The process calls for shipping and storing the active tellurium as damp solid $Te^{*}O_2$ in a special glass "generator" inside a shipping shield. To milk off the I^{132} which has grown in, the user adds a measured amount of $NaOH$ solution, which dissolves both the TeO_2 and the I^{132} , and then adds a stoichiometric amount of acetic acid which reprecipitates the TeO_2 and leaves the I^{132} in solution. This solution is then withdrawn from the shipping shield by applying vacuum; it is filtered through two sintered glass discs contained in the generator.

A "purge" system compatible with the new milking system has been worked out. The system is built into the shipping unit to enable the user to withdraw from the unit only as much I^{132} as is needed and in higher purity than would otherwise be possible.

1) The user milks off all I^{132} present, passes it through the purge vessels, retaining the radioactive material inside the shipping unit and withdrawing only the decontaminated solution, which is then discarded. 2) Fresh I^{132} is then allowed to grow in for a predetermined short length of time. 3) This fresh I^{132} is then milked off and withdrawn from the unit. The present purge system comprises two small hold-up vessels to permit some radioactive decay and a third vessel containing a chemical bed for final cleanup of the purge solution.

The necessary "generator" and shipping shield with its special built-in valve which permit shipping, milking, and purging in a simple, safe, convenient manner have been built and tested satisfactorily. A schematic diagram of the generator is shown in Figure 1.

Figure 1. I^{132} generator schematic diagram.

Several hot runs have been made in which multicurie quantities of I^{132} have been prepared. For any one Te^{132} charge as many as 35 milkings have been made over periods as long as 52 days. Approximately 130 mc of I^{132} have been given to A. Edelman of the Brookhaven Biology Department for both long term and short term experiments in mice and rats.

In spite of the present adequacy of the Te^{132} separation and I^{132} milking processes, refinements are being made in order to improve the methods still further. Typical of these efforts is the empirical correlation of the activity of a sample with the radiation level measured by a portable (MX-2) ionization chamber under standard conditions of geometry; this correlation will permit assay of the sample by a simple rapid measurement of its radiation level and will obviate the necessity of taking an aliquot and performing a radiochemical analysis on it.

LIFE SCIENCES

BIOLOGY

The biology research program can be described under six headings: namely, mammalian physiology, plant physiology, general physiology, metabolism, biophysics and genetics. Because of the wide variety of interests of the staff, it is hoped that any university biologist who would find it advantageous to utilize the ideas and techniques of atomic energy in his research might come to the Laboratory and find a Brookhaven staff member well acquainted with his field of work and ready to cooperate with him.

Completion of the second phase of the Biology building program made a very significant difference in the functioning of the Department. The entire Department is now under one roof; this has resulted in much higher efficiency and smoother operation. A new greenhouse and potting shed have almost doubled the Department's greenhouse facilities.

The cobalt source in the gamma field has been increased from 260 curies to 2200 curies. In addition, the location of the source in the field has been changed and the field has been enlarged. This increase in size is an indication of the usefulness of the field in the Biology program. The other radiation facilities of the Department, i.e., the x-ray installation, the radiation greenhouse, the beta-ray sources and the thermal neutron facility, continue to be used extensively.

A new radiation facility has been added during the year in the form of a fast neutron source. This consists of a plate of U^{235} covered with bismuth and arranged with material that is to be irradiated in a box which can be lowered into the thermal column. The U^{235} absorbs thermal neutrons and the resultant fission produces fast neutrons which impinge on the material to be irradiated. Preliminary calculations indicated that the remaining slow neutrons and the gamma ray contaminations are probably insignificant biologically compared to the effect of the fast neutrons, and the preliminary measurements that have been made tend to confirm the calculations.

During the year a new program was initiated to test the feasibility of producing useful mutations in plants by means of ionizing radiations. The program was started at a conference at Brookhaven on December 19, 1952 called by the Biology Department to discuss this possibility and ways of carrying it out. All the major experiment stations in the east as well as the Department of Agriculture were represented at the conference. It was decided then that the experiment stations will take the responsibility for selecting the material to be treated, it will be treated at Brookhaven, and any mutations produced will be screened for usefulness at the originating experiment station. It was further decided that the idea could be tested more easily if the main emphasis of the program is on the production of somatic mutations in plants, shrubs and trees which are normally propagated asexually. For this reason it is known as the somatic mutation program. Most of the material in this program is being grown in the gamma field, where careful observations are made of abnormalities. However, a good deal of material, principally scions, has been sent to Brookhaven for irradiation in the thermal neutron facility and then returned for grafting. So far, 17 institutions are cooperating in this program, and such numbers of plants are being used that a positive answer to the usefulness of this tool in plant breeding should be available in a few years.

The research activities of the Department continue to center around the special facilities. In general this involves (1) the use of radiations of various kinds for studies of their effects on biological material and also as a tool for the study of life processes; and (2) the use of radioactive tracers in studies of life processes.

In the first category the gamma field is proving extremely valuable; a number of interesting phenomena are being observed. The continuous radiation upsets the normal growth of the plant and at the present time it appears that each plant responds in a different way. In some plants, certain dosage rates will induce much faster growth than usual, in others flowering will be induced much earlier, in others the leaves grow in peculiar ways, in others the pattern of shoot production is abnormal. The field is, of course, being used extensively for genetic studies in plants.

The thermal neutron facility is being used a great deal for mutation production in plants; it has been shown here that thermal neutrons are much more effective in producing mutations for a given amount of damage than other forms of radiation. It is also becoming clear from other studies that thermal neutrons produce radiation damage in biological material by quite a different mechanism than do x-rays, and are thus becoming a very important facility for radiobiological research. It is to be expected that fast neutrons will be another useful tool for this work.

The completion of the new animal quarters has resulted in a decided acceleration of the work in mammalian physiology. One phase of this work attempts to assay the effect of radiation on the mammal, and in this the endocrine system has been given special attention. The carcinogenic properties of radiations are also under study.

There is a wide variety of different uses to which radioactive and stable isotopes can be put in biology, and a number of them are in use at the Laboratory as will be discussed below.

Mammalian Physiology

The study of the part played by the endocrine glands in the response of animals to radiation is continuing. It is found that when the pituitary gland is removed before irradiation, rats do not show the changes in glycogen content of the liver and cholesterol content of the adrenal gland which are characteristic of the intact irradiated rat. It is thus clear that normally these effects of irradiation are primarily a pituitary response, and one is tempted to generalize by saying that in this respect radiation merely acts as a form of general stress. It is difficult to think of this effect as the result of the action of the radiation on the pituitary itself; rather it must be due to some indirect action.

It is interesting that a direct effect of radiation on the pituitary gland has been observed, but only at doses very much higher than those given for total body irradiation. Here the electron beam from the Van de Graaff generator was focused on the pituitary gland and delivered a dose of about 10,000 rep to this tissue alone. A great many of the effects typical of total body irradiation, such as a fall in white count, increased adrenal ascorbic acid, decreased testes weight, are also seen in these animals, which lends further support to the idea that many of the responses observed after total body irradiation are mediated, in part at least, through the pituitary.

It was reported last year that radiothyroidectomized mice will live normally but if they are also given a sub-lethal dose of x-radiation when quite young, they develop pituitary tumors at the age of about 15 months. A good deal of the effort of the group in mammalian physiology has gone into an elucidation of this interesting phenomenon, but since it takes 15 months to complete an experiment, there is nothing further to report at this time.

During the course of these studies the properties of a little-known drug, anethol, were investigated to determine its site of action. It was found that the drug will selectively block the action of the adrenal hormone on the liver. It has virtually no effect on the other function of the adrenal hormone, namely, the retention of sodium by the kidney. This drug should be very useful in analyzing the functions of the adrenal gland and its response to stress.

A study of capillary permeability has been under way which makes use of the blood-perfused hindlimb of the cat. With a precise control of the perfusion pressures in both arteries and veins, and an accurate and rapid recording of the weight of the leg, the permeability of the capillaries to various substances under various conditions may be determined. A study of a series of derivatives of 5-pyrazolone and urea has recently been completed. These substances are all lipid-soluble, and it was found first that they pass through the capillary wall with extreme rapidity when compared with molecules of comparable size which are not lipid-soluble. Further, the permeability was not influenced by molecular size or shape but was dependent entirely on lipid solubility. These findings have led to a dual theory of capillary permeability. First, the non-lipid-soluble substances seem to penetrate by filtering through pores in the membrane, and here size and shape of the molecule are very important. The pore area is only a small fraction of the total membrane area, and filtration is relatively slow. For lipid-soluble substances a very much larger area is available for passage through the membrane, which is apparently accomplished as a simple solubility in the lipid of the capillary membrane. An apparatus has now been built which will record the concentration of radioactive isotopes in both arterial and venous blood simultaneously, and this is being used in a further study of the factors affecting permeability to sodium, potassium, chloride, etc.

A new program has been started during the year on the general problem of the mechanism of the immune reaction. Diphtheria toxin has been successfully labeled with radioactive iodine and its course in the lymphatic system of the guinea pig will be followed and the relation between the antigen and antibody formation will be determined.

Plant Physiology

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

The work on the effect of radiation on the desoxypentose nucleic acid (DNA) of cells has been concentrated mainly on a study of the synthesis of DNA during the different stages of microsporogenesis in *Tradescantia*. The conclusions drawn from these results are that synthesis of DNA occurs prior to cell division at specific periods which are not necessarily identical morphologically but which are special to each of the four divisions involved in pollen maturation. Moreover, it appears that phosphorus incorporation in DNA occurs to a significant extent only during actual DNA syntheses. Hence, P^{32} uptake, while it may also represent some turnover, must represent incorporation of phosphorus in the new DNA molecule.

The concept of constant DNA content of chromosome sets within an individual or species has received considerable support. However, because of recent discrepancies in the literature, a set of experiments was designed to test the hypothesis by a different approach. Leaf cells from tomato plants known to be an autopolyploid series of n , $2n$, $3n$ and $4n$ plants were measured cytophotometrically for DNA content. A careful statistical analysis of the results was made and within experimental error the content followed the 1:2:3:4 ratio predicted on the basis of degree of ploidy.

It was reported last year that there is an apparent stimulation of plant growth for plants growing at certain dose rates in the gamma field. Evidence in support of this fact seems to be increasing: it was with considerable relief that the same phenomenon was observed during the early summer of 1953, i.e., increased stalk height and early flowering in snapdragons and tobacco plants. It was found in gladioli that the plants are very little affected even by growth at very high dose rates in the gamma field, but when the bulbs were dug up about 10 times as many bulbils were found to have been

formed on the irradiated plants as on control plants. Again, in the irradiation of stem sections of lombardy poplar, moderate doses gave a marked stimulation of bud production, whereas high doses produced inhibition.

One of the important observations of the year is the finding that under certain conditions root production can be stimulated. For example, *Kalanchoe* grown in the gamma field shows many roots growing from the stems far above the ground (see Figure 1). Further, plants given local irradiation of the stem will stimulate root production at a point just above the irradiated section (see Figure 2). This obviously has some very interesting practical applications. The mechanism of this stimulation is not known, but in all probability it is in reality a response to an injurious agent. In any event, it provides an excellent opportunity to study normal physiological mechanisms in plants as well as radiobiological action in higher plants.

The work on the morphological changes taking place in plants after irradiation is continuing, and more interesting abnormalities continue to be found. One of the more spectacular abnormalities is that of fasciation, shown in Figure 3. In this, stem growth seems to be stimulated but the adjacent stems fuse together forming a single, very thick, irregularly shaped stem.

Last year it was reported that thermal neutrons produced quite different qualitative effects in seeds from those produced by x-rays. This work has been confirmed and extended. The number of mutations produced in barley seed by doses of x-rays and thermal neutrons has been compared with the amount of damage indicated by growth inhibition and the amount of visible chromosomal damage. It was found that the mutation frequency was closely correlated with the chromosomal damage but not correlated with growth inhibition. This means that with thermal neutrons many more mutations will be produced for a given degree of injury than for x-rays, and thus thermal neutrons give great promise as a tool for genetic study; this is the reason that many of the treatments for the somatic mutation program were done with thermal neutrons.

It was also reported last year that seeds that have been irradiated with thermal neutrons give a great deal less variability in seedling height than seeds given corresponding treatment with x-rays (see Figure 4). It was found that seeds are as much as 20 times more sensitive to x-rays when they are wet than when they are dry, whereas it makes relatively little difference whether the seeds are wet or dry when they are exposed to thermal neutrons. A possible explanation of the phenomenon is that the water content of the seeds treated with x-rays is very critical compared with that of seeds injured by thermal neutrons. A series of experiments with barley seeds has been completed and seems to bear out this hypothesis. Whether this is the explanation of the phenomenon or not will have to await an analysis of the water content of individual seeds. However, this is a striking demonstration of the fact that the fundamental mode of action of x-rays and thermal neutrons is different.

Another reason for the difference in variability in seedling height resulting from x-rays and from thermal neutrons may lie in the difference in oxygen content of different seeds. Preliminary results indicate that this is also a possible explanation. They show that the O_2 content of the atmosphere with which the seeds are in equilibrium is very important for determining the radiosensitivity of the seed to x-rays whereas it is relatively unimportant for thermal neutrons. (See Figure 4.) This again emphasizes the basic difference between these two radiations.

The work on photosynthesis has continued to concentrate on an isolation and identification of photosynthetic intermediates and the enzymes responsible for their production. It was found that in sunflower leaves which had undergone photosynthesis in an atmosphere of $C^{14}O_2$, the distribution of the labeled carbon was always the same in alanine, glucose and fructose extracted from the leaves. However, when alanine and malic acid were compared it was found that the distribution of the labeled carbon was

Figure 1 (Left). Kalanchoe plant 123 days after removal from the gamma field. It was grown the entire summer in the gamma field at 1280 rep/day. Note the abnormal growth of roots from stems far above the ground. This is a post-irradiation response, and is not seen while the plant is under the influence of the radiation.

Figure 2. (Right). Xanthium plant 42 days after an acute dose of 1500 rep of x-rays to a short section of the stem just below the point at which roots are seen emerging from the stem. This same response has been observed in several plants.

unirradiated

Figure 3. Xanthium plants growing in the gamma field. The control plant is on left and the irradiated plant at 250 rep/day is on right. Note fasciation in the irradiated plant. Stem formation seems to be stimulated, but the stems fuse to form a thickened irregular stem. This same phenomenon is observed in many plants in the gamma field.

irradiated

Figure 4. Photographs of barley seedlings after irradiation. The seedlings in the upper photograph were treated with x-rays (30,000 r) and those in the lower with thermal neutrons ($1.3 \times 10^{13} n_{th}/cm^2$). In each case they represent, left to right, controls and seed equilibrated before irradiation with air, O₂, CO₂, N₂. It can be seen that oxygen but none of the other gases had a profound effect on seeds exposed to x-rays; there was no effect on seeds exposed to thermal neutrons. Seeds treated with x-rays were damaged non-uniformly, whereas the neutron treatments produced very uniform damage.

different in these two molecules when the photosynthesis had been carried out in strong and in weak light. These results can be interpreted to mean that strong light blocks the conversion of pyruvic acid to malic acid via the tricarboxylic acid cycle.

It has previously been shown in spinach that hexosemonophosphate is formed from ribose-5-phosphate via sedoheptulose-7-phosphate. By starting with ribose-5-phosphate labeled in specific carbon atoms, and analyzing the intermediates in the reaction, it has been found that a 2-5 condensation of the sedoheptulose from pentose takes place. The hexosemonophosphate comes partly from sedoheptulose-7-phosphate and triosephosphate by a transaldolase reaction. The way in which the rest of the reaction takes place is under active investigation.

General Physiology

Studies in this field continue principally on the use of radioactive tracers for the investigation of mineral metabolism in insects. A good deal of effort has gone into the perfection of methods for such work. Perhaps chief among these is a study of autoradiographic methods which has resulted in resolution by this method of the order of one micron. Neutron activation analysis as a tool is also being studied.

In an investigation of the tolerance of Drosophila to salts of some alkali metals, lithium was found to be by far the most toxic metal, while potassium was slightly more toxic than sodium. Drosophila fed on high lithium diets take two to three times longer to develop than normal, and when they are mated, the subsequent generations are almost wholly males. There are many growth abnormalities noted.

Phosphorus turnover has been studied in Drosophila by having larvae live on a P³²-containing diet until they are mature, then taking them off this diet and following

the P^{32} loss. It is found that the excretion curve has two parts, indicating two distinct phosphorus pools. The fast phase has a half-time of about 2 days and the slow phase about 10 days. The phosphorus turnover in females is faster than in males.

Metabolism

The work on the mechanism of degradation of carbohydrates by molds and yeast has continued. Molds, but not yeast, are capable of fermenting pentose, and rapidly growing cultures form one mol of ethanol and 2 mols of CO_2 per molecule of pentose fermented. However, resting cultures yield one mol each of ethanol, CO_2 and acetic acid per mol of pentose fermented. This fact indicates a different route of degradation depending on the growth condition of the organism. A number of different microorganisms have been studied and the general features of the metabolic pathways of each have been determined.

It has been found that many microorganisms degrade sugars by the same mechanism as do plants and animals, but many use another pathway. By changing conditions it is often possible to force degradation by a different pathway. At the present time it is not possible to generalize on these pathways, but the indications are that a very few, perhaps only two, possible pathways exist for the degradation of sugars by plants, animals or microorganisms.

The problem of enzyme kinetics is being attacked from two points of view in a very active program. First, a study is in progress to determine the chemical structures of molecules which will inhibit enzymes, and second, there is a study of the way in which labeled oxygen is transferred in hydrolytic enzyme systems.

In the first case it has been found that in one enzyme, d-amino acid oxidase, the substances which are most effective in causing inhibition have structures quite similar to those of the amino acid, and that the inhibitor would thus fit the enzyme in the same way as does the amino acid. This idea is being pursued with other enzyme systems.

For the second attack, a number of different enzymes have been investigated by determining the cleavage point in the substrate molecule for each. As a result of these experiments it is now possible to write the detailed chemical reaction for these enzyme systems. It includes the hydrolysis of adenosine triphosphate, sucrose and phosphoric acid esters. On the basis of the data so far, it is not possible to formulate a general theory of enzyme action, but more of the same kind of data should lead to one.

The work on the utilization of ingested labeled sugars in mice has continued with an identification of the amino acids labeled from these sugars. It was found that all the non-essential amino acids were labeled in varying amounts, but the label did not appear in any of the essential amino acids. This result is just what would be expected, but is the first direct proof of the fact that none of the essential amino acids are synthesized in the body.

Biophysics

The calibration of the thermal neutron facility is nearing completion, and it appears that the original estimates were very nearly correct, i.e., the neutron flux equals about 6×10^9 n/cm²/sec and the gamma-ray contamination is about 50 rep/hr. This is a very low contamination and means that the biological effects observed should be almost entirely due to the thermal neutrons. It was gratifying to find qualitative differences between gamma-ray and thermal neutron effects, as outlined in different sections of this report, which bear out the physical measurements on biological material.

The U^{235} plate in the thermal column, for converting thermal neutrons to fast neutrons, has not yet been accurately calibrated. However, preliminary results indicate

that the dosage rate is of the order of 40 rep/min of fast neutrons with rather small gamma-ray contamination. This calibration should be greatly improved in the next few months.

During the year a program designed to determine molecular size from particle bombardment was started. Preliminary measurements have been made of the pneumococcus transforming principle. Molecular weight of about 10,000,000 was indicated; the inactivation of an active nucleoprotein fraction was used as a criterion. Further work is continuing, not only with this molecule but with a number of others.

An attempt has recently been started to find the mechanism by which duplication of nuclear material takes place in the dividing cell. Bacteria are labeled with phosphorus and the cell divisions followed by means of autoradiographs. It is hoped that by refining the technique it will be possible to follow the nucleoproteins through nuclear divisions.

Genetics

The corn genetics program has continued with a check on the results of mutations produced in the gamma field. The results of the 1950 experiments indicated that there was a non-linear relation between mutation rate and dose rate, but the source was so small at that time that there was quite a large experimental error in the high dose points. The source strength in 1952 was much larger, and the earlier results were confirmed and extended. This gives positive evidence that in order to produce a mutation in corn there must be two or more almost simultaneous "hits" on a single locus.

In conjunction with this work there has been an extensive program to determine the spontaneous mutation rate for a number of genes. It was found, as expected, that the spontaneous rate is different for different genes, but it was also evident that these rates are 10 to 100 times the accepted value for corn. Much lower spontaneous mutation rates are observed in the megaspore than in the microspore. This is explained by the fact that only that portion of the mutations are detected that occur before the first nuclear division in the megaspore, because of the triple fusion endosperm nucleus formed on fertilization.

Corn irradiated only in the morning will undergo mutations at about twice the rate of corn irradiated to the same extent in the afternoon. This fact is undoubtedly correlated with the higher mitotic rate occurring in most plants in the morning as opposed to that occurring in the afternoon.

A comparison has been completed of the effectiveness of thermal neutrons and x-rays in producing chromosome aberrations and mutations in *Drosophila*. Four criteria were used, i.e., sex-linked recessive lethal mutations; reciprocal translocation; dominant lethal mutations; and viable sex chromosome losses. In these cases, 1 rep of x-rays is equivalent to, respectively, 1.2, 1.0, 0.7, and 0.4×10^{10} of neutrons per cm^2 . Thus these two radiations must produce their effects by quite different mechanisms. Calculations show that for the viable sex chromosome losses, 7.1 times as much energy is dissipated in the tissue for x-rays as for thermal neutrons to produce comparable damage.

Somatic mutations were observed in snapdragon flowers when the plants were exposed to chronic irradiation in the gamma field. The mutation shows up as a white spot in an otherwise solid color. Most of the spots were very small, which indicates that the mutations usually take place late in flower development; only very rarely will the mutation take place early enough to produce even a large colorless sector in the flower. It is most interesting that significant increases in mutation rate over the controls are observed at 0.5 rep/day. This dose rate is surprisingly close to the accepted tolerance dose rate for humans.

During the year a new program on chemical mutagens in plants has been inaugurated. It has been found by preliminary studies that the spontaneous mutation rate of a plant is very dependent on the chemical composition of the soil, and that an excess of some elements causes increased mutation rates while a soil deficiency in other elements has the same effect.

A careful comparison has been made of x-rays and thermal neutrons producing growth inhibition, chromosome damage and mutations in barley seeds. It was found that x-rays produce much more severe growth inhibition for a comparable degree of chromosome damage than do thermal neutrons. Further, there is a straight line relationship between chromosome aberrations and mutations however the aberrations are produced. This indicates that x-ray damage is primarily to the cytoplasm and that this cytoplasmic damage is somehow passed on from cell to cell to produce growth inhibition. In other words, for somatic divisions, cell division takes place reasonably normally in spite of severe chromosomal damage. However, if the chromosomal damage is too great, the cell cannot undergo maturation divisions and so the plant is sterile.

MEDICINE

As the Medical Department concludes its fourth year of operation, it is becoming more and more evident that the special facilities of Brookhaven play an ever-increasing role in the medical research.

The scientific program of the Department can be very generally described under six comprehensive titles which give a better idea of the extensive interrelationships between work in the various divisions than can be obtained by more detailed listings. The achievements of the past year will be discussed under these headings rather than by division. Space does not permit a complete review of all the work, but those areas of greatest development will be covered.

The utilization of thermal neutrons from the reactor to determine their biological effects, their application to medical therapy, and their effects on biological, biochemical, cytological, and physiological systems

The most spectacular work being carried on in this program is the utilization of thermal neutron capture by boron-10 and the resulting alpha-particle radiation in the treatment of glioblastoma multiforme in patients. During the past year, two additional patients were admitted for therapy, and a total of seven treatments were carried out at the reactor. This brought the total number of patients up to 10 and the number of reactor treatments to 21. At this juncture further admissions and treatments were temporarily discontinued while a complete assessment of results to date was made. The results were reported before the American Radium Society in St. Louis, Missouri, on April 21, 1953, and are being published in the American Journal of Roentgenology, Radium Therapy and Nuclear Medicine. The conclusions regarding the clinical observations made can best be summarized by quoting the summary of this paper:

- 1) The feasibility has been shown of the use of a nuclear reactor to provide a neutron source for B^{10} capture therapy of glioblastoma multiforme.
- 2) A series of 10 patients were treated, of whom five received a single radiation; one patient received two radiations; two patients each received three radiations; and two patients each received four radiations. Multiple radiations were, in general, given at five to six week intervals.

3) Temporary amelioration of clinical symptomatology suggestive of retardation of tumor growth was seen to occur following eight of 21 capture therapy efforts, questionable improvement in six of the remaining 13 efforts, and no detectable change following seven of the treatments. Only one of five patients receiving multiple treatments registered no improvement at any time.

4) Periods of observation of up to six months, during which patients received up to four capture therapy procedures, have revealed no serious complications of this therapy.

5) Further extensive exploration of neutron capture therapy is warranted.

The histological material has been prepared and is at present undergoing study and evaluation prior to being reported in another publication. No patient has been cured of his disease nor has prolonged control of tumor growth been established, but encouraging results scientifically have been obtained as well as invaluable experience.

As a result of the analysis made to date, it was seen to be highly desirable to modify the facility on top of the reactor to permit more efficient handling of patients and animals. There has been designed and placed under construction a large armor steel shutter which will permit precise timing of exposure to the thermal neutrons, a better estimation of total neutron dosage delivered, and increased safety for the participants; use of the shutter will eliminate the necessity for shutting the reactor off and bringing it rapidly to full power within the time limits prescribed by the physiological behavior of the capture element. During the six months required for this alteration no work can be done, but it is believed that by September 1953 the facility will be completed and ready for instrumentation studies prior to resumption of patient treatments.

In the course of the projects carried out this year, data were also obtained on the effects of neutron radiation on the blood-ventricular fluid barrier of patients under the conditions of therapeutic runs. If the radiation resulted in a destruction or alteration of the blood-brain barrier, radically different procedures would be indicated in subsequent treatments. Fortunately, it appears that within the range of exposures thus far studied no significant alteration in the barrier results. These data are being prepared for publication.

The critical factors in this therapeutic approach are the available neutron flux, the concentration of capture element in the tumor and surrounding normal tissues, and the permissible time over which neutron exposure will be effective. Extensive studies have been made of the neutron attenuation in tissue equivalent plastic phantoms and in tissue equivalent liquid phantoms. Results obtained by this study have been compared with data gathered by insertion of gold wires in patients' tumors during runs and determination of the activation of the gold. Agreement with phantom measurement was satisfactory, and it is now possible to estimate depth dose values for any given incident neutron flux on the skin of patients. This work is also being prepared for publication.

One of the thorniest problems has been the accurate determination of the boron content of tissue. The range of the method must be large and its accuracy great at the lowest concentration; extreme economy of samples must obtain. During the year, a great deal of effort has been spent on the development of a suitable chemical method, since available procedures which were investigated have been found wanting. It now seems that with certain modifications yet to be evaluated such a method can be foreseen. Until this type of analysis can be made, it is not profitable to explore control of experimental glioblastoma in mice since the time relationships will be much different from those in humans. Success in this problem of methodology will permit rapid development of a large number of biological problems which cannot be carried out satisfactorily without this information.

Attention has also been directed toward the use of lithium-6 as a capture element and to uranium-235. Dr. William H. Sweet and his colleagues at the Massachusetts General Hospital are collaborating on the early lithium studies.

Since all the capture elements most suitable for this type of approach are toxic, it was necessary to begin more extensive studies on the toxicology of boron and its

compounds and the other capture elements. This work will greatly increase in the coming year when it is hoped rather good parameters can be established.

Preliminary investigation of the distribution of uranium azo dyes in the central nervous system has been done and the use of dyes as carriers of boron is being evaluated. If a suitable carrier could be found, the time of exposure relative to injection might be changed considerably, which would eliminate the extreme dependence on exact timing coordination now required. Until such a substance has been found, and none has yet come into view, studies are being made of the distribution of boron in body tissues and tumors as well as in the central nervous system, by means of the present borax compound.

To equate further the results obtained by capture therapy, studies have been undertaken of the effects of cobalt-60 gamma radiation on transplanted brain tumors in mice.

As part of the general study of protein synthesis, the effects of neutron radiation on protein metabolism in rats is under preliminary investigation. The development of the new facility at the reactor will permit a more aggressive study in this respect than was possible in the past.

The distribution of body water and its solutes in body compartments and factors affecting the movement of these constituents

The use of radioactive isotopes, and particularly the use of stable elements which may capture thermal neutrons, rests upon available knowledge of the distribution of those compounds within the body and the rates at which they move through the various body compartments. In capture therapy, it is necessary to develop precise knowledge regarding both the fast and slow components in such movements and the barriers, if any, which may exist. Much information can be gained by a better knowledge of hemodynamics and of the factors concerned in edema formation. One of the better ways to obtain the desired knowledge is by use of the radioactive tracer substances.

In patients with edema and fluid accumulation in the various body cavities, it is possible to obtain samples of this fluid to compare with concentrations in the blood and from such data, together with knowledge of the total body content of the element in question and its distribution, to deduce transcapillary exchange rates. Patients with the nephrotic syndrome have yielded much information in this type of study. It was found that inulin is very slowly distributed through the fluids accumulating in body cavities and that measurements of extracellular fluid by inulin are invalid under these conditions. Sucrose, on the other hand, appears to distribute uniformly through extracellular fluid, even when this compartment of the body is distorted by edema. Technically, sucrose studies are relatively prolonged and difficult, so various elements which are radioactive have been investigated in a search for a substance which would yield information regarding changes in the size of the extracellular compartment, if not of its absolute size.

The distribution of sodium-24, chlorine-36 and chlorine-38, bromine-82 and stable bromide, and to a degree the kinetics of distribution of these elements, have been studied. It has been found that when the data are calculated in terms of the space occupied, (if uniform distribution throughout extracellular fluid is assumed), reproducible results can be obtained with each of these elements and that, with the exception of sodium-24, an equilibrium state appears to be reached much more rapidly than it is for sucrose. Further, the technical procedures for analysis of body fluids for content of the radioactive tracer are simpler than those for sucrose or inulin. The spaces measured by chloride and bromide are nearly identical and remain constant, in the normal, over a period extending from 3 to 24 hours after administration; that measured by sodium is of the order of 10 percent larger at the end of 24 hours.

Figure 1. The injection of iodine-131 into chicks, a step in the bioassay of thyroid stimulating hormone.

The rates of movement of these elements provide parameters within which to explore fluids for capture elements such as boron or lithium and may give knowledge regarding the concentration gradients to be found in any given tissue fluid at any given time after administration. These studies are also yielding information on when and under what conditions distribution of the tracer element may differ from that obtaining in any set of standard conditions. Experimental animal studies on the effect of variations of sodium intake and of desoxycorticosterone administration in the relationship of the chloride space to the sodium space have also been carried out, and the results are being prepared for publication.

Such experimental observations taken in conjunction with space studies in the nephrotic patients and studies on patients with various stages of thyroid disease, both malignant and otherwise, are yielding extremely useful information which permits certain limited descriptions of the nature of the body water in various tissues. The development of a satisfactory method of tritium analysis on small samples of body fluids now permits study of total body water by methods believed to be more physiologically reliable than the use of antipyrine. Elements such as chlorine and potassium, which move very rapidly across cell membranes, are also being studied for better knowledge of the cell water relations to the extracellular fluid compartment. One such study deals with the movement of sodium and potassium across the cell membrane in sickle cell anemia, and several reports dealing with this work are now in preparation. From these projects will inevitably come knowledge regarding the behavior of one body compartment compared with another and the influence upon such relationships of specific disease states.

The effects of isotopic radiation on physiology and histology of body systems, and the exploration of the use of short-lived radioactive isotopes for medical purposes

It is clear that, in many instances, studies to be discussed under this heading merge and are either dependent upon or actually a part of those described in the previous section. The administration of radioactive isotopes for diagnostic and therapeutic purposes is dependent not only upon a full knowledge of the pathways these substances may take in the human body but also upon a precise knowledge of their metabolic, physiological, and cytological effects on the tissues which may be exposed to radiation. The avoidance of undesirable effects and the enhancement of desired effects are to be sought. Experience must range from partly well-established bases, such as the use of iodine-131 in the treatment of thyroid disease and malignancy, to exploration in the use of radioactive gaseous isotopes exhibiting certain specific types of physiological and radiological behavior. Typical instances of these types of studies are briefly given below.

Figure 2. Sickled red blood cells from a patient with sickle cell anemia.

In a metastatic ovarian carcinoma, fluid accumulations within the abdominal cavity and often within the pleural cavities may frequently completely disable a patient. It was previously observed that administration of radioactive gold may be followed by alleviation of this crippling condition. The use of chlorine-38, with a 38.5 min half-life, in the control of such fluid accumulations has been explored. Administration of a soluble chloride salt permits, in theory, uniform bathing of the cavity surfaces studded with metastatic growths. The very short half-life militates against extensive distribution of the radioactive element throughout the body and in particular to the hematopoietic system.

Ten patients have been treated with this chlorine isotope or with krypton-87, an isotope which is a pure beta emitter and has a 78 min half-life. The chlorine isotope appears to be effective in significantly retarding fluid accumulation if the fluid is not loculated within the body cavity and if no large masses are present. The latter condition may be presumed mechanically to alter circulation dynamics in such a way that local fluid accu-

mulations are produced in certain instances. The krypton studies are at this time inconclusive, since adequate doses could not be given with the isotope available. Studies of the use of radioactive gases in the control of some lesions of the central nervous system, started about two years ago, are being renewed since in the meanwhile much more satisfactory methods for producing, transporting, and administering the gaseous isotopes have been developed.

Studies have progressed of histological changes in cells directly or remotely exposed to radiation as a result of therapeutic or experimental administration of radioactive isotopes. Studies of sections of small metastases of ovarian carcinoma studding the peritoneal lining have shown that unexpected radiation effects were present. The therapy was initially carried out as palliative only and to control fluid accumulation, since it was not believed that significant tumor radiation would occur without concomitant undesirable changes in the normal structure. The dosimetry of intraperitoneal isotope administration is exceedingly complex since the geometry cannot be established. Histological studies are the best available check on the accuracy of the assumptions made in calculation of the delivered dose. Although in those patients no changes were observed in the peripheral blood, changes in the bone marrow have been observed, and an attempt is being made to relate these to the presumed dose given. The effectiveness of iodine-131 in the control of thyroid cancer is being determined, insofar as feasible, by biopsy control. Specimens are taken at intervals in relation to treatment in an endeavor to establish bases for prediction of results under described physiological conditions.

Extensive studies are under way on the effects of small doses of iodine-131 on the thyroid and pituitary of rats over their normal life span. Animals are given doses

Figure 3. A freezing microtome used in the rapid diagnosis of various diseases, particularly neoplasms.

corresponding to those administered to patients and also receive thyroid hormone, thiouracil, and other drugs used in the treatment of patients. The data collected are correlated with those taken from patients treated over long intervals. The relationship between the pituitary and the thyroid, and the effects thereon of iodine-131 administration, are being studied. Several reports on these results are being prepared.

Studies have previously been reported by the Department on the estimation of the total radiation dose delivered to the blood after iodine-131 administration in the treatment of thyroid cancer. It was pointed out that under certain assumptions, and with knowledge of the behavior of a tracer dose of iodine-131, a reasonably satisfactory prediction of radiation dose to the blood could be made.

In this report a degree of correlation was shown between the calculated radiation dose to the blood and the change in the numbers of circulating leucocytes. Further work is being done to relate the calculated dose to changes observed in bone marrow. The assumptions involved in the soft tissue method are not strictly valid for bone marrow. In the latter tissue a correction for the energy absorbed in the bony matrix must be taken into consideration.

Considerable work has been done on the effects of isotopic radiation on the immune mechanisms with respect to viral, bacterial, toxic and parasitic agents.

For the study of immune mechanisms, exposure of animals to radiation permits many experimental procedures which otherwise could be done only with the greatest difficulty. Animals can be given a radiation dose which will completely suppress the antibody response to bacteria. It has been found that the immunity to parasites such as *Trichinella spiralis* is also suppressed by radiation. One of the most significant observations was that, in mice, cobalt-60 gamma radiation effectively destroyed immunity to pneumococcus infection even when abundant specific antibody was present. Although effects upon the body mechanism for developing protective antibodies have been known, it is apparent that radiation effects must be more far-reaching in the alteration of immune mechanisms when adequate amounts of administered antisera fail to protect radiated animals. On the other hand, the presence of antitoxin in the blood at the time of radiation was able to prevent death from administered toxin subsequent to radiation. The mechanisms of bacterial and antitoxic immunity thus differ significantly in this respect. Immunity to virus infections which existed at the time of radiation was also not altered. Transplants of lymph node and spleen tissue from immunized donor mice were found to produce significant amounts of tetanus antitoxin. The recipient mice were exposed to gamma radiation prior to transplant to suppress their antibody production, and the tests were carried out within a six-day period. This time is not sufficient for recovery of the normal immune response of the host mice. Certain differences were observed in the behavior of spleen and lymph node, and these are being investigated further.

In a study of tumor and tissue transplants into the anterior chamber of the eye of the recipient animal, it was found that sublethal radiation of the host results in a higher

percentage of successful transplants. These small transplants of lymph node did not alter the mortality from an LD₆₀ exposure to gamma radiation, whereas spleen transplants did. The reduction in successful transplants caused by previous immunization of the host with the tissue in question could be largely suppressed by radiation, which indicates that in at least one respect this mechanism was similar to that studied in bacterial immunity. When tissue from immunized mice was transplanted, its capacity to react to antigenic stimuli could be suppressed by radiation. Papers have been submitted for publication which give the results of these experiments in detail.

Some similarities of effect on immune mechanisms of ACTH and cortisone on the one hand and radiation on the other, as well as clinical reports suggesting a favorable response to ACTH and cortisone in human trichinosis, have led to an exploration of the effects of these compounds on the development of immunity to *Trichinella*. Studies of the effects of cortisone and ACTH on the susceptibility of mice to trichinosis suggest that ACTH caused a slight increase in susceptibility to trichinella infection, whereas

Figure 4. *Trichinella spiralis* larvae isolated from muscle cysts by papain digestion. This is the infectious stage for man.

cortisone produced a significant increase in susceptibility. Work on various aspects of immunity is being carried forward at an active pace stimulated by these most significant and interesting results.

The mechanisms of protein synthesis and degradation in the intact animal body as elucidated by radioactive labeled proteins, precursors, and products

The precise mechanisms by which amino acids are used in the synthesis of protein are not known, and it is of particular interest to try to explain why no recognizable

intermediates have been found between amino acids and protein; to search for those intermediates and to isolate them if they be demonstrable; to study the metabolism of amino acids with specific reference to their oxidation, storage, and incorporation into protein; to study the effects of hormones and other homeostatic mechanisms on amino acid metabolism; and to study the relationship of intra- and extracellular free amino acids as well as other factors related to the incorporation of labeled amino acid into tissue protein. This knowledge will help to explain certain disease phenomena and aid in exploration of the effects of radiation on the biochemical systems related to protein synthesis, degradation, and distribution in the body.

To carry out comprehensive studies in this area, it is necessary to have suitable methods for isolation or specific and quantitative identification of the substances under investigation. Suitably labeled preparations for study are also necessary. In the field of biological syntheses of protein, suitable methods of qualitative estimation and also properly labeled compounds are often lacking. During the last two years, it was necessary to investigate the preparation of C^{14} -labeled amino acids in order to have available compounds for study. Although the chemical reactions required to alter the optically active desired unlabeled amino acid to an optically active labeled form often appear quite feasible, in practice it is very difficult to obtain adequate yields of the reaction. Consequently, it is more economical to acquire the desired specific compounds from specific suppliers than to synthesize any large variety in a single laboratory primarily devoted to other activities. Fortunately, during the past year several adequately labeled amino acids of the natural occurring variety have become available. With these, it is possible to proceed directly to the problems of metabolism of this compound in the animal. At this point the requirement of adequate methodology for the compounds in question becomes paramount. The quantitative separation of proteins, peptides, or amino acids is a procedure requiring great skill in the laboratory, even with well-developed methods. In many instances these methods are lacking and considerable development work is a necessary precursor to the planned study.

The metabolic relation between hydroxylysine and lysine is not known. Possibly hydroxylysine is a derivative of lysine, and possibly it has an independent origin. These amino acids are found in collagen, and in turn this compound can be readily extracted from skin. By means of a Dowex-50 ion exchange column, the basic amino acids of rat skin collagen were isolated and several were identified to establish the validity of the method. In vivo tagging is being used and the rat is fed carbon-14 labeled β -lysine during the period of active growth. The animal is then sacrificed and collagen is isolated from the skin. Calculations indicate that the amount of carbon-14 incorporated into the collagen of the growing rat should be ample to determine whether or not hydroxylysine is formed from lysine. Studies with other amino acids are also being carried out. The availability of collagen would appear to make it a very satisfactory tissue to study. By use of single labeled amino acids and serial study of various organ tissues, considerable light should be thrown on the mechanisms of protein synthesis. Several preliminary attempts have been made to assess the role of peptides in protein synthesis. The major difficulty has been the isolation of a tissue peptide fraction for study. Various procedures are being investigated, such as a reduction in peptide-protein interaction by blocking all the amino groups in crude tissue extracts with reagents such as dinitrofluorobenzene prior to extracting the tissue with organic solvents in which substituted peptides are soluble.

Tryptophane is considered an essential amino acid for mammals, i.e., the mammalian organism is incapable of synthesizing it from simple substances. However, reports have been published which could be interpreted as suggestive of the use of anthranilic acid as a precursor for tryptophane synthesis in mammals. A carbon-14 labeled anthranilic acid was obtained from the Chemistry Department and is being fed to rabbits. The rabbit excretes kynurenine and kynurenic acid as an end product of

Figure 5. A rat metabolizing carbon-14 labeled fat. The $C^{14}O_2$ produced is collected in the absorption tower.

tryptophane metabolism, and this can readily be isolated in the urine. If labeled kynurenic compounds appear after administration of anthranilic acid labeled with carbon-14, the problem of tryptophane synthesis through this compound will warrant further study, for it will suggest the possibility of tryptophane synthesis by mammals when specific precursors are furnished.

Studies of plasma amino acid in patients, particularly those patients with the nephrotic syndrome, are also in progress. In the young child with the nephrotic syndrome, there is a persistent lowering of the concentration of plasma amino acids. In these patients there also exists a decrease in the plasma albumin protein and presumably considerably wasting of all tissues. Whether failure to synthesize protein to normal concentrations is a result of a deficit of one or more amino acids, or whether

it is a result of faulty mechanisms of protein synthesis, is not known. Procedures are now almost satisfactory for a complete plasma analysis for constituent amino acids, which should throw considerable light on this question.

In any consideration of protein in mammals, the significant role of lipo-proteins cannot be neglected. The metabolic relationship between fat and protein is also close, as is evidenced by the fact that man cannot tolerate a lipid-extracted diet in which the residual protein and carbohydrate are adequate. Diets of this sort induce gastroenteritis within a period of one or two days. If, however, the protein is fed as amino acid, it is well tolerated. Diets of natural foods containing fat can also be taken with a very large protein intake without difficulty. The role of essential fatty acids in metabolism is not well defined. The pathways whereby fat moves from the digestive tract to its incorporation into body tissues are not fully mapped. Work has begun on some aspects of lipid metabolism with carbon-14 labeled glycerol used as a triolein glyceride. The oxidation of the glyceride to carbon dioxide and the incorporation of the glyceride into liver and intestinal lipids are being followed.

Studies are also under way of the metabolism of lipids in rats on diets lacking essential fatty acids. Rats on a fat-free diet will develop a deficiency disease manifested by skin lesions, increased water consumption, scaly tails, kidney necrosis, and retarded growth. These signs disappear when the animals are given linoleic, linolenic, and arachidonic acids. Recently there has also been adduced evidence that these essential fatty acids may give some protection against radiation damage. The effects of such deficiencies on lipid metabolism and relief by administration of essential fatty acids are being studied with observations on glyceride metabolism.

Methodology

In the course of work it has become necessary to evaluate, develop or modify some general methods used in clinical chemistry which have wide application. These methods have not yet been published but are now undergoing laboratory trial.

In the determination of lipids in blood and tissues, it is desirable to obtain quantitative yields of lipids with zero combination with water-soluble extractives. The use of compounds labeled with radioactive elements permits an exact quantitative measure of the completeness of the lipid extraction. The carry-over of water-soluble extractives can be assessed satisfactorily by determination of nitrogen in the two components. Phosphatides have caused the most difficulty in the lipid fraction, and the completeness of their removal can readily be followed with label preparations. Work is in progress to determine the best combination of techniques to yield the desired efficiency of separation.

The determination of protein-bound iodine in the blood as a measure of thyroid function is a complex and difficult procedure. By addition of radioactive iodine to the sample, it is possible to measure the percent recovery of protein-bound iodine in the sample analyzed; this permits a correction for incomplete recovery and also a check on the technical procedures followed in each assay. This method has been developed and is at present undergoing laboratory trial prior to publication.

The determination of calcium in the blood and body fluids is also a prolonged procedure subject to technical error. The present methods require about 24 hours for completion. A preliminary paper has been read on a new photometric determination of calcium which gives promise of a more rapid, accurate, and simple procedure than has been available. The method is based upon the fact that the azo dye 1,8 dihydroxy-2-naphthalene-3,6 disulfonic acid changes color in alkaline solution upon addition of certain cations. Under proper conditions calcium ions react by chelation to shift the absorption spectrum of the dye in a characteristic manner, and the change in optical

density at the proper wavelength is proportional to the calcium concentration. Preliminary results indicate that the total serum calcium may be determined directly in diluted clear human sera and in trichloroacetic acid filtrates prepared from lipemic human sera. The results can be obtained within a few minutes of the time the blood is drawn.

The use of radioactive isotopes to evaluate disease states and therapy

It is possible that one of the greatest uses of radioactive isotopes in medicine will be in the evaluation of a patient's condition and the effectiveness of the therapy. Careful study of the disease mechanisms will be required, as well as development of isotopic compounds capable of yielding the desired information. Short-lived isotopes should be particularly useful in these adaptations.

As one example of the type of information developed, the work done on sodium space in relation to sucrose space in nephrotic patients may be cited. Although under usual circumstances the sodium space is significantly larger than the sucrose space, it has been observed that in some nephrotic patients on a diet rigidly restricted in sodium, the sodium space reduced over a period of time to a value approximately equal to that of the sucrose space. At this juncture the patient developed severe acidosis, renal failure, cerebral dysfunction, and was critically ill. Administration of large amounts of sodium resulted in alleviation of the clinical syndrome. Subsequently sodium space measurements at intervals have permitted the administration of required sodium before clinical signs were manifest, which thereby carried the patient safely through dangerous periods of his disease.

The cause of hypertension is unknown, and the therapy for this prevalent condition is at present inadequate. It has been found that many but not all patients with this disease will respond to a decreased sodium intake by a lowering of blood pressure. Studies are under way which use radioactive isotopes to follow the changes of body sodium and potassium in such a regime, and the data are being correlated with the clinical response to the diet. These studies may yield information which will permit a more rational basis for the therapy, or data which will show which patients may be expected to respond to this therapeutic approach. The adrenal glands are also under observation, as they are intimately connected with many phases of salt and water metabolism. A variety of quaternary ammonium compounds is known to have blood pressure lowering effects, usually of transient character. These are all ganglionic blocking agents. It was shown by Lorente de No and others that the quaternary ammonium ions can substitute for the sodium ion in transmitting nerve impulses. Since restriction of sodium is known to have a marked potentiating effect on the lowering of blood pressure by these agents, quantitative studies of the drug effects in various stages of sodium depletion are being carried out.

Iodine-131 is, of course, being used for patients with thyroid cancer to evaluate the effectiveness of the large radiation doses in the control of tumor spread and growth. It is also used to evaluate thyroid function in patients with Graves disease.

Collaborative studies

During the past year two collaborative studies have been carried out at Brookhaven. Dr. H.C. Dudley of St. Albans Naval Hospital, St. Albans, N.Y., has been working on the

usefulness of germanium oxide needles in the administration of radioactive isotopes in local areas. The isotope can be incorporated in the needles in any desired amount and will remain there for its life or the life of the needle. The life of the needle is limited, as the germanium oxide is dissolved in body fluids and the germanium apparently quantitatively excreted. Further development work is planned.

For the second year a research team from the State University of Iowa College of Medicine has come to Brookhaven to collaborate with staff members of the Department in studies of the distribution of xenon and the kinetics of the distribution. Xenon is an inert gas with surgical anesthetic properties. Since a radioactive isotope can be followed readily in tissues, it is hoped that studies of this kind may eventually throw more light on the mechanisms of anesthesia.

Administrative Report

On July 1, 1952, Dr. Lewis K. Dahl assumed his duties as a Senior Physician with administrative appointment as Head of the Division of the Hospital and Chief of the Research Medical Services in the hospital. During the year, the organizational responsibilities of physicians in the hospital have been reoriented so that, in general, each physician has complete responsibility for only those patients who are being studied as a part of the scientific program in which the physician is primarily engaged.

During the past year, the loss of several staff members into active military service sharply reduced the number of qualified physicians available for patient care and

study in the Research Hospital. By the fall of 1953 the situation will be partially alleviated, but while the draft is operative it appears that the medical manpower problem will remain. Total patient days during the past year were 6713, compared with 8061 the previous year, and admissions were 109 compared with 238. The development of new projects in the hospital also contributed to the reduction in patient days. Of the total patient days noted above, 133 were accounted for by employees and 28 by employees' dependents. All these employee and dependent patients were assigned to the Personnel Medical Services of the hospital under Dr. Love.

Throughout the year, intensive studies of all hospital operations have been carried out, directed toward more efficient and economical performance of the necessary services. Extensive reviews of the dietary section have been made. The occupational therapy group has operated at capacity and has developed an exceedingly efficient and capable program of patient welfare.

In the Division of Industrial Medicine, the number of clinic visits was slightly

Figure 6. A potter's wheel provides recreation during a long period of hospitalization.

occ. therapy

lower than that for the preceding year, totaling 7392 compared with 7625. Throughout 10 months of the year, only one full time physician, Dr. Love, was available. Part time physicians assisted in the work of the clinic. It is hoped that in the near future it will be possible to recruit another full time staff member for this Division. The number of x-rays taken during the year has also decreased slightly to 1973 compared with 2243 for the previous year. Over 80 percent of these were taken of employees for occupational reasons such as pre-employment, annual physical examination, injury on duty, etc.

TECHNICAL OPERATIONS AND SERVICES

The Laboratory's technical operations and services, in general, are performed by special organizational units. The operation of the reactor, the supervision and operation of the health physics program, fabrication of equipment by the central shops, are typical of the many types of operations and services performed by these units. Their major efforts are in the support of direct research activities carried out by others; however, in several instances they also carry out some direct research along their own lines of interest. Examples are found in health physics, in meteorology and in instrumentation. The research activities of the Instrumentation Division are reported in a separate portion of the Physical Sciences and Engineering section; reports on the research activities associated with other supporting groups are found later in this section.

REACTOR OPERATIONS

The reactor operated about 90 percent of the time throughout the year; the accumulated output was 7,501 megawatt days, against 6,370 megawatt days for the preceding year.

Additional in-pile facilities have been completed and installed during the year. The very fast pneumatic rabbit is now in operation on the west face of the reactor. A large volume irradiation facility was placed in the central core hole to handle larger samples than ever could be accommodated before. Also a liquid nitrogen cooled irradiation facility was installed on the east face to provide very low temperatures for solid state investigations.

Research usage during the year increased to bring the total number of research projects to very near reactor capacity. There are now about 40 separate and distinct experimental arrays set up at the faces of the reactor. Seven crystal spectrometers are in operation on various research problems, and it appears that one or two more will be installed soon. A number of guest research projects have been in progress throughout the year conducted by the General Electric Co Research Laboratory, Columbia University's Department of Physics, Westinghouse Electric Corp's Atomic Power Division, California Research Corporation, Atomic Energy of Canada Ltd, Wesleyan University's Department of Physics, the US Weather Bureau, Argonne National Laboratory, the Brown Instrument Division of Minneapolis-Honeywell Regulator Co, the Chemistry and Metallurgy Departments of the Massachusetts Institute of Technology, Consolidated Vultee Aircraft Corp, Cornell Aeronautical Laboratory, Inc, and the US Geological Survey. The number of guest scientists associated with these projects totaled 33.

Early in the year, it was decided to discontinue two programs which had been adjuncts to the reactor operations since the early days of the Laboratory. The information and data collected over a period of years by the Meteorology group demonstrated that the activity carried by stack effluent under routine conditions does not present an operational problem. Therefore, continuous forecasting of local meteorological conditions for the ultimate control of reactor operating levels is no longer necessary. The personnel and functions of the group have been curtailed, and its primary role in the future will be based on collaborative research with other government and private organizations. The information developed by the group from the US Geological Survey is

also sufficiently extensive to provide answers to ground water problems associated with reactor operations and waste control. This Laboratory-sponsored program was terminated at the close of the fiscal year, and a comprehensive, final report covering the several years of investigation will be presented. It is likely that the US Geological Survey will continue some research at the Laboratory under its own sponsorship.

For the past several months, the practice of operating the reactor at maximum power levels during the daytime and reduced power during the night and weekends has been discontinued. The pile power has been kept constant day and night; one fan has been held as standby and four fans have been used for cooling. This mode of operation is attractive to the research people and to the operating organization. The maximum power level of 31 megawatts was achieved during the colder winter months.

The manufacturer of the 1500 hp primary fan motors had stated that these motors could be operated continuously at 1725 hp (15 percent overload) without damage. A test was conducted to determine the advantages of operating the pile with the primary fans overloaded. Since the operating levels are satisfactory to most research personnel at the present, the advantage of operating under fan overload conditions seems small except during the hot summer months when it is required in order to maintain constant power levels.

During the late summer of 1952, the 1500 hp No. 5 primary fan motor suffered severe damage when the windings shorted from phase to phase at one point on the out-board end of the stator windings. This motor has been rewound by the manufacturer and returned to normal service. On three separate fans, packing material plugged the water supply lines to the water-oil heat exchangers and this resulted in bearing temperature rise. In each case, the loss of water was discovered in time to prevent damage to the bearings. A by-pass with a pressure alarm switch has been added to the water supply to give early warning in case of pressure drop. Alignment checks of the primary motor fan units were completed early in 1953. Average settlement required the removal of shims under the motor to the amount of 0.010 - 0.015 in.

As a result of many discussions and predictions as to what would happen if a fan were shut down without the simultaneous insertion of the control rods, a test was conducted, under safe conditions, to obtain this information. The results have been forwarded to the Reactor Locations Committee.

The exit air ducts and filters were inspected during the Christmas shutdown. Operating conditions have not caused any apparent damage to the duct structure. Debris dropped from the north plenum chamber was removed in bags. The filters read as high as 400 mr/hr at 1 ft and did not appear to be seriously discolored. Pressure drops taken across these filters did not indicate much loading at this time.

During the period in which the reactor has operated, a considerable number of defective fuel units have been discharged into the canal. Since the installation of the softener and ion exchange column, canal water clarity has improved and contamination has decreased substantially. Approximately 3,000,000 gal of water have passed through the ion exchange column.

Loss of humidity control of the reactor building during a period in July, 1952, was experienced when two 300 hp Freon compressor motors burned out. The damage was reported to have been caused by lightning. These motors have since been rewound and returned to service.

Inspection of the 10-ton travelling crane revealed considerable wear on the drive gears in the north hoist gear box. No attempt to replace gears has been made, since it appears the wear is not sufficient to warrant this.

On two separate occasions, water was accidentally spilled from experimental equipment into the reactor through the top shield. No permanent loss of reactivity was observed in either case.

Level blocks have been installed on the four upper corners of the reactor shield to check for possible differential settlement between the reactor and the surrounding building.

The No. 1 cooling water pump has been rebuilt and placed in normal service. It has performed satisfactorily to date.

Instrument Maintenance and Development

The instrument group continues to be primarily concerned with repair and routine maintenance of the reactor instruments. This group develops and modifies equipment primarily in the interest of pile operations, and frequently works in support of research performed by other groups. The following exemplifies the type of work done in support of operations: The power regulator power supplies were rebuilt to utilize batteries and eliminate the VR tubes. An on-off timer switch with variable period has been installed in the regulator to correct overshooting due to rod overtravel and delayed neutron effects.

A Kanne air chamber has been incorporated into a vehicular radioactive gas and dust collector by the addition of a vacuum cleaner and a Beckman micromicroammeter designed to locate faulty fuel elements when the usual methods fail. A new compensated ion chamber has been designed. Special attention has been given to favorable saturation characteristics, low chamber activity and rigidity; construction has been started.

A second independent logarithmic system was installed to improve the system's capability to shut down the reactor in the event that a short period develops and to better the maintenance of the system. Present plans call for the addition of a third separate system as a further improvement.

A Bailey recorder was modified and placed in operation in the fan house to provide a record of temperatures developed in the stator windings of the No. 5 fan motor. When the motor was rebuilt, six resistance thermometers were wound into the stator.

In support of research work, a complete control rod and monitor assembly was designed and built for a classified project. An oscillator and filter were designed and built for metallurgical work with microformers. A Brown recorder was modified for use with microformers on the same job.

The facilities at the reactor have been modified and additions made to them. The lower balcony on the east side of the pile has been extended to allow more freedom of movement. The fast pneumatic tube has been placed in the pile and is available for use.

The medical irradiation facility on top of the pile is temporarily out of service. A shutter-type arrangement is being made for it which will permit patient irradiations without the necessity of a shutdown of the reactor and which will give a substantial increase in the neutron flux at the irradiation point.

The pneumatic tubes have been converted to vacuum operation to reduce the spread of contamination which was unavoidable with the pneumatic pressure tubes, to give positive assurance that the sample is at the proper place in the tube, and to permit the handling of more fragile samples.

The electrical supply has been increased on the west face to take the additional load imposed by the heavy use of the reactor and to allow for further expansion.

ISOTOPE DISTRIBUTION AND SPECIAL MATERIALS

The activities of this group have centered on the processing and shipment of radioisotopes and on service irradiations to external users. This latter activity has increased

Table 1
Summary of Isotopes and Service Irradiation Shipments

Institution	Number of Shipments			
	Fiscal 50	Fiscal 51	Fiscal 52	Total
*Abbott Laboratories	-	37	65	102
Aberdeen Proving Ground - Ordnance Corps	-	-	1	1
American Cyanamid Co.	-	-	3	3
American Optical Co.	-	1	-	1
Argonne National Laboratory	-	2	4	6
Army Chemical Center	-	1	2	3
Atomic Energy of Canada Ltd.	-	-	23	23
Bartol Research Foundation	-	-	6	6
Bell Telephone Laboratories, Inc.	-	9	12	21
Bendix Corp.	-	-	2	2
Breed Radium Institute	-	-	1	1
Brown Instrument Division	-	-	1	1
California Research Corp.	-	2	4	6
*Columbia University	22	54	89	165
Connecticut Hard Rubber Co.	-	-	1	1
Consolidated Vultee Aircraft Corp.	-	-	2	2
Cooper Hewitt Electric Co.	-	1	1	2
*Cornell Medical College (N.Y. Hospital)	-	16	29	45
Curtiss Wright Corp.	-	-	5	5
Elder & McNulty	-	-	1	1
E.R. Squibb & Sons	-	1	-	1
Ethyl Corp.	-	-	1	1
Garte, Mathew J.	-	-	5	5
Foster D. Snell, Inc.	-	1	-	1
General Electric Co.	-	-	4	4
*Goldwater Hospital	-	2	33	35
Hamilton College (McMasters University)	-	-	-	-
Canada	-	-	5	5
*Harvard University	32	124	114	270
Johns Hopkins University	2	-	9	11
Kearfott Co., Inc.	-	1	1	2
Knolls Atomic Power Laboratory	2	21	47	70
*Massachusetts General Hospital	4	3	22	29
*Mayo Clinic	-	-	16	16
Merck & Co., Inc.	-	-	1	1
Mine Safety Appliance Co.	-	-	1	1
Massachusetts Institute of Technology	10	19	20	49
Montefiore Hospital	1	4	19	24
Naval Medical Center	-	-	1	1
Naval Research Laboratory	-	1	4	5
New Brunswick Laboratory (USAEC)	1	7	-	8
*New England Medical Center	-	11	18	29
New York University	-	-	1	1
*New York College of Medicine	29	-	33	62
North American Aviation, Inc.	-	-	9	9
Nuclear Research Corp.	-	-	2	2
Ohio Agriculture Experimental Station	-	-	2	2
Ohio State University	-	-	1	1
Patterson-Moos & Co., Inc.	-	1	13	14
Peter Bent Brigham Hospital	4	-	5	9
*Routine (weekly or monthly) shipments				

Institution	Fiscal 50	Fiscal 51	Fiscal 52	Total
Pittsburgh Plate Glass Co.	-	2	-	2
Pough, Frederick H.	-	-	4	4
Princeton University	1	5	9	15
Rensselaer Polytechnic Institute	-	10	-	10
Rutgers University	-	-	1	1
Southwest Research Institute	-	-	5	5
*Sloan-Kettering Institute	-	52	54	106
Standard Oil Co. of Indiana	-	-	2	2
Stanford Research Corp.	-	-	1	1
State University of New York	-	-	4	4
Sylvania Electric Products, Inc.	-	-	13	13
Syracuse University	-	2	-	2
Tracerlab, Inc.	-	7	34	41
University of California	-	7	7	14
University of Chicago	-	-	1	1
University of Illinois	-	1	1	2
University of Michigan	1	1	-	2
University of Rochester	-	-	2	2
University of Nebraska	-	3	-	3
University of Wisconsin	-	1	2	3
*US Naval Hospital	-	-	34	34
US Signal Corps	-	-	4	4
US Testing Co., Inc.	-	-	1	1
US Third Coast Guard	-	-	1	1
*Veterans Administration Hospital	20	56	57	133
Vitro Corp. of America	-	-	2	2
Washington University	-	-	1	1
Watertown Arsenal	1	2	-	3
Wesleyan University	-	-	2	2
Westinghouse Electric Corp.	-	1	2	3
W.K. Mitchell Co.	-	1	1	2
Worcester Foundation	-	-	1	1
Yale University	1	2	2	5
TOTAL (82 Users)	131	472	887	1490
*Routine (weekly or monthly) shipments				

by a factor of two in the last year, and by a factor of almost seven in the last two years. Table 1 shows the different customers that have received shipments to date. Of the 82 shown, 72 were active during this fiscal year. Failure of the Chalk River reactor, in Canada, resulted in a shift of a portion of the work being done there to the Brookhaven reactor.

In addition to the regular facilities offered to external users, there have been added three air-cooled holes and a core hole. The air-cooled holes are converted pneumatic tubes that now provide for irradiations at approximately 50°C; they are accessible only during shutdowns. The core hole was designed and installed as a result of the demand for irradiation of large size samples. This facility is 12 in. square and is located in a high flux region which averages 10^{12} neut/cm²/sec over long periods of time.

The irradiation of approximately 150 pieces of cobalt metal (1/8 in. in diameter by 1/8 in. long and 1/8 in. in diameter by 1/4 in. long) was stopped when the activity reached a point that interfered with safe operation of the target conveyor. When discharged, these cobalt pieces averaged about 300 mc each for the smaller size and about 600 mc each for the larger.

The irradiation continues of some 50 pounds of cobalt and tantalum distributed in a number of individual sources. These will ultimately become kilocurie sources.

Outside orders to be placed for stable and processed isotopes not available from the Brookhaven reactor totaled 97 and 24 requests for special materials were placed through the Commission.

For internal users, the reactor provided approximately 330 irradiations from the target conveyor and approximately 890 from the pneumatic tubes. Table 2 shows a comparison of the irradiations for internal users for the past three years.

The manual on S/F Accountability Procedures, which was issued to supplement BNL's basic quota application, was revised. The brochure describing radioisotopes and irradiation services available at Brookhaven has also been revised and enlarged to include description of the newer facilities.

Table 2 Summary of Reactor Services						
External Users	Fiscal 1950		Fiscal 1951		Fiscal 1952	
	Number of Irradiations	\$ Billed	Number of Irradiations	\$ Billed	Number of Irradiations	\$ Billed
Target Conveyor	124	3974	464	18,663	737	40,590
Pneumatic Tubes	60	260	575	2,931	68	1,495
Air-Cooled Holes	-	-	-	-	12	4,175
Water-Cooled Hole	-	-	-	-	24	825
Thermal Column	-	-	-	-	18	912
Experimental Holes	-	-	8	5,971	24	6,533
Special	-	-	-	-	12	190
Multicurie Cobalt Sources	-	-	2	11,750	5	52,382
Sub Totals	184	4,234	1,049	39,315	900	107,102
Reactor Rentals	-	-	-	24,563	-	61,493
Totals		4,234		63,878		168,595
Internal Users						
Target Conveyor	138	8,433	288	18,443	329	38,982
Pneumatic Tubes	211	1,055	819	4,095	888	4,440
Totals	349	9,488	1,107	22,538	1,217	43,422

Submission of monthly inventories of special materials to the Commission has been routine, with one exception: because of the small quantity involved, the tritium inventory was discontinued.

METEOROLOGY

Meteorological work during the past year has been divided into three distinct programs involving somewhat different aims. These include the virtual completion of the

original reactor control program for which the group was established, the planning and initial development of a new research program, and the start of a specialized climatological project undertaken for the Department of the Air Force.

The staff now totals ten persons: three are assigned to the reactor and general Laboratory service, four to research, and the remaining three to the Air Force study. The work schedule has been reduced from seven-day coverage to the normal five-day week.

Reactor Control Program

For some time, the Laboratory has been anticipating a change in the policy governing the off-site dose rate level as it applies to operation of the Brookhaven reactor. From the experience gained since 1947, it is clear that the expected alteration would eliminate the necessity for daily estimates of the radiation dose rate. Even under present restrictions, it has been necessary to shut down the reactor because of adverse weather conditions only a few times during an average year.

Emphasis on the control program has been progressively reduced in an attempt to adjust to the future situation, although the prescribed procedure in terms of the current definition of operating level has been maintained. Routine 24-hr forecasts of radiation dose rates were discontinued on November 30, 1952; since that date, the 6-day dose rates have been computed daily from past meteorological data, but forecasts have been made only if some chance of exceeding operating level existed.

In terms of reactor operations, the year has been a curious one. Although the calculated dose rates have reached the off-site operating level on a number of occasions, appropriate shifts in the wind direction, or routine reactor shutdowns, have made restriction unnecessary in each case. The possibility of a full year of this type was foreseen in the original estimates of the problem, but it was interesting to find such a long period in which very persistent wind directions were absent.

It was considered desirable to complete detailed reports that would provide full reference on the various aspects of the development and operation of Brookhaven's meteorological control program. Accordingly, one report on instrumentation and the meteorological facility has been completed, and a second report summarizing the comparison of actual and calculated radiation dose rates, as well as the forecast program, is nearly finished. These two reports will be published separately, although simultaneously, since they actually cover somewhat different fields of interest.

Climatological Studies

The continuation of the studies of wind gustiness, mentioned in the last Annual Report (BNL 196 (AS-6)), has resulted in two publications. One report is on the relationship of gustiness to meteorological parameters, and the other emphasizes the importance of the correct evaluation of the frequency of occurrence of each gustiness type in air pollution problems.

Continuous recording of data at many levels of the Ace (410 ft) tower was terminated on December 31, 1952. The climatological record, at that time, included approximately three full years of well calibrated, reliable data. Not only is this sufficient for Brookhaven needs, but it is certainly adequate for most requests originating outside the Laboratory. Routine recording is now restricted to stack-level winds (355 ft) and to appropriate temperature difference readings, and the full installation is operated for specialized research purposes only.

Many earlier reports stressed the unusual character of the Brookhaven meteorological data and implied that they were applicable to a variety of problems. During the summer of 1952, the Department of the Air Force decided to sponsor a program that

would greatly simplify utilization of the data. Joint discussion of the program resulted in a decision to process and transfer to machine punch cards the hourly mean values of every meteorological variable continuously recorded at this installation, as well as several related parameters which could be determined from the synoptic charts. This study covers a 2-year record of the best material (all data complete in 96 percent of all hours) and includes:

- a) all elements of the standard synoptic weather observation
- b) wind direction, wind speed, and temperature at all measured levels
- c) wind gustiness at 355 ft above ground
- d) geostrophic wind
- e) solar radiation
- f) designation of sea breeze hours
- g) temperature advection

The result of this project will be two identical sets of machine cards: one to be held and used by the Air Force and the other by Brookhaven. The abstracting and processing of these data is a much greater task than the above list might suggest, but once it is completed, almost any study for which the data are applicable can be accomplished in a few days at a relatively small cost.

The processing is now more than half completed, and the transfer of data to the cards should be finished early in 1954.

Planning and Program Development

The original work of the meteorological group had one major objective: the design and operation of a meteorological control program for the nuclear reactor. Thus, the research accomplished during the past five years may properly be designated as applied, but from it has come considerable fundamental information of general interest. Early in 1953, the AEC and the Laboratory decided to continue certain aspects of the work which consist primarily of basic research.

The core of the new program involves the investigation of low-level atmospheric turbulence and diffusion from both the empirical and theoretical points of view. A new oil-fog project is being developed to provide data that will assist in the evaluation of both the form of the diffusion equations and the quantitative values of the parameters. The work of the past three months has led to the adoption of a fluorometric technique to provide the necessary data.

Research and development in instrumentation will also be continued. Two bi-directional wind vanes of an improved design are almost completed; they will be used to obtain information concerning the variation with height of various properties of the vertical wind. Preliminary consideration has also been given to the design of an instrument to be supported by a balloon or Kytoon which will measure wind direction, speed, and gustiness.

The service aspects of the group's work will not be entirely eliminated. Much of the meteorological data has specific and valuable application to Laboratory activities. For this reason, adaptations have been made to permit continuous, automatic recording of standard weather observations, with the exception of cloud data. Naturally, the calculation of radiation dose rates for reactor operation will also continue for as long as they are required.

HOT LABORATORY OPERATIONS

Except for the waste handling operation, which serves the entire Laboratory, by far the greatest demand for the use of the facilities and services of the Hot Laboratory

comes from the Nuclear Engineering Department. The various aspects of these operations are covered below.

Building Operation and Maintenance

During the first part of the year, two major pieces of equipment for the building were completed and tested. The closed dissolver (for dissolving from 2.5 to 25 lb of irradiated uranium) was tested by means of a "hot green" slug irradiated in the BNL reactor and was later used to provide a solution of irradiated uranium for experimental work. The electric rectilinear manipulator was installed in Semi-Hot Lab No. 1 and has since been extensively used to manipulate hot objects.

A high-level gamma irradiation facility was completed in the "future semi-hot cell area" of the Hot Lab building for use by the fission products utilization group. Among other features, this facility contains a "swimming pool" 18 ft deep at one end to permit manipulation and storage of kilocurie sources.

Ventilation was installed in the electrical room on the ground floor; this will permit installation of equipment for a heat transfer experiment to be conducted by the heat transfer group.

An "alpha facility" has been built by partitioning off two of the semi-hot labs and an equipment clean-up room from the rest of the hot area of the building. This new area has personnel showers and lockers and will permit the handling of large amounts of toxic α -emitting materials.

Equipment Clean-Up Room No. 4 has been turned into a sample preparation facility with the addition of a permanent 3-in. thick steel bench and equipment noted below; this permits extremely hot samples to be diluted, aliquoted, etc.

Equipment Development

A manually operated rectilinear manipulator (similar to the electric manipulator installed in Semi-Hot Lab No. 1) has been designed, built, and put into successful operation in the new Sample Preparation Room. A special turntable to hold and manipulate volumetric flasks and pipettes has been installed, and various pieces of handling equipment for transfer of samples to and from this room have been built. A similar design for a modified mechanical manipulator, to be used in Semi-Hot Labs No. 2 and No. 5, is well under way.

A device for the mechanical dejacketing of BNL fuel elements under water has been designed, built, and tested. This will be used to provide feed material for the volatility studies group.

A very simple special three-way valve for use on the I^{132} shipping unit has been built.

Liquid Waste Operations

The waste concentration plant and building were completed on April 28, 1953. Test work on this plant is nearly finished and the results so far indicate satisfactory operation. Minor modifications and adjustments have been made and others are being made. On June 8 and 9, the first run using "D" waste was made. In this run 3062 gal were concentrated into 81 gal. The concentrate was then put into three drums which were filled with Portland cement. All equipment performed satisfactorily. The figures in Table 1 indicate the magnitude of the liquid waste operations for the past year.

Radiochemical Analysis

In addition to the radiochemical analyses done on a direct service basis and to the development or improvement of analytical procedures in connection with these analyses,

the radiochemical analytical section has also performed some research and development work.

Of particular interest is the study being made of the $\text{Te}^{132} - \text{I}^{132}$ disintegration scheme, with the assistance of the BNL Physics Department and of personnel at Argonne National Laboratory. As a result of some recent data which suggested the possibility of a hitherto unreported isomer of I^{132} with a half-life of 10 to 20 min, two experiments were performed to determine empirically the composite growth and decay curves for I^{132} . Both the gross betas were counted with a G-M tube; the individual 0.23 Mev γ -ray from Te^{132} decay and the 0.67 Mev γ -ray from I^{132} decay were counted with a γ -scintillation spectrometer. From these results and from other work with this spectrometer, it is concluded that if any isomer of I^{132} exists it must have a half-life of less than ~ 1 min and must occur only in low abundance. The determination of the exact energies and relative abundances of the various betas and gammas from these two isotopes is still in progress.

Work is also continuing on the improvement of techniques to permit absolute counting.

Table 1				
Waste Inventory				
	Fiscal 1951		Fiscal 1952	
	"D" Waste	"A" Waste	"D" Waste	"A" Waste
Volume on hand at beginning of fiscal year (gal)	1433	203	90,102	347
Volume received during year (gal)	108,914	144	100,581	1243
Volume to evaporator (gal)	20,245		21,979	
Volume on hand at end of fiscal year (gal)	90,102	347	168,704	1590
"F" Waste Discharged to Sewer				
Period	Volume (gal)	Average Activity Level (c/ml)	Total Activity (mc)	
Fiscal 1951	2,963,997	2.29×10^{-12}	25.71	
Fiscal 1952	3,124,822	5.64×10^{-12}	66.16	

HEALTH PHYSICS

The Health Physics Division, which is a part of the Instrumentation and Health Physics Department, is responsible for providing equipment and establishing proper procedures and practices to guarantee safe operations in areas where radiation is present. The work of this Division, although primarily of a specialized character, has involved several research and development activities. Training activities have continued as in the past with the provision of field training for a group of AEC Fellows in Radiological Physics. All the activities relating to health physics are reported in the following paragraphs.

Training and Consultation

As in past years, a group of AEC Fellows in Radiological Physics spent nine weeks at BNL last summer; during this time they received field experience in health physics activities to supplement their academic programs at the University of Rochester. The 1952 group was given two days of general indoctrination before being assigned, in rotation, to various parts of the Division. One day a week was devoted to review sessions and lectures on special topics. This plan worked well and is being followed with the 1953 group.

Radiation protection is a subject evoking wide interest and, as a result, 17 lectures on health physics or visits to BNL facilities were arranged for technical and civic groups. Half-a-dozen short training courses in certain aspects of the program were provided for individuals from other laboratories.

Research and Development

Research and development activities of the Division have been sharply curtailed because of a temporary decrease in staff. In addition to a number of small projects connected with the development and testing of instruments, or with the measurement of dosage rates, two major activities have been carried on. One is the study of the propagation of cobalt-60 gamma rays in water and air, and the other deals with numerous problems connected with Cosmotron surveys. Several special instruments suitable for use with pulsed, highly mixed radiations were built and calibrated for use at the Cosmotron. A beginning was made in the study of the composition of the scattered radiation, in the evaluation of the depth dose curve, and in the application of tissue equivalent chambers.

A method for reclaiming contaminated lead was developed in cooperation with the shops group. When the melt was skimmed and decanted from some grossly contaminated lead, a one-hundredfold reduction in radiation levels from the lead was obtained and smear tests of the product showed only slight surface contamination.

Waste Disposal

During the past year, there has been a large increase in the volume and activity of contaminated solid waste produced at the Laboratory, particularly in connection with the operation and use of the nuclear reactor. When the activity is too long-lived to decay to a negligible value in a reasonable length of time, the waste is packaged in 55 gal drums, sealed with concrete, and dumped at sea. Sixty-five drums, containing approximately 25 curies of activity, were disposed of in this way during the last 12 months, and another 100 drums are packed and ready for shipment. This compares with a total of 50 drums containing 0.05 curies accumulated during the previous five-year period. To handle this amount of waste, some of it extremely active when first sent to the waste storage area from the pile, an inner fenced area with underground storage pits and trenches has been provided. Handling techniques and arrangements for pouring concrete have been improved until the necessary sorting and barrel-filling can now be performed without objectionably large exposures.

A summary of operating data for the liquid waste system is presented in Table 1, together with the averages for the previous year. The concentration of activity at the input to the filter beds continues to be low compared with the limit of 3×10^{-12} curies/cc stipulated by present policy. Runoff of rainfall has been much higher and has resulted in twice as much dilution of the sewage effluent by the stream to which it is discharged as in the previous year. The relatively small amount of activity released is particularly gratifying in view of the steadily increasing tempo of experimental activity and the increased volume of contaminated clothing processed at the decontamination laundry.

Table 1
Summary of Liquid Waste Data

Item	July-Sept. 1952	Oct.-Dec. 1952	Jan.-March 1953	April-June 1953	1952-53 Average	1951-52 Average
Input to filter beds (gal/day)	314,000	258,000	289,000	290,000	288,000	250,000
Output from filter beds (gal/day)	258,000	137,000	167,000	222,000	196,000	195,000
Net loss in filter beds (%)	18	47	42	23	33	22
Stream above discharge point (gal/day)	38,000	10,900	202,000	1,574,000	456,225	120,575
Stream at site boundary (gal/day)	325,000	149,000	677,000	2,296,000	862,000	411,000
Rainfall (in./mo)	3.04	2.32	6.46	3.03	3.71	4.09
Activity concentration at input to filter beds (c/cc)	3.8×10^{-13}	1.28×10^{-13}	6.5×10^{-13}	2.7×10^{-13}	3.57×10^{-13}	4.9×10^{-13}
Activity concentration at output from filter beds (c/cc)	1.2×10^{-13}	0.54×10^{-13}	3.5×10^{-13}	1.03×10^{-13}	1.57×10^{-13}	1.5×10^{-13}
Reduction in activity concentration (%)	68	52	43	64	57	67
Activity at input to filter beds (mc/mo)	13.6	3.7	18.8	8.7	11.2	13.1
Activity at output from filter beds (mc/mo)	3.7	0.9	5.8	2.6	3.3	3.5
Percent of permissible	12.6	4.4	21.0	9.5	11.9	16.0

Survey Activities

The health physics surveyors and survey technicians continued to deal with a wide variety of problems in radiation measurement, prevention of overexposure, and contamination control. The nuclear reactor is, of course, the most prolific source of such problems because of the huge quantities of activity that it produces. Experimental equipment and sources removed from the pile frequently read 100 r/hr or more at a distance of 1 ft, so that great care must be exercised. Charging and discharging fuel elements and manipulation of objects in the pile canal are operations that occasionally result in the spread of contamination; but clean-up after such incidents has been very successful. Urine samples from the operations and health physics staff at the pile were analyzed for gross radioactivity, since the members of this group are most likely to inhale small amounts of activity during the course of their work. In most cases no excretion of activity was detected; the remainder showed small amounts not considered to be in any way serious. Such analyses serve to check the routine measurements of air contamination, and they will be repeated at intervals.

A 170-curie cobalt-60 source was loaded into its container for the Medical Department by means of special tools fabricated in the Health Physics shop. Detailed surveys were made of the area in which this source is used, and a set of operating and safety instructions was prepared by the surveyor concerned.

A great deal of effort has been spent on the survey of the radiation fields associated with the Cosmotron and on the establishment of safe operating practices. Although

the working areas are protected by shielding, there is a great deal of scattered radiation reaching all regions adjacent to the machine. For example, in the control room, when the accelerator is operating at full power, exposure rates of 2 to 4 times the maximum permissible value for a 40-hr week are found. Actually, the machine operates at full power only part of the time, so that the average rate is only 65 to 70 percent of the maximum permissible value. In addition, personnel do not in general spend as much as 40 hours a week in this or similar locations, and the actual exposures recorded by the personnel monitoring equipment are well below the permissible limit in all cases. In the evaluation of such exposures, a relative biological effectiveness ratio of 10 has been used for the mixture of radiations encountered. This is thought to be a conservative value, chosen to allow for a lack of detailed information concerning the composition of the radiation and to protect personnel adequately from possible eye damage. Detailed surveys have established that a large part of the scattered radiation originates from the target inside the vacuum chamber.

An increase of the source strength at the Biology Department's irradiation field to an effective value of about 2000 curies necessitated a re-evaluation of the fencing arrangements and operating procedures. The high inner fence was left unchanged, but the outer fence was moved back to enclose all areas showing levels of more than 4 or 5 mr/hr. Safety mechanisms are provided to prevent the opening of the field entrance if the source is up and to sound an alarm if the source is being raised or lowered or if it should not be properly shielded in the down position.

Operation of the area monitoring stations and analysis of rain and settled dust samples continued throughout the year. The usual fallout from tests in Nevada was detected on several occasions. For the spring series, a more detailed study of the fallout was made in cooperation with the US Weather Bureau staff at Brookhaven. The distribution of activity with time during periods of precipitation was measured. As expected, the results varied greatly depending on meteorological conditions. Contamination of this type is usually pretty well washed away by the rain. On one occasion, however, it was deposited by a light drizzle and was left on exposed surfaces. Although too dilute to constitute a health hazard, it was tracked into experimental areas where it was somewhat of a nuisance for a few days until it decayed.

Personnel Monitoring

During the winter, an off-site neutron film badge service was established and is now being used by 11 organizations. These mainly consist of research contractors of the New York Operations Office of the AEC, at whose request the service was initiated.

However, other groups may subscribe for the present price of one dollar per badge. Neutrons are monitored by the nuclear track method, and conventional beta-gamma films are included in the badge. This activity has grown rapidly in recent months and it now totals 125 badges per week.

The use of personnel monitoring services on the BNL site is shown in Table 2, which does not include the off-site service just described. The average use of neutron films is low because of a film shortage during the winter. The current rate is about 400 per week as a result of the increased call for such monitoring at the Cosmotron. In September

Table 2		
Use of Personnel Monitoring Equipment		
	1951-52	1952-53
Pairs of pocket chambers	1470	1330
Regular film badges	707	844
Visitors' film badges (on-site)	192	230
Visitors' film badges (off-site)	84	124
Total film badges	983	1198
Neutron films used	308	214
Neutron films read	108	115
Figures have been averaged on a per week basis.		

arrangements were made to permit badges to be worn interchangeably in and out of all radiation areas. This has greatly reduced the need for duplicate badges and for visitors' badges for BNL employees.

An analysis of the personnel monitoring records of 144 individuals who worked regularly at the pile from July to December 1952 showed an average exposure of 9.6 mr per week. The five highest had averages of 136, 129, 73, 73, and 69 mr/week, respectively. Only ten individuals averaged more than 30 mr, or 10 percent of the maximum permissible value, per week.

INSTRUMENTATION

The research and development activities of the Instrumentation Division, which is a part of the Instrumentation and Health Physics Department, have been reported earlier in the Physical Sciences and Engineering section of this report. The activities of this Division, however, include a large amount of construction and maintenance of electronics equipment, as well as the operation of the Laboratory's glass shop. Some 25 non-overload amplifiers, five gray wedge analyzers, and a large number of conventional circuits for specific applications were constructed during the year. Over 300 electronic items have been repaired, including 122 scalars, 75 meters, and 22 amplifiers, and over 2500 items have been calibrated and serviced for the Health Physics Division. The glass shop has processed 800 job orders, and the tube shop has filled 65 G-M and proportional counters.

MECHANICAL ENGINEERING AND DESIGN

The Mechanical Engineering and Design Division operates essentially in three locations within the Laboratory: at the Central Machine Shops, at the Cosmotron Department and at the Nuclear Engineering Department. A fourth unit has recently been established for the Accelerator Development Division. Staff engineers are taking an increased responsibility for the delivery of completed units by following through the development design and construction phases of the work. The members of this Division have daily supervisory responsibility for the operation and maintenance of some of the components of the major facilities. Expanded effort in accelerator development during the year has resulted in an increase in staff. The staff on June 30 was composed as follows:

	<u>1952</u>	<u>1953</u>
Engineers	8	9
Designers and draftsmen	19	22
Clerical	2	2
	<hr/>	<hr/>
Total	29	33

Accelerator Group

Cosmotron

The semicircular shielding wall was designed, constructed (by AP&PM), and installed. An additional shielding structure to enclose the east target section was designed at the end of the year and is now under construction. Two 18 x 36-in. analyzer magnets

and one 9 x 18-in. magnet for deflection of meson beams have been designed, constructed, and placed in operation. A number of other mechanical accessories, such as target injectors, have also been provided. Electrical studies have resulted in the design of a motor generator house and associated rotating machinery and a switch gear to provide all experimental dc power needs for research at the Cosmotron. This house is now under construction.

60-Inch Cyclotron

An extensive program of overhaul was carried out during the winter in cooperation with the cyclotron staff. At that time, the pole tips were realigned and were firmly anchored in position by pre-stressing them and inserting accurately machined spacers at all interfaces. Magnetic measurements were made, and shims were inserted to produce a field in which the first order harmonic was less than 1 gauss at all radii. Rose rings were adjusted to produce the desired fall-off of magnetic field.

Alternating Gradient Synchrotron

The engineering staff assisted members of the Accelerator Development Division in the preparation of a set of design parameters and preliminary cost estimates of 20, 50, and 100 Bev alternating gradient synchrotrons. Engineering staff members have constructed a dc magnet model, full size in its cross section but of reduced length, and magnetic measurements are now being made. An alternating gradient focused linear accelerator capable of delivering protons at a highly uniform energy of approximately 50 Mev is being designed as an injector for the AGS machine. Models of some portions of this device are being constructed.

Nuclear Engineering Group

This group supervised the operation of heat transfer and hydrodynamic equipment that had been built to secure data in the Reactor Components Test Program. These studies were completed during the fall of 1952.

Designs and specifications of a liquid metal pumping loop were completed, and drawings of a second metal pumping system are nearing completion. An extensive series of lattices for exponential studies have been designed and have either been built or are in the process of construction. A number of special tools and instruments have been developed.

Design studies are in progress on pilot plants for radioactive waste disposal, waste utilization, and a volatile separation process. In collaboration with the scientific groups, a continuing program of exploratory studies is maintained to evaluate liquid metal fuel reactors and various types of breeder blankets.

Central Shops

Thirty-six major pieces of equipment and fifteen smaller units have been designed. The time allocated to this work was distributed as follows:

Physics Department	40%	Reactor Operations	10%
Reactor Experimental Facilities	20%	Medical Department	12%
Hot Laboratory Operations	8%	Biology - Chemistry - Meteorology	10%

Projects of particular interest have included a double crystal spectrometer for installation at the unclassified face of the reactor; a shielding unit for the Medical Department's Cl^{38} isotope administration; new mount and neutron shielding enclosure and

related accessories for counting equipment for the fast neutron chopper; and the design of an improved and more flexible patient irradiation facility at the reactor for the Medical Department. Technical assistance was made available to Reactor Operations in the reconversion of the pneumatic tube system and in the design of a liquid nitrogen facility. At the end of the year, work began on a second double spectrometer.

MACHINE SHOPS

The major effort of the Central Shops group continues to be directed toward the fabrication of parts and equipment for the research which is centered about the Laboratory's major research tools. This is in contrast to its contribution of earlier years toward the construction of the reactor, Cosmotron, cyclotron, and other accelerators. Among the more interesting items requiring use of the Machine Shops during the year were the manufacture and installation of a neutron spectrometer at the reactor; fabrication of large analyzer magnets that required the manufacture of jigs, fixtures, and tools for coil winding; fabrication of a double crystal spectrometer; manufacture of an adjustable beam collimator and its related shield; fabrication of source containers; fabrication and assembly of a mechanical manipulator; fabrication and installation of a high-speed rabbit at the reactor; and fabrication of a rotating target holder.

The Shops group assisted several AEC contractors in the fabrication of items which were essentially duplicates of previously manufactured Brookhaven equipment. The two major items in this category were for use at the Materials Testing Reactor by the Philips Company and consisted of a neutron crystal spectrometer and the rotor assembly for a fast chopper.

The Shops group assisted in the placement of several jobs with outside firms for work which required equipment and facilities not available at the Laboratory. Some 20 such jobs were placed with five different firms and involved special hardening, anodizing, plating, balancing, etc.

The operation of the Central Shops is handicapped by the separation and wide dispersion of its facilities. Responsibility for operation of the metals warehouse was transferred to the Receiving, Warehousing, and Distribution group in the fall of 1952. Normal shop operations are now carried out daily in three separate locations, and special jobs that require the handling of special materials, e.g., graphite or radioactive materials, are handled in two other locations.

Staff changes for the past four years are shown in the following table, which gives the staff levels at June 30 for each year indicated.

	<u>1950</u>	<u>1951</u>	<u>1952</u>	<u>1953</u>
Superintendent, foremen, and supervisory personnel	8	9	10	9
Skilled	54	57	54	52
Semi-skilled	16	13	8	6
Unskilled	-	-	2	2
Tool-crib attendants, clerical	8	8	7	6
Total	86	87	81	75

TECHNICAL INFORMATION

During this review period, as in the previous year, the staff of the Technical Information Division has remained constant at a figure of 21. However, the Division has continued to note an over-all increase in the demands on its services, due to the steady progress in the Laboratory's entire research program.

The basic collection in the Research Library has now been well rounded out, and the annual acquisition of books is fairly steady, at a rate of approximately 2400 volumes. In addition to this, about 300 bound volumes of journals were obtained, at the specific request of the scientific staff. From funds allocated by Associated Universities, Inc., a small collection of books, mainly on the history and philosophy of science, has been started, and it is proving to be extremely popular. This collection will be built up at a slow but steady rate.

The Circulation Desk reports a 5 percent increase over the previous year in the number of books, periodicals, and documents charged out. As an index of the self-sufficient stage that has now been reached, a steady drop in the number of inter-library loans requested by the Library is noteworthy. Requests for loans from other institutions have increased by 35 percent, which indicates to some extent the growing interest of industry and education in the entire field of atomic energy.

At the Reference Desk, there has been a marked increase in the number of bibliographical and literature search assignments received from the scientific staff. Reading room attendance rates are approximately the same as those for the previous year. During the summer months, an extra librarian will be on duty at the Reference Desk until 10 PM on weekdays to assist new staff members and summer visitors in locating and using library materials.

In late 1948, a collection of translated Russian scientific articles was started. There were 650 loans made from this pool, which now comprises over 1300 items. The success of this service is largely due to the cooperation of the libraries in this country, Great Britain, and Canada which have contributed the majority of the translations. A cumulative list of holdings is distributed periodically by the Library.

Now that the AEC's program for reproducing reports on microcard is under way, it has been possible to save some library space by the retirement of reports when microcard copy is available. In such cases, the microcard is filed behind the appropriate index card in the main subject catalog; this system is proving very satisfactory.

The Classified Library, along with its continuing responsibilities in the safeguarding and distribution of classified documents, has devoted much time and effort to a report retirement program. This has been possible largely because of the microcard program, which has enabled 5800 documents to be disposed of. The consequent saving in classified storage space has obviated an expensive addition to the present vault which would otherwise have been necessary. The growing demand by staff members for microcard as an information source has resulted in the requisitioning of two readers, and a special reading room for this facility is being planned.

In June 1953, the Classified Library was visited by the Chief, Declassification Branch, Classification Office, USAEC, with a view to the declassification of as much material as possible. This two- and one-half-week visit resulted in the declassification of a considerable amount of material, comprising most of the classified drawings, photographs, and correspondence issued at Brookhaven prior to January 1949. A vigorous program has been pursued for the recall and destruction of obsolete Brookhaven documents now at other sites.

The Laboratory-wide inventory of all secret documents, completed in November 1952, revealed not a missing item. Over 21,500 classified research and development reports were checked. In order to help reduce its ever-increasing work load, the Classified Library has eliminated from its holdings all material marked Official Use Only and Restricted.

During the past year, the publication group has edited and processed for publication 58 technical documents originating within the Laboratory; of this total, 33 were classified. In addition, the group provided its services for Brookhaven's contributions to the AEC's Classified Reactor Handbook. The Guide to Russian Scientific Periodical Literature, issued by the Laboratory since early 1948, was discontinued, at least temporarily. After providing since its inception the only readily available access to Russian scientific progress, this publication was duplicated last fall by the Library of Congress Monthly List of Russian Accessions. Under the direction of the Library, the Weekly Selected Reading List has continued on a routine basis. In addition to its service to Brookhaven staff members, this list is mailed out each week to over 700 other individuals and libraries with interests in the literature of nuclear energy.

The Division has processed for publication in the scientific and professional journals 307 technical manuscripts originating within the Laboratory. This figure represents a 27 percent increase over last year. With the Laboratory's research facilities still expanding, it is not expected that the leveling-off period in this function of the Division has yet been reached.

The Division has continued to distribute its unclassified reports as widely as possible. Although requests from outside the atomic energy project must be referred to the Office of Technical Services, all reasonable requests from within the project, as well as from government agencies and the officially designated repository libraries, are honored. Thus, the average distribution for an unclassified Brookhaven report is over 1000 copies. This does not include the dissemination of reprints from the Progress Reports, which are sent out to interested individuals at the nine Associated Universities, thereby encouraging closer research relationships between Brookhaven and other scientific programs in the northeastern region.

TECHNICAL PHOTOGRAPHY AND DUPLICATING

A minimal turnover of personnel is resulting in a well skilled group of 30 people, which is working to improve and extend its techniques. There is a growing requirement for more precise methods and a consequent interest in better measuring techniques.

Production figures for the period and the two previous years are as follows:

	<u>Fiscal 1951</u>	<u>Fiscal 1952</u>	<u>Fiscal 1953</u>
Photographic negatives	2506	4344	4488
Photomicrographs	338	1471	1334
Lantern slides	1919	2983	3487
Prints	21,567	25,393	29,491
Photostats	27,165	32,789	30,271
Ozolid prints	(not recorded)	187,046	197,429
16 mm film processed	9.0 miles	10.0 miles	10.8 miles

The illustration section has completed 2405 tracings for slides and publication, as well as work on publications and visual aids. A three-dimensional display using color

photographs of pathological material, entitled "Atomic Energy for Human Disease," was designed for the Pathology Division. This has been shown at a number of scientific meetings and at the Laboratory.

The duplicating group has put into operation a 17 x 22-in. Harris offset press, with its auxilliary equipment of vacuum frame, light table, and a Baum sextuplet folder. Extensive alterations of the group's quarters to accommodate the new machines were completed. The ability to run pages "four up" will shorten production time on reports during the coming year.

Work completed during the year is as follows:

	<u>Fiscal 1951</u>	<u>Fiscal 1952</u>	<u>Fiscal 1953</u>
Offset pages	1,804,308	2,610,415	2,175,640
Offset plates	1893	2469	1454
Offset negatives	3431	4681	3672
Mimeo impressions	1,231,480	1,886,400	1,716,480
Stencils cut	(not recorded)	3510	2387
Stencils run	(not recorded)	(not recorded)	10,201
Sheets collated and bound	637,770	769,775	589,065
Report copies issued	(not recorded)	28,945	31,335

ADMINISTRATION AND MAINTENANCE

In this section are included reports on Personnel, Safety, Architectural Planning and Plant Maintenance, Security and Plant Protection, Purchasing, Inventory Management, Fiscal, and Office Services activities.

The Personnel report covers status and turnover data for both the scientific and nonscientific staffs. Some of the broader aspects related to the scientific staff are discussed in the general introduction at the beginning of this report.

An impressive safety record was established in the calendar year 1952 as is noted in the statistics given in the Safety report.

The activities of the Architectural Planning and Plant Maintenance Department involve direct technical support of the Laboratory's research program as well as the general operation and maintenance of the Laboratory plant. The work of the Receiving, Warehousing, and Distribution group, which for organizational purposes is part of this Department, has increased in scope through the transfer to it of all metals warehousing responsibilities. This change effected the complete consolidation of all warehousing functions for the Laboratory. The most significant trend in the inventory and warehouse activities has been the reduction of stocks through extensive analysis of requirements and the elimination of excesses, which has resulted in a more effective use of stores supplies. Customer service has been improved through increased use of delivery service. This improvement in the inventory-stores functions was the result of the combined efforts of every group associated with the procurement, handling, and appropriate recording of materials required for the Laboratory's operations.

Details of these activities, as well as of the groups responsible for the general business administration and operation of the Laboratory and for the operation and protection of the plant, are given in the following sections for each organizational unit.

Personnel

Scientific Staff

The composition of the scientific staff on June 30th for the past three years is given in Table 1. 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." There has been an increase in the number of both salaried and nonsalaried visitors, the total of the two being 23 percent higher than that of 1952. While there has been no net change in the regular scientific staff, 45 new members have been added, 44 former members have terminated to take positions elsewhere, and one died.

The continued increase in the flow of scientific personnel into and out of the Laboratory is gratifying. During the fiscal year, 237 visiting scientists reported for work and 195 departed. This net change of 42 is composed of 26 salaried visitors and 16 who received no compensation from Brookhaven.

A more detailed analysis of the participation of individuals from other institutions in the work of the Laboratory is given in Table 2. The review period of June 1, 1952 through May 31, 1953, inclusive, has been selected in order to include all information on only one summer program, namely, that of 1952. The table gives the numbers of salaried and nonsalaried (guest) scientists who participated in the Laboratory program

Table 1									
Total Scientific Staff Employed June 30, 1953 Compared with June 30, 1951 and 1952									
Appointees	Regular Staff			Visitors					
				Salaried			No Compensation		
	1951	1952	1953	1951	1952	1953	1951	1952	1953
By Appointment Category									
Senior scientist	35	33	34	4	5	10	--	2	6
Scientist	20	29	42	8	5	12	3	16	21
Associate scientist	109	153	141	14	12	15	4	20	27
Research associate	--	--	--	5	13	9	2	4	3
Junior scientist	53	30	29	2	1	--	--	2	7
Jr. research associate	--	--	--	12	7	15	21*	26*	18*
Research assistant	--	2	1	26	63	71	2	1	5
TOTAL	217	247	247	71	106	132	32	71	87
By Academic Degree									
Ph.D. or M.D.	125	152	152	26	32	44	9	31	52
Master	38	36	34	17	11	19	5	15	7
Bachelor	50	54	56	26	38	50	18	25	27
No Degree	4	5	5	2	25	19	--	--	1
*Includes Radiological Physics Fellows.									

Table 2						
Classification of Visiting Scientists Participating in BNL Program for Period of One Month or More						
June 1, 1952 - May 31, 1953						
	More than 3 months		Less than 3 Months		Total	
	Salaried	Guest	Salaried	Guest	Individuals	Institutions
University						
Staff	11	9	34	19	73	40
Thesis students	14	6	--	1	21	11
Student helpers	1	1	64	3	69	36
Special students	--	--	1	22	23	3
Total	26	16	99	45	186	64 different
Industry	2	8	--	7	17	10
Other institutions	17	13	--	6	36	16
Total	45	37	99	58	239	90 different

under two groupings. The first group includes those scientists who worked at the Laboratory for more than three months; and the second includes those who worked at the Laboratory from one to three months. Scientists who worked at the Laboratory for less than one month or on an intermittent basis are not included in this summary.

In all, 239 individuals from 90 institutions participated in the program during the twelve-month period indicated. Eight of the 21 predoctoral students completed their theses during the year. The majority of these scientists have university affiliations either as faculty members or as students. The numbers of both the individuals and the educational institutions represented have increased over those of previous years. Compared with the previous year, there is a slight decrease in the number of visitors who worked at the Laboratory for more than three months and a 100 percent increase in the number who remained from one to three months. The increase is due, in part, to the organized summer program for students first instituted in 1952.

Of the educational institutions represented, approximately two-thirds are located in the northeastern region. With the exception of two foreign institutions, the remaining third are scattered about the rest of the continental United States. The number of representatives from nonacademic organizations also increased over that for the previous year. Among the visitors who did not represent either academic or industrial organizations were those from medical research centers and AEC organizations, as well as postdoctoral fellows, including ten appointees to the BNL staff for terms limited to a maximum of two years. The majority of the visitors from noneducational organizations received compensation from their home institutions or from sources other than the Laboratory. About four-fifths of them worked at the Laboratory for more than three months.

The services rendered by consultants are shown in Table 3, in which comparisons are made between the current report year and the two previous fiscal years.

Table 3			
Consultants' Services			
Item	Fiscal Year		
	1950-51	1951-52	1952-53
Total contracts	124	105	120
No. of consultants	38	51	48
No. of man-days of service	338	691	466

Summer Program

Because of the success of the first summer program for students in 1952, a similar program was arranged for the summer of 1953. Announcements were sent to 99 different educational institutions in the northeastern region. Applications were received from 276 students representing 72 institutions. Of these, 192 were undergraduates in 54 different institutions. Selections from these applicants were made on a competitive basis. Forty-seven appointments were offered, of which 38 were accepted. Of the 84 graduate students who applied, 43 were offered summer appointments, and of these, 33 accepted. Four additional graduate students and one undergraduate student were appointed in special categories, either to carry on work on the basis of their previous experience at the Laboratory, or to assist in collaborative research projects initiated by staff members of their universities. In all, 37 graduate students and 39 undergraduate

students will have worked at the Laboratory during the summer; these students represent 46 colleges and universities. About 85 members of the faculties of 36 colleges and universities plan to work at the Laboratory for periods of from three weeks to four months during the summer of 1953.

Employment

The number of Laboratory employees on June 30, 1953 totaled 1431, which represented a net increase of 19 staff members during the fiscal year. This augmentation of personnel partially reflects the trend of continued moderate growth of the scientific staff, with a concomitant reduction in the ratio of scientific to nonscientific staff members. Pertinent personnel statistics are set forth in Table 4.

Table 4						
Staff Data	Fiscal Year Ending					
	June 30, 1952			June 30, 1953		
Total number of employees	1412*			1431**		
Turnover data	Total Numbers	Annual Rate (%)	Average Monthly Rate (%)	Total Numbers	Annual Rate (%)	Average Monthly Rate (%)
Accessions	302	21.45	1.79	227	16.14	1.35
Separations (turnover)	252	17.84	1.49	208	14.88	1.24
Net accessions	50	3.62	0.30	19	1.28	0.11
Replacements (net turnover)	226	16.02	1.34	170	12.22	1.02
*Not including 89 temporary appointees.						
**Not including 112 temporary appointees.						

Although the accessions during the fiscal year 1952-53 were somewhat less than those of the preceding year, the Employment Office operated at an accelerated pace during the last six months of the year compared with the first six months. This resulted, primarily, from filling positions which previously had been held open because of the indefinite budget situation in the early part of the year, as well as from the need for additional skilled personnel in connection with new activities. Fortunately, the Laboratory is becoming increasingly well known in the surrounding communities as a place of stable employment with diversified job opportunities. This has been an important factor in enabling the Laboratory to continue to attract better-than-average employees on a competitive basis, even though the employment market is not overly abundant. It also is a factor in continuing to reduce the already low net turnover rate.

Labor Relations

Maintenance and Service Employees: The collective bargaining contract negotiated with Federal Labor Union No. 24426, AFL, on July 21, 1950, which covered maintenance and some service employees extends until June 30, 1955, without any mandatory reopening provision. However, the Laboratory is undertaking to explore with the Union the possibility of modifying certain provisions of this contract on a mutually voluntary basis. This is being done in recognition of changing conditions which suggest the

desirability of considering such modifications. Although no definite agreements have been reached in this regard, the Laboratory management hopes that because of this demonstration of its willingness to "live with" a long-term contract on a reasonably flexible basis, the Union in turn will continue to subscribe to the philosophy of long-term agreements. The Laboratory management believes that such contracts, whenever feasible, generally are more conducive to operational stability and enhanced employee morale than frequent or lengthy bargaining over the terms of a new contract document.

In accordance with the provisions of the present contract, the fourth and fifth semi-annual cost-of-living adjustments were made effective on January 5, 1953 (an upward adjustment) and on July 6, 1953 (a downward adjustment); the third annual improvement factor also was made effective on July 6, 1953. The use of the fourth step in the five-step grievance procedure was required only eight times during the entire year, and only one of these eight grievances required resolution at the fifth step of the grievance procedure which provides for arbitration on a limited number of issues. The minimal use of the terminal provisions of the grievance procedure is indicative not only of the continuing ability of the Union officials and the staff officers of the Laboratory to resolve nonroutine problems which could not have been anticipated during the drafting of the long-term agreement, but also of the ability of the Union stewards and the line supervisors of the Laboratory to resolve effectively the immediate on-the-job and more routine situations that arise under the collective bargaining agreement.

Patrolmen: Pursuant to an election conducted by the National Labor Relations Board on March 20, 1953 under the terms of a consent election agreement, the United Security Employees Union was designated as the exclusive bargaining representative for "all patrolmen and patrolmen trainees, excluding sergeants, lieutenants, clerical employees, all other employees and professional employees and supervisors as defined in the Act."

Under date of March 30, 1953, the Union forwarded a series of demands to the Laboratory which were reviewed at an exploratory meeting between the Laboratory and the Union on April 10. Formal bargaining sessions which followed on April 21 and April 25 culminated in the signing of a collective bargaining contract on May 4, 1953. The contract document which extends through September 30, 1954, reflects an authentic acceptance by the Union of the Laboratory personnel policies, augmented by such items as a formal grievance procedure, a firm "no strike" covenant, and several other specific provisions required in recognition of the unique role of the security forces in an operation concerned with the national atomic energy program. The dispatch and facility with which contract negotiations were completed, the general acceptance by the Union of the Laboratory personnel policies with specific supplements thereto in recognition of special circumstances, the limited use of the formal grievance procedure provided in the contract, and the continuing cooperative attitude of the Union officers give evidence of a mature collective bargaining relationship, notwithstanding the relatively short period of time in which this union local has been operative.

Wage and Salary Administration

The annual area wage survey conducted during the spring of 1953 by the Personnel Division indicated the desirability of a moderate upward adjustment of the range limits for each labor grade. This adjustment was made in conformance with the Laboratory's policy of paying rates which are equivalent to those paid for comparable jobs by other organizations in the survey area. The revised wage schedule became effective on July 6, 1953.

As a result of changes in general economic conditions during the past several years, it became necessary to revise the Laboratory's salary schedule. This is the first revision

that has been necessary since 1947. In effect, the adjustments reflected increases in the cost of living from pre-Korean levels to the present. The revisions in this schedule became effective on July 1, 1953.

In accordance with established policy and practice, the performance and progress of all employees were examined at the semi-annual reviews, and appropriate adjustments were made.

Employee Benefit Programs

Participation in the hospitalization and group insurance programs by more than 80 percent of the staff has continued. Participation in the retirement plan (Teachers' Insurance Annuity Association) has continued to increase markedly each year with approximately 65 percent of the staff taking part in the plan on June 30, 1953. It might be noted that almost half of those who share in the retirement plan have elected to participate in the College Retirement Equities Fund, which provides a variable annuity based in part upon the valuation equity-type investments, which are considered more sensitive to economic fluctuations.

Policy Modifications, Revisions and Supplements

Modifications to Laboratory personnel policy have included revised wage and salary schedules, the addition of several classifications covering new jobs, the deletion of other classifications no longer in use, and additional interpretive statements related to the method of determining wage payments for part-time weekly and hourly personnel. The inclusion of all Laboratory personnel policies in the "Supervisor's Manual of Personnel Policies," which also constitutes the basic Reimbursement Authorization document with the Atomic Energy Commission, continues to provide an efficient and valuable mechanism for indoctrination of new employees, as well as a method of handling reimbursement requests with the Commission.

Selective Service

The Laboratory is continuing to receive excellent cooperation from the local selective service boards which exercise jurisdiction over many of the younger scientific personnel. The previously established procedure of notifying local boards whenever an employment offer has been accepted by draft-eligible scientific and technical personnel has been continued, as well as that of advising the boards of the individual's contribution to the Laboratory program after employment has begun. This practice has been a major factor in the Laboratory's success in obtaining deferments for all essential scientific and technical personnel during the past year.

Employee Activities

The Brookhaven Employees' Recreation Association continues to sponsor some 20 social, cultural, and physical activities which function without direct subsidy from the Laboratory. The Theatre Group, with nearly 65 members, was particularly successful this past year. Short plays, scenes, and readings were presented monthly for Theatre Group members, and two full scale productions were staged for more general audiences. "Arsenic and Old Lace," produced in June, played to an audience of about 700 persons.

With the purchase of five electric power tools, a tool-rental program has been initiated by BERA at a small service fee for employees who desire to borrow this type of equipment for home use.

Residence Services

Renewal of the contract in April 1952 with the Suffolk Improvement Company for 12 apartments at Stony Brook, L.I., as the most economical protection available to the Laboratory in the form of supplemental housing facilities for use by on-leave and term appointees appears to have been a most desirable move. By June of this year, these apartments were fully occupied and, in view of the waiting list which now exists, it is probable that this high occupancy rate will be maintained for some time to come.

The occupancy rate in the on-site apartments during the early winter months exceeded the occupancy rate for the comparable period during the preceding year. Scheduled summer occupancy for the apartments is again at a maximum.

The regular annual survey to determine rents charged for private housing facilities in nearby communities was prepared in January 1953. The survey indicated no appreciable shift in the rents for off-site facilities, the rental cost for such facilities continuing to be comparable to the charges for similar accommodations provided by the Laboratory. Accordingly, no modification of the rent structure for Laboratory housing units was indicated.

Safety Engineering

During the past fiscal year, the disabling injury frequency and severity rates decreased to their lowest levels in the history of Laboratory operations. In recognition of the accumulation by the Laboratory of more than one million consecutive man-hours without a disabling injury during calendar year 1952, the National Safety Council presented Associated Universities, Inc., with the Award of Merit. It may be recalled that in 1950 the Council conferred upon the Laboratory its distinguished Service to Safety Award for an outstanding safety performance. Further recognition of the low accident experience in the past year came from the Atomic Energy Commission by its award of the AEC Safety Trophy. This resulted from the achievement of top rating in accident

prevention among the principal operating contractors of the Atomic Energy Commission during the calendar year of 1952. Significant disabling injury data are recorded in Table 5. These data may be compared with a frequency rate of 5.10 and a severity rate of 0.55 reported by the National Safety Council for the chemical industry during 1952.

The effects of the Laboratory safety program are reflected not only in the low disabling injury rates but also, as should be expected, in the amount of the refunds received each year from the compensation and public liability insurance carrier after the annual adjustment of the premi-

ums. Although such adjustments are subject to revision under a retrospective rating plan in the event of unanticipated claims or awards, the net effect of the various adjustments which were made from 1947 through the end of the calendar year 1952 indicates that insurance costs for Laboratory operations have amounted to only slightly more than 10 percent of the estimated standard insurance premiums which might have been anticipated in the absence of a better-than-average safety performance.

In recognition of constantly changing conditions and modifications of procedure and policy which have occurred since the Laboratory Safety Manual was issued in 1948, a

Table 5

Disabling Injury Rates

Rate	Fiscal Year Ending	
	June 30, 1952	June 30, 1953
Frequency *	1.66	1.33
Severity **	.04	.01
*Number of disabling injuries per million man-hours worked.		
**Days lost per thousand man-hours worked.		

detailed administrative revision to this manual was completed during the year. Several draft editions of supplements to the manual have been initiated, and the Hazardous Chemical Reference Series was augmented by the addition of a completed section on trichlorethylene.

The Safety Engineering group, in cooperation with the Architectural Planning and Plant Maintenance Department, has continued to review all proposed plans and specifications for new construction and alterations to existing facilities, in order to insure the inclusion of requisite safety and fire protection engineering features. However, with the completion of most major facilities, it has been possible to devote more time and attention to the solution of problems related to the design and safe operation of the experimental equipment intended for use in these new facilities. These efforts have been directed toward such projects as the alteration of the cryogenics laboratory for the production of liquid hydrogen and the design of heat transfer experiments to be conducted by several nuclear engineering groups.

Assistance was furnished to the Joint Fire and Marine Insurance Committee on Radiation in the preparation of their publication on "Fire Protection for Particle Accelerators." At the invitation of this organization, and upon suggestion by the Atomic Energy Commission, a member of the Laboratory Safety Engineering group now attends the meeting of this Committee, which is a voluntary group composed of all major fire insurance interests, whose principal activities are concerned with the development of standards for the solution of the unique fire protection engineering problems which have arisen with the advent of the "atomic age."

Continued emphasis on the provision of automatic fire protection in new facilities, in order that a level of "improved-risk" fire protection eventually might be attained, is evidenced by the installation of such equipment as a fixed carbon dioxide flooding system in the chemistry storage facility of the new waste concentration plant. For the third successive fiscal year the fire loss ratio has been maintained at nil, although the assessed property valuation has risen to more than \$57,000,000. This ratio may be compared to the 1952 annual average fire loss ratio for all AEC contractors of \$.035 per \$100 of assessed valuation.

Architectural Planning and Plant Maintenance

As indicated in Table 6, the Architectural Planning and Plant Maintenance Department (exclusive of the Receiving, Warehousing, and Distribution group) reduced its personnel for the third consecutive year. The most recent annual decrease is 14, which left a net strength of 244 on July 1, 1953.

Table 6		
Date	AP & PM Dept Personnel Strength	Decrease During Year
July 1, 1950	284*	
July 1, 1951	270*	14
July 1, 1952	258	12
July 1, 1953	244	14
*Not included are five persons in Maintenance Warehouse Service, which merged with Receiving, Warehousing, and Distribution on November 1, 1951.		

The major portion of this decrease (from 47 to 35) occurred in the heating section as a result of two factors: a) the completion in April of the Rochester Avenue steam line which will allow the closing during the summer months of the central steam plant (473) at the corner of Center Street and Bell Avenue as well as reduced operations in this same plant in spring and fall; b) the completion of the program of conversion to oil burning of all individual building heating units. The

only two coal-burning heating plants remaining at the site are the central steam plant (473) mentioned above and the boiler plant, which serves the Medical Department and

apartment area. The consequent reduction in coal handling and ash removal has permitted a decrease in personnel in the sections responsible for this work. On the other hand, small increases in personnel, notably electricians and plumbers, have occurred in some areas to keep pace with increased work loads.

Table 7		
Activity	Percentage of Total Activity	Man-Years
1. Building maintenance and repair	13.4	30.3
2. Janitorial services (exclusive of dormitories and apartments)	13.3	30.1
3. Heating and ventilating (including plant operations, maintenance and repair; underground steam lines; coal handling and ash removal)	25.6	57.8
4. Air conditioning	6.0	13.5
5. Electrical distribution, street and area lighting, security and fire alarms, fire protection (sprinkler systems, etc.)	1.6	3.6
6. Water supply, sewerage, storm sewers (operations, maintenance and repairs)	3.2	7.2
7. Grounds, roads, streets, parking areas, sidewalks	11.2	25.4
8. Sanitation (garbage and refuse disposal, incinerator and disposal dump operations, insect control)	1.4	3.1
9. Contaminated garbage and refuse disposal, decontamination (buildings)	1.1	2.5
10. Protective clothing service (laundry)	1.6	3.6
11. Motor vehicles maintenance and operation, busses	5.4	12.2
12. Miscellaneous services	3.3	7.5
13. Technical services	12.9	29.2
Total	100.0	226.0

On July 1, 1952, a complete work order system was instituted for the Buildings and Grounds Division to cover its many activities and to give better cost information and control. Table 7, based on the resulting cost reports and on the average personnel level of 226 for the Division, shows the manner in which its effort is distributed.

The technical services rendered by the Buildings and Grounds Division are not limited to the construction of apparatus and equipments for the scientific departments but include a great variety of other services, such as maintenance and repair of scientific apparatus, routine maintenance, repair and operation of certain portions of scientific facilities (the most notable example is the ancillary equipment of the reactor: fans,

Table 8		
Craft	Total Man-Years	Man-Years in Tech. Serv.
Electricians	13.6	4.9
Plumbers	11.4	3.3
Carpenters and Cabinet Makers	20.6	7.1
All others	180.4	13.9
	226.0	29.2

fan motors, cooling tower and pumps, switchgear, etc), electrical maintenance of shop tools, etc. The largest single job undertaken by the Division during this past year was the construction of the reinforced concrete shielding blocks for the Cosmotron. Construction of facilities (minor building improvements, alterations, modifications, etc) enters into the total of technical services to the extent of 3.3 man-years. It is also of interest to note that three of the crafts in the Division, which represent slightly over 20 percent of its total effort, contributed more than half (52 percent) of the technical services rendered. Table 8 illustrates this point in detail.

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:

These new facilities were added during the year:

1. Biology laboratory II,	approx 25,000 sq ft	\$1,000,000.00
2. Biology greenhouse and head house	approx 5000 sq ft	40,000.00
3. Rochester Avenue steam line	approx 2000 lin ft	120,000.00
4. Irradiation equipment laboratory at Hot Laboratory (Building 801)	approx 1000 sq ft	20,000.00
5. Micro-biochemistry - Medical Dept. laboratory (Building 333)	approx 500 sq ft	25,000.00
6. Waste concentration plant for Nuclear Eng. Dept (Building 811)	approx 1500 sq ft	250,000.00

In addition, more than 60 smaller jobs involving changes to and extensions of various laboratory services and equipments, such as piping, electrical work, air conditioning, dehumidification, laboratory furniture and fume hoods, etc, as well as approximately 25 jobs concerned with physical improvements to and maintenance of buildings (exterior painting and repair, roof painting and repair, fire and security protection, and approximately ten jobs in the category of additions to and modifications of site-wide facilities (steam lines, electric power lines, water and sewage lines, grading, and paving).

B. Planning and Design (approximately 150 jobs, excluding operational and maintenance engineering):

1. Special reports: Basic data describing existing and future facilities and requirements were assembled and furnished by this Department in connection with two contracts undertaken during the year by the Brookhaven Area Manager, AEC:

- a. A Master Site Plan, forecasting the future development of permanent Laboratory facilities, was prepared for the AEC by Skidmore, Owings, and Merrill, Architects-Engineers; included were preliminary plans for the Medical Research Center and the Physical Science Center, Phase I, for purposes of more accurate budget estimates.
- b. Electric Power Report: a study of future electric power requirements of BNL, including the modification and extension of existing electric facilities, is being prepared for the AEC by Gibbs and Hill, Consulting Engineers.

2. Complete architect-engineering services for new facilities were furnished for:

- a. Rochester Avenue high pressure steam line extension.
- b. Cosmotron motor generator house (dc power for experimental work) - approximately 1500 sq ft.
- c. Chemistry counting room - approximately 800 sq ft.
- d. Greenhouse and head house for Biology - approximately 5000 sq ft.
- e. Twelve jobs involving improvements or modifications of existing space in various buildings to provide new or improved facilities, such as: Gamma irradiation room in the hot laboratory; micro-biochemistry laboratory in the medical laboratory; printing press installation and related alterations in the classified document section (Building 197); cyclotron and Cosmotron control rooms' air conditioning; experimental animal room air conditioning in the medical laboratory; experimental cubicles in the metallurgical laboratory, and Vande Graaff faceplate relocation in the cyclotron-Van de Graaff Building.

3. Architect-engineering services for minor improvements included:

- a. About 50 jobs concerning changes to or extensions of existing laboratory services, which involve electrical work, piping, ventilation, air conditioning, dehumidification, laboratory furniture, and fume hoods.
- b. About 20 jobs involving other miscellaneous improvements to existing buildings and separate laboratories.
- c. Approximately 25 jobs concerned with services and improvements of the Laboratory site, such as land surveys for Biology gamma fields and Health Physics monitoring, neutralizing tank design and engineering, utility and topographic map work, and design of minor changes to electric power and steam distribution systems.

4. Preliminary studies and engineering estimates have been undertaken to assist the management in budget or operational decisions. These included about 40 jobs for Alternating Gradient Synchrotron Project, criticality experiment facilities, office rearrangements and relocations, and laboratory additions and laboratory services additions.

Receiving, Warehousing, and Distribution

In Table 9, the evolution of the personnel performing the functions now discharged by the Receiving, Warehousing, and Distribution group is reviewed for the past 4 years. The small increase in personnel during the past year reflects the increasing volume of material and services handled by this group, which in turn is an indication of the continuing growth and increasing activity of the Laboratory as a whole. It is worth noting that during the 12-month period just ended a total of 57,000 stores issues were written for stockroom materials, which covered about 118,000 separate items, compared with the corresponding totals in the previous year of 29,000 issues and 75,000 items. At the end of the Fiscal Year 1951-52, issues were being made at the rate of 3300 per month. Monthly rates have climbed steadily during Fiscal Year 1952-53, from slightly under 4000 during its first quarter to more than 6000 during the last three months.

Figure 1 charts the issues from stores by quarters during the past year and shows the steady growth in all three categories of services rendered: a) Over the counter issues at Central Stores (Buildings 100 and 452); b) issues from Central Stores delivered to users; c) issues from branch stockrooms (impressed) in Reactor Building,

Table 9	
Date	Personnel Strength
July 1, 1950	48*
July 1, 1951	44**
July 1, 1952	41†
July 1, 1953	44

*This figure includes five employees in Maintenance Warehouse Service.

**This figure includes five employees in Maintenance Warehouse Service (merged with Receiving, Warehousing, and Distribution on November 1, 1951) and two employees in Metal Stockroom (Central Shops).

†This figure includes two employees in Metal Stockroom transferred to Receiving, Warehousing, and Distribution, in November 1952.

Figure 1. Chart of stores issues by quarters for 1952-53.

Hot Laboratory, and Building 197. The relative importance of these three categories is as follows:

Counter issues - Central Stores 43 %
 Deliveries from Central Stores 33 %
 Branch stockrooms 24 %

From this breakdown it can be seen that more than half (57 percent) of all stores issues are made available directly to the users at or close to the using points, either by delivery or issue from branch stockrooms, with a resulting saving in time to the users.

The Receiving, Warehousing, and Distribution group has continued its efforts along the general lines of the program described in some detail in the last annual report; special note should be made of the progress achieved during the year in stock storage methods in the two principal stockrooms (Buildings 100 and 452) with the resulting further consolidation and saving of space, and improved and faster service over the counter.

In November 1952, responsibility for operation of the metals stockroom was transferred to Receiving, Warehousing, and Distribution. All metal stocks have been consolidated into one building, which provides better control as well as better service. On the basis of determinations made by Inventory Management, the excess metal inventory was established and physically segregated from the active stocks. The magnitude of this operation is indicated by the fact that prior to its disposal by sale, the excess metal inventory had a value of almost \$130,000. All active metal stocks have been rearranged in adequate racks and bins.

Business Operations

Fiscal

In July 1952, the financial report of the Laboratory was revised in form and content which enabled the Fiscal Division to furnish better managerial information and to meet the earlier reporting requirements established by the AEC.

A detailed systems study was initiated in January with a view to installing a punch card accounting system. This study was made in collaboration with several scientific

departments to determine which system would be best suited to the requirements of the Fiscal Division, as well as to those of computation for scientific programs. A decision to install punch card equipment was made and the new equipment and procedures are to be placed in operation January 1, 1954. Computational problems which can be handled by punch card methods will be solved as a part of the service of this organization.

The records and performance of the Laboratory fiscal operations were examined by the following audit agencies: General Accounting Office; Atomic Energy Commission Audit Branch; Haskin and Sells, Certified Public Accounts; Army Audit Agency (re Project East River).

The Fiscal Division personnel level stood at 55 on June 30, 1953, compared with 57 at the end of the previous fiscal year.

Purchasing

Activities of the Purchasing group remained at a level consistent with the previous year. The continued lessening of major construction work at the Laboratory and the increased research activity is reflected in the smaller dollar value per purchase order issued.

Table 10			
	FY 50-51	FY 51-52	FY 52-53
No. Personnel (June 30)	18	16	16
No. Requisitions Received	10,887	10,816	10,890
No. Purchase Orders Issued	11,333	11,019	12,329
No. Change Orders Issued	1442	1647	1553
Dollar Value, Orders Issued	\$2,419,000	\$1,922,000	\$1,933,000

The revised purchase order introduced during the previous fiscal year continued to prove its worth. Considerable interest has been shown in it not only by other AEC contractors but also by universities and industrial organizations. About 1000 samples of the new purchase order form have been provided to others for study.

With the exception of certain selected items such as some metals and special electronics items, there appears to have been some improvement during the year in the availability of most materials and supplies. This has meant increased competition among suppliers and a widening choice of vendors for the Laboratory.

In cooperation with Inventory Management and Warehousing, Purchasing has expanded its activities in the direction of bulk buying, whenever possible on an as-needed basis, of items in general and constant use. Purchasing, as sales agent for AUI-BNL, has had an active part in the Laboratory's program for disposition of excess equipments and supplies.

Inventory Management

In cooperation with the scientific, maintenance, warehousing, purchasing, and fiscal groups, particular attention was given to several areas of the inventory problem:

- removal from active inventory of items which were no longer of interest because of technological advances
- reduction of quantities of items, held in active inventory, which were in extremely large supply
- standardization of items in common use and restriction of size and style ranges to those in active use

- increase of the variety of items in inventory, which minimizes direct purchases and over-stocks in the various departments
- enlargement of bulk-buying, whenever possible on a deliver-as-needed basis, in order to obtain the most favorable terms
- utilization of excess lists of other AEC contractors and installations, as well as other government agencies, for favorable purchases of needed items
- disposition of excess inventory

The results of these various areas of activity are summarized in Table 11.

Table 11			
Inventory Changes			
Type of Inventory	Fiscal Year		
	1950-51	1951-52	1952-53
Active Inventory			
Opening active inventory July 1	\$1,080,884	\$ 803,322	\$ 552,139
Net of purchases, stores issues, adjustments, additions to inventory, transfers to excess	-277,562	-251,183	-133,530
Closing active inventory June 30	803,322	552,139	418,609
Excess Inventory			
Opening excess inventory July 1	38,843	180,568	311,855
Net of transfers from active inventory, dispositions, and adjustments	141,725	131,287	-157,657
Closing excess inventory June 30	180,568	311,855	154,198
Total Inventory			
Opening total inventory July 1	1,119,727	983,890	863,994
Net of purchases, stores issues, adjustments, transfers to excess and dispositions	-135,837	-119,896	-291,187
Closing Total Inventory June 30	\$ 983,890	\$ 863,994	\$ 572,807

Number of months' investment in active inventory:

	<u>1951</u>	<u>1952</u>	<u>1953</u>
at June 30	14 months	10 months	7.9 months

Table 12			
Disposition of Excess Inventory			
	Fiscal 1950-51	Fiscal 1951-52	Fiscal 1952-53
Book values of excess inventory sold	\$82,700	\$77,400	\$202,300
Receipts from sales	19,300	33,700	110,700
% of book value recovered	23.4	43.5	54.7

Office Services

In addition to the established functions of the Office Services section, including mail handling, telephone and telegraph service, messenger service, typewriter and other office machine maintenance, and archives, several other responsibilities have been assumed by this group during the latter part of the fiscal year.

These include the acquisition, issuance and retirement of office furniture, the preparation of pads of all types, responsibility for the program for the scheduled replacement of over-age typewriters and other business machines, and a start on an active records program beginning with the disposal of quantities of non-record material from archives.

As part of the records program, all requests for filing equipment are being carefully studied to eliminate unnecessary purchases and secure more effective utilization of existing equipment through disposal of inactive records.

Security and Plant Protection

Activities of the Security and Plant Protection Division during the past fiscal year roughly paralleled those of the previous year, as shown below (figures taken as of June 30th).

Table 13		
	1951-52	1952-53
Division personnel	118	116
Regular visitors processed	13,000	17,667
Conference visitors processed	3,500	2,555
Clearances processed	1,300	1,235
Fire group inspections	1,500	1,706
Fire group responses	56	59 On site 3 Off site

Regularly scheduled police posts have remained the same and require assignment of approximately 24 men on each 8-hour tour, 7 days per week. In addition approximately 9000 man-hours were expended to cover other special posts and details, compared with approximately 11,000 man-hours during the previous year. The totals would have been more nearly equal had an anticipated special project (classified) not been cancelled. As heretofore, these extra man-hours were needed in the controlled areas, for new construction and repairs in restricted areas, for escorting non-cleared sub-contractor employees and others, for tours and classified conferences, for special projects and experiments in the metallurgy laboratory after hours and for classified work outside the restricted areas, etc.

The Fire Group, in addition to responding to 62 alarms, also made 19 investigations of small fires extinguished locally by other personnel. Regular fire inspections increased from 1500 to 1706, and there are the normal monthly inspections of each of the 1049 fire extinguishers and approximately 550 monthly inspections covering sprinklers, alarm boxes, hydrants, etc. All physically able patrolmen have now qualified as auxiliary firefighters with 547 hours of fire training.

Retraining classes for all police personnel were held during the month of June and included firing on the pistol range and a written examination. Sixteen men qualified as "Expert" on the range with scores of 90 or better and have received appropriate medals to be worn with official uniform.

On May 4, 1953, a contract was signed by the Laboratory and the United Security Employees Union acting as bargaining agent for the Police Group; lieutenants and sergeants are excluded. Provisions of the contract in no way affect or interfere with normal operating procedures required under AEC security regulations.

Several test runs of the Emergency Organization were conducted during the past few months in conjunction with state or county-wide civilian defense test alerts. Retraining of the various emergency squads will be undertaken during the fall in medical, rescue, police, fire and special detail work. All members of the Emergency Organization are volunteer Laboratory employees who have demonstrated an interest in this extra-curricular work.

There have been no police or fire problems of a critical nature during the year.

APPENDIX

A. UNCLASSIFIED PUBLICATIONS, JULY 1, 1952 - JUNE 30, 1953

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, 1952 (BNL 195 (AS-6))

Quarterly Progress Reports:

July 1 - September 30, 1952 (BNL 209 (S-15))

October 1 - December 31, 1952 (BNL 219 (S-16))

January 1 - March 31, 1953 (BNL 232 (S-17))

April 1 - June 30, 1953 (BNL 243 (S-18))

Conference Reports:

Brookhaven Symposia in Biology No. 5. Major Metabolic Fuels (BNL 205 (C-15))

Notes on the High Energy Accelerator Conference (BNL 213 (C-16))

*General Instrumentation Conference (Abstracts) (BNL 217 (C-17))

Proceedings of the Mev Neutron Cross Sections Conference (BNL 224 (C-18))

Guides to Russian Scientific Periodical Literature No. 46 (BNL 169 (L-96))

Weekly Bulletin 5, #50-52; 6, #1-49

Weekly Selected Reading List 5, #18-52, 6, #1-17

STAFF PUBLICATIONS AND ABSTRACTS

Accelerator Department

Blewett, J.P., Blewett, M.H., Green, G.K., Moore, W.H. and Smith, L.W.

Magnet, Part I - Design

Rev. Sci. Instr. (In press)

Blewett, J.P. (See Courant, E.D.)

Blewett, J.P., Blewett, M.H., Moore, W.H. and Smith, L.W.

Pole-face windings, Part I -- Design

Rev. Sci. Instr. (In press)

Blewett, J.P.

Radial focusing in the linear accelerator

Phys. Rev. 88, 1197-9 (1952)

Blewett, J.P.

R-F system, Part I -- Design principles

Rev. Sci. Instr. (In press)

Blewett, J.P., Rogers, E.J. and Swartz, C.E.

R-F system, Part II -- Frequency control

Rev. Sci. Instr. (In press)

Blewett, J.P., Plotkin, M. and Rogers, E.J.

R-F system, Part IV -- Accelerating unit

Rev. Sci. Instr. (In press)

Blewett, J.P., Blewett, M.H. and Plotkin, M.

R-F system, Part V -- Properties of ferromagnetic ferrites

Rev. Sci. Instr. (In press)

Blewett, M.H.

The Cosmotron -- A review

Rev. Sci. Instr. (In press)

† Also included are those listings from the last Annual Report (BNL 196 (AS-6)) for which complete reference information was not then available.

* For official use only.

- Blewett, M.H.
Eddy current phenomena in the Cosmotron
Rev. Sci. Instr. (In press)
- Blewett, M.H. (See Blewett, J.P.)
- Blewett, M.H., Kelly, J.M. and Moore, W.H.
Magnet, Part IV -- Testing program for the individual blocks of the magnet
Rev. Sci. Instr. (In press)
- Blewett, M.H., Green, G.K., Kassner, R.R., Moore, W.H., Smith, L.W. and Snyder, H.S.
Studies of injection phenomena in the Cosmotron
Rev. Sci. Instr. (In press)
- Cottingham, J.G., Moore, W.H., Rogers, E.J. and Turner, C.M.
Injection system, Part II -- Injection optics
Rev. Sci. Instr. (In press)
- Courant, E.D. and Sternheimer, R.M.
Calculations of the protons' radial oscillations at injection
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- Courant, E.D.
Field inhomogeneities in alternating gradient synchrotron
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Phys. Rev. 91, 202-3 (1953)
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Revision of gas scattering theory
Rev. Sci. Instr. (In press)
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The strong focusing synchrotron -- A new high energy accelerator
Phys. Rev. 88, 1190-6 (1952)
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Rev. Sci. Instr. (In press)
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Control system, Part III -- Peaking strips
Rev. Sci. Instr. (In press)
- Green, G.K. and Kassner, R.R.
Control system, Part I -- Central control and wiring
Rev. Sci. Instr. (In press)
- Green, G.K. (See Giordano, S.)
- Green, G.K. (See Blewett, J.P.)
- Green, G.K., Kassner, R.R., Moore, W.H. and Smith, L.W.
Magnet, Part II -- Magnetic measurements
Rev. Sci. Instr. (In press)
- Green, G.K. and Shelton, E.E.
Magnet, Part VI -- Power supply
Rev. Sci. Instr. (In press)
- Green, G.K. (See Blewett, M.H.)
- Jacobus, D.D. and Polk, I.J.
Vacuum system, Part I -- Vacuum chamber
Rev. Sci. Instr. (In press)
- Kassner, D. and Lasky, C.
Vacuum system, Part II -- Pumping system
Rev. Sci. Instr. (In press)
- Kassner, R.R. (See Green, G.K.)
- Kassner, R.R. (See Blewett, M.H.)
- Kelly, J.M. (See Blewett, M.H.)
- Kosh, J.A. and Livingston, M.S.
Magnet, Part V -- Coil
Rev. Sci. Instr. (In press)
- Lasky, C. (See Kassner, D.)
- Leavitt, C.P. (See Smith, L.W.)
- Leavitt, C.P. (See Widgoff, M.)
- Livingston, M.S. (See Kosh, J.A.)
- Livingston, M.S. (See Courant, E.D.)
- Mede, J.J.
Pole-face windings, Part II -- Fabrication
Rev. Sci. Instr. (In press)

- Meyer, R.A. and Moore, W.H.
 Magnet, Part III -- Mechanical design, fabrication and erection
 Rev. Sci. Instr. (In press)
- Moore, W.H. (See Cottingham, J.G.)
- Moore, W.H. (See Blewett, J.P.)
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- Moore, W.H. (See Blewett, M.H.)
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 R-F system, Part III -- Power amplifier
 Rev. Sci. Instr. (In press)
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- Rogers, E.J. (See Giordano, S.)
- Rogers, E.J. and Turner, C.M.
 Injection system, Part I -- Van de Graaff accelerator
 Rev. Sci. Instr. (In press)
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- Shapiro, A.M. (See Smith, L.W.)
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- Shelton, E.E. (See Green, G.K.)
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 Bull. Am. Phys. Soc. 28, 15 (1953)
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 Phys. Rev. 88, 851-9 (1952)
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 Rev. Sci. Instr. 23, 629-34 (1952)
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 Phys. Rev. 89, 1148 (1953)
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 The Cosmotron building
 Rev. Sci. Instr. (In press)
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 Control system, Part IV -- Pick-up electrodes
 Rev. Sci. Instr. (In press)
- Swartz, C.E. (See Smith, L.W.)
- Swartz, C.E. (See Blewett, J.P.)
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- Turner, C.M. (See Rogers, E.J.)
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- Yuan, L.C.L. (See Plotkin, M.)

Architectural Planning and Plant Maintenance Department

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 The unique Brookhaven National Laboratory Cosmotron motor generator foundation
 Engineering-News Record, March, 1953

Biology Department

- Agnew, A. (See Moses, M.J.)
- Bard, R.C. (See DeMoss, R.D.)

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- Christensen, E. (See Gunkel, J.E.)
- Clarke, E. and Koshland, D.E., Jr.
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- Smith, A. (See der Mateosian, E.)
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Reactor Department

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B. OFFICERS AND SCIENTIFIC STAFF

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Gerald F. Tape, Deputy Director

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Marvin Fox, Chairman, Reactor Department
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Edward W. Dexter
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 Jack J. Kraushaar
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 Jules S. Levin
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 Phyllis Levy
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 Marshall H. Sirvetz
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 Alan Thorndike
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 William L. Whitemore
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 Mildred Widgoff

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Reactor Department

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Wallace deLaguna

(assigned from US Geological Survey)

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Hughie L. Foote

(graduate student from U. of Utah)

Eugene R. French

(assigned from US Geological Survey)

Walter W. Godsin*

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Gerald S. Lellouche*

Walter Lones

Philip W. Mathay

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Daniel A. Mazzarella*

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