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Annual Report

July 1, 1968

BROOKHAVEN NATIONAL LABORATORY

Upton, Long Island, New York

Brookhaven National Laboratory is operated under a contract between the United States Atomic Energy Commission and Associated Universities, Inc. This, the nineteenth in a series of unclassified Annual Reports, gives an account of the progress of the Laboratory during the period July 1, 1967 - June 30, 1968, and its plans for the future. It is submitted under the terms of Contract No. AT-30-2-GEN-16 between Associated Universities, Inc., and the Atomic Energy Commission.

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BNL 682 (AS-15) July 1, 1961
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THE NUMBER OF EMPLOYEES IN EACH ORGANIZATIONAL UNIT ON
JULY 1, 1968, IS SHOWN. TOTAL FOR THE LABORATORY, 3341.

Aerial view of the central portion of the Laboratory site. New construction and major facilities: A. Alternating Gradient Synchrotron and 80-in. Bubble Chamber; B. High Flux Beam Research Reactor; C. Graphite Research Reactor and Hot Laboratory; D. Physics and Applied Mathematics Buildings; E. Chemistry Building; F. Tandem Van de Graaff Building; G. Lecture Hall-Cafeteria; H. Medical Research Center and Medical Reactor.

Introduction

The program and activities of Brookhaven National Laboratory during the fiscal year 1968 are described in this annual report. The progress and trends of the research program are presented together with a description of the operational, service, and administrative activities of the Laboratory. The scientific and technical details of the many research and development activities are covered more fully in scientific and technical periodicals and special reports of the Laboratory. A list of all publications published or submitted for publication during the year may be found in Appendix A.

Technical publications.

RESEARCH PROGRAM

The Brookhaven research program, which covers a wide range of subjects in the physical and biological sciences and in engineering, has as its central motif the development and exploitation of nuclear

science and technology. It can be broadly described under five main headings:

1. FUNDAMENTAL STUDIES OF ATOMIC NUCLEI, THE PARTICLES THAT CONSTITUTE THEM, AND THE FORCES INVOLVED IN THEIR STRUCTURE. These studies, which are basic to all nuclear science and technology, involve the use of all the major machines of the Laboratory. They range from measurements of the properties of undisturbed nuclei to study of the violent disruptions resulting from nuclear fission or from bombardment with high energy protons from the Laboratory's 33-BeV Alternating Gradient Synchrotron (AGS).

2. STUDIES OF THE PHYSICAL, CHEMICAL, AND BIOLOGICAL EFFECTS OF NUCLEAR RADIATION. The effects of radiation are utilized to determine the characteristics of physical and chemical structures and to elucidate the more complex properties of living systems and the changes they undergo in their life and reproductive cycles. Of direct practical interest are the possible deleterious effects of radiation upon biological systems and upon various materials, for example, those involved in reactor construction. Of equal interest are the potentially beneficial effects of radiation in the treatment of diseases, in the induction of genetic changes in plants or animals, and in the improvement of manufacturing processes.

3. THE USE OF NUCLEAR TOOLS, SUCH AS NEUTRONS, CHARGED PARTICLES, GAMMA RAYS, AND ISOTOPIC TRACERS, IN ALL BRANCHES OF SCIENTIFIC RESEARCH. In this broad and diversified field, which overlaps the one just mentioned, nuclear particles and radiations are used as tools in studying physical, chemical, and biological systems in their undisturbed states. Neutrons and other particles are used as probes: by observing their penetration and scattering, minute details of physical and chemical structure can be studied. Wide use is made of isotopic tracers in many fields to yield information on such matters as the mechanisms and rates of chemical reactions and biological processes.

4. RESEARCH AND DEVELOPMENT, NOT NECESSARILY ITSELF OF A NUCLEAR NATURE, DIRECTED TOWARD SOLVING THE PROBLEMS OF ATOMIC ENERGY DEVELOPMENT. The more basic aspects of this

Patient having his blood pressure checked by one of the physicians who carry out research on hypertension, one of the varied clinical research programs of the Hospital of the Medical Research Center.

The electromagnetic isotope separator in the Chemistry Department, used to sort products of high energy nuclear reactions produced by 30-BeV protons in the AGS. In many cases, such products are not uniquely identifiable by radioisotopic assay and must first be vaporized, ionized, and separated electromagnetically in the 60-in.-radius magnet (right). In recent experiments at Brookhaven, the rare-earth nuclides (masses 143 to 161) produced by irradiation of uranium targets with high energy protons were studied. Evidence was obtained for formation of neutron-deficient nuclei in processes in which hundreds of MeV energy are deposited, whereas the deposition of small amounts of energy (tens of MeV) leads to neutron-excess masses. These results establish on a much more general basis ideas previously developed here for high energy nuclear reaction mechanisms.

category include the chemistry of elements and compounds of special interest, isotope effects, the metallurgy of materials used in nuclear reactors and other devices of importance in the atomic energy program, the neutron scattering and absorbing properties of substances used in reactors and other nuclear devices, and similar subjects. Among its applications are the development of reactor components such as fuels, structures, and shields, the development of components and processes for the chemical processing and useful recovery of reactor products, and theoretical and experimental studies in the field of reactor physics.

5. THE DEVELOPMENT OF SPECIFIC DEVICES FOR USE AS RESEARCH TOOLS OR IN PRACTICAL APPLICATIONS OF ATOMIC ENERGY. This category includes both the design and development of special research tools, such as accelerators, reactors, and other technical equipment, and the development of devices for practical applications of atomic energy, such as the preparation of special isotopes, the development and packaging of high-intensity radiation sources, and basic development work on power reactor systems.

The involvement of the various scientific disciplines in these areas of study and development results in a coherence and mutuality of interest that enhance the entire program of the Laboratory in both tangible and intangible ways. Specific research projects are described in those sections of this report devoted to the particular discipline or organizational unit in which the work is being carried out. It will be noted that research interests overlap from one department to another, and similar problems are being attacked from different points of view.

In addition, the international aspects of the research program should be pointed out. Besides providing research opportunities for many scientists and students from other countries, Brookhaven has a general program of international cooperation which includes cooperative agreements with the nuclear centers in Greece and Puerto Rico and participation in the "Atoms for Peace" traveling AEC nuclear energy exhibits in Europe, Asia, and South America.

RESEARCH FACILITIES

Research at Brookhaven is centered on, although not confined to, the use of several large machines and other special facilities, some of which are described below.

Multiple-layer insulation being applied to the liquid helium Dewar containing the 7-ft test facility superconducting magnet. The assembly is completed by lowering a stainless steel vacuum tank, 10½ ft in diameter and ½ in. thick, over the superinsulation. In this way the space can be evacuated to make the aluminized Mylar layers a very efficient radiation shield. The Dewar is cooled to about 4.5° K and filled with liquid helium. This allows the coil to be in a superconducting state (i.e., the conductor has zero resistance). The magnet coil, consisting of reinforced turns of stabilized Ni-Ti superconductors, is wound with a cooling spacer strip, which permits one side of the superconductor to be in contact with the liquid helium. The coil is designed to produce a uniform field of 30 kG in the central region, which has a bore of 7 ft. 8 in. and a height of about 9 ft. In May 1968 the magnet was powered and tested at half field (15 kG); it is, at present, the world's largest superconducting magnet to be energized. The magnet will be used for studies of design concepts for large cryogenic bubble chambers, as well as for research in high energy physics. The magnet surrounds a 7-ft test vessel or bubble chamber; the magnetic field is needed to analyze the bubble tracks produced in this chamber. It is planned to extend the results of these studies to the construction of even larger "new-generation" bubble chambers.

Cell structure being studied by means of staining techniques in the Biology Department's cytology laboratory. Differences between cells from irradiated, normal, young, and old mice are thus made apparent. This work is part of the study of the acceleration of the aging process that occurs in animals as a result of doses of radiation.

Alternating Gradient Synchrotron

The AGS, Brookhaven's 33-BeV proton synchrotron, continues to be one of the major centers for research in high energy physics. Increases in the peak and average intensities of the accelerated beam continued during the year. A major improvement to the facility, the slow extracted beam system, has been successfully tested and is now available for limited operational use.

struction involved the AGS conversion program, for which funds were available during the fiscal year. By the end of the year about 40% of the project funds had been committed.

A complete report on the AGS will be found in the section on High Energy Accelerators.

Low Energy Accelerator Facility

Upon completion of the new 30-MeV tandem Van de Graaff accelerator, the principal research

A chemist using the gas-liquid chromatographic apparatus to investigate the products formed when atoms of very high kinetic energy interact with organic molecules. Following irradiation, a small amount of target material is passed through the spiral column; the different organic species travel at different rates and can be separated, and the amount and radioactive content of each species is determined. The data are recorded on magnetic tape, and the results are then evaluated and corrected on a computer.

This year, for the first time, the AGS was required to run for extended periods with the proton intensity intentionally reduced. The peak intensity reached (2.6×10^{12} protons/pulse) was a 20% increase over last year's peak, with shift averages $> 2.2 \times 10^{12}$ realized. This intensity was well above that required by experimenters. Because of this and the need to prevent excessive increases in radiation levels at the machine, the intensity was held to an average of 1.7×10^{12} .

The AGS was shut down from November 12 through January 11, primarily to install phase I of the slow extracted beam system. Other con-

efforts of the accelerator center will begin to be transferred to that machine. However, since full-scale operation of the tandem Van de Graaff on a routine basis is not expected before mid-1970, the modified 60-in. cyclotron and the 4-MeV Van de Graaff will continue to be used as major research tools for the next two years. These machines will gradually be placed in a support operations category to the tandem Van de Graaff, as part of an over-all low energy accelerator facility (LEAF) concept. LEAF will also include the 3-MeV electron accelerator used in the solid state physics program.

The Van de Graaff electrostatic generator accelerates protons, deuterons, He^3 , and He^4 ions with beam currents up to 75 μA and energies up to 4 MeV. The machine has been modified to permit acceleration of beams of tritons and of doubly ionized helium. These beams, together with recently improved measuring devices, will be used in the study of a wide variety of new nuclear reactions and in establishing the properties of energy levels heretofore inaccessible at Brookhaven.

The variable-energy spiral-ridge conversion of the 60-in. cyclotron has been completed. The nominal energy range is from 40 MeV down to 5.5 MeV for protons; from 20 to 12 MeV for deuterons; from 40 to 24 MeV for He^4 ; and from 57 to 18 MeV for He^3 . These limits can be extended downward considerably by use of third harmonic acceleration and upward a small amount by pushing the design limit to higher fields. A switching magnet is in place, and three beam pipes will be available. A negative ion extraction facility is also available for small beams of hydrogen ions. The machine is undergoing performance tests at present, and the deflector to provide external beams of positive ions in the target room has not yet been installed. Its use, both current and projected, involves isotope production with some emphasis on particularly short-lived species, molecular scattering, organic chemistry, direct irradiation of biological systems, and especially charged particle reaction and scattering.

The small Van de Graaff machine can be very useful in the low energy region for which the tandem Van de Graaff is not well suited and, in some cases, in preliminary setup and testing measurements before the start of a tandem experiment. After the tandem Van de Graaff goes into full operation, such needs can be met by maintaining the small machine on a ready-standby basis. The cyclotron as well will provide valuable support for the tandem program. Experimental difficulties that can be checked out on this machine will represent substantial cost savings in the tandem operation. Time spent on the three-stage tandem accelerator for solving background and other experimental problems that do not provide useful data is considerably more expensive than it would be on the cyclotron. Irradiation of particular targets for nuclear structure work, nuclear chemical work, and biomedical work can be accomplished better and less expensively by using the cyclotron. In addition, maintenance of the cyclotron as an operat-

ing machine will permit its future use for negative ion injection into the tandem Van de Graaff. In the LEAF concept, maintenance and operational crews for all machines will be employed in a single unified operation.

High Flux Beam Research Reactor

The High Flux Beam Research Reactor (HFBR), which achieved initial criticality in October 1965 and attained its full design power of 40 MW in February 1966, produced a total of 9742 MWd of energy during the year, compared with 8854 MWd during fiscal 1967. The experimental program with this reactor continued to grow, and at the end of fiscal 1968 all the experimental beam holes were in use. No major operating difficulties were encountered.

The HFBR, designed at BNL to meet the need for very high neutron fluxes, has a compact core of 28 ETR-type enriched-uranium fuel elements cooled, moderated, and reflected by heavy water. Sixteen experimental facilities are available; nine of these convey beams of neutrons outside the reactor, and seven allow materials to be irradiated inside it. Additional information on the HFBR may be found in the section on Technical Operations and Services.

Graphite Research Reactor

The Brookhaven Graphite Research Reactor (BGRR), which has been in almost continuous operation since its initial startup in 1950, was placed on standby duty as of the week of June 10, to be reactivated only when an experimental program can support the financial burden. The duty cycle of this reactor had been reduced in July 1967 to a basic schedule of 24 hr/day for 5 days every fourth week, coinciding with the shutdown of the HFBR, at a power level of 20 MW, and the remainder of the time at 15 MW for 7 hr/day during the Laboratory's normal working hours.

Medical Research Reactor

The Medical Research Reactor (MMR), which achieved criticality in March 1959, was designed for the purpose of exploring the possible applications of nuclear reactors to the study of man and his diseases. During the past year it was operated on 122 days, and 415.659 MWh of operation were accumulated. No serious operating difficulties were encountered.

Several changes in the MRR were completed prior to the BGRR's being placed on a standby basis to enable the MRR to perform the irradiations previously available at the latter reactor.

Hot Laboratory

The Hot Laboratory, which is adjacent to the BGRR, contains extensive facilities for the processing, handling, and analysis of highly radioactive materials. It includes three hot cells in which chemical operations can be performed remotely while being observed by periscope, a large hot cell for complete physical examination of radioactive metals and other materials, and several totally sealed systems, some of which are shielded, for working with alpha emitters alone or accompanied by gamma radiation. A program for the development of special radioisotopes, especially those intended for medical research, has been carried on in the Hot Laboratory since 1950.

Critical Assembly Laboratory

The Critical Assembly Laboratory provides specialized facilities for research in reactor physics

and for reactor development studies. These facilities include five assembly cells and their associated control areas, a counting room, two uranium storage vaults, and an analogue computer and two digital computers used for on-line processing as well as for standard data reduction. Two of the cells contain neutron source reactors, and a fast source reactor (designated FS-1) is now available for experimental use in another cell. The FS-1 Reactor achieved criticality last October.

High Intensity Radiation Development Laboratory

The primary function of the High Intensity Radiation Development Laboratory (HIRDL) is to obtain engineering data on a variety of radiation sources in the million-curie range and to develop more efficient techniques for handling large-scale radiation sources. This information is essential for the design of future irradiation facilities needed for a wide range of applications of radiation energy. During the fiscal year more than one million curies of Co^{60} and Cs^{137} were received at HIRDL and made available for research at Brookhaven and elsewhere. A portable cesium

The cask section of a shipboard irradiator, packed in its shipping frame, being lowered at the HFBR onto a flat-bed trailer for shipment to Iceland on May 20. This facility, which is loaded with about 30,000 curies of Co^{60} , is now in use to develop techniques in the radiation preservation of fresh fish.

The Fast Source (FS-1) Reactor in the Critical Assembly Facility Building, shown with the halves separated and the core exposed. This reactor, designed to investigate the general characteristics of all types of fast reactors, achieved initial criticality on October 31. The core is built up of 29 layers of U^{235} alternating with layers of graphite, surrounded by a minimum of 18 inches of steel on each side. A radium-beryllium source is located under the center of the core. The maximum power output of FS-1 is ≈ 1 kW, but the reactor will generally be operated at ≈ 1 W, to minimize residual radiation.

Students visiting the High Intensity Radiation Development Laboratory on High School Visitors' Day on October 21 were fascinated by the remote-control manipulators. These devices are used in handling radioactive materials to avoid direct contact, which would present hazards to personnel. They are operated from behind heavy glass shielding windows.

irradiator (PCI) with a 190,000-curie source of Cs^{137} was completed and mounted on a trailer; the food irradiation capabilities of this unit have now been demonstrated extensively throughout the nation. A shipboard irradiator, having undergone modifications at Brookhaven, is on loan to Iceland for fish preservation studies.

80-in. Liquid Hydrogen Bubble Chamber

During the year the 80-in. liquid hydrogen bubble chamber, located in the North Experimental Area of the AGS, produced 1.5 million photographs. This chamber, the largest operating device of its kind, has an effective volume of 850 liters. It is positioned inside a vacuum chamber; a magnet capable of producing magnetic fields as high as 20,000 gauss with its 280-ton steel yoke

completes the assembly, which is constructed in two units that separate to give access to the chamber. The entire 450-ton chamber and magnet assembly rides on an undercarriage and can be translated, rotated, and elevated as required by the experimental program. The flexibility of the chamber has been increased by the use of a neon-hydrogen mixture in several experiments in place of pure hydrogen. More information on the 80-in. chamber may be found in the section on Physics.

Central Scientific Computing Facility

The operations of the Central Scientific Computing Facility (CSCF) are supported by three large-scale and two small-scale digital computers: two CDC 6600's and one IBM 7094, and one CDC 924 and one IBM 1401. The two CDC 6600 computers were operated essentially as one system and, as such, constituted the principal computing system at the Laboratory. They are utilized for general-purpose scientific computation. The delivery of a one-million-word extended core storage unit, to be coupled to and shared by both CDC 6600's, is scheduled for July 1968. The second

Tandem Van de Graaff Accelerator Facility. Shown in this cut-away view are two model MP Van de Graaff electrostatic accelerators (3, 9), each independently capable of accelerating a wide variety of ion species from external ion sources (2, 7) through beam switching magnets (4, 10) into the target rooms (11, 12, 13, 16). Highest particle energies are achieved in three-stage operation with the first accelerator (3) injecting energetic negative ions through the connecting link (5) directly into the second accelerator (9). The accelerators are operated from the centrally located control room (15), which gives direct access to the accelerator rooms through one of the shielding doors (8). The mechanical equipment room (1) contains the pumps and compressors necessary to transfer insulating gas from the storage area (6) to each accelerator pressure vessel. Laboratory and office space (14) is available for resident and visiting scientific personnel.

Construction progress on the building to house the Tandem Van de Graaff Accelerator Facility. At the rear are the Graphic Research Reactor stack and the containment dome for the High Flux Beam Research Reactor.

The new Lecture Hall-Cafeteria Building, now almost ready for occupancy.

Construction progress on the new East Experimental Building for the Alternating Gradient Synchrotron. This is part of the AGS conversion project.

major computer system, consisting of the IBM 7094 computer supported by the IBM 1401, was devoted entirely to special-purpose computing, such as the processing of bubble chamber experiments. Further information on the Laboratory's computer program is contained in the section on Applied Mathematics.

MAJOR RESEARCH FACILITIES UNDER DESIGN AND CONSTRUCTION

Tandem Van de Graaff Accelerator

The Tandem Van de Graaff Facility currently under construction will consist of two High Voltage Engineering Corp. model MP Van de Graaff accelerators capable of being operated independently or in conjunction. Independently, each accelerator will provide protons with energies up to 20 MeV and a large variety of heavier ions at higher energies. The two machines operating as a three-stage accelerator will provide protons with energies up to 30 MeV and some heavier ions at higher energies.

The building for the tandem facility will be completed by September 1968. The two 80-ft-long accelerator tanks, fabricated on site, have been moved into the building and aligned. The fast gas-transfer system necessary for handling the high-pressure insulating gas is currently being installed and will be tested before the building is accepted. All the accelerator components have been fabricated and packed by the High Voltage Engineering Corp.;

however, they will not be shipped until the building is completed and accepted.

The Laboratory's Tandem Group has assumed responsibility for modifying the standard accelerators to achieve three-stage operation. A terminal ion source system for the first accelerator is currently being fabricated. A detailed study has been made of the beam optics of these accelerators in order to ensure satisfactory performance from ion source to target in both modes of operation.

Research programs at the tandem facility are expected to begin about July 1969. Beams from the three-stage accelerator should become available early in 1970. These plans depend on the completion schedule of the building. An artist's conception of the completed facility shows the main features of the building design.

GENERAL CONSTRUCTION PROGRAM

During the year, construction was completed on new animal laboratories for the Medical Research Center.

The Lecture Hall-Cafeteria building, for which ground was broken in July 1966, is almost ready for occupancy. This facility has a gross area of 51,000 sq ft and includes a 750-seat cafeteria, a 450-seat lecture hall, and three meeting rooms for small groups.

In the AGS conversion program, for which >\$25 million has been allocated to date, construction of several of the new facilities is proceeding. Completion is scheduled for 1971. In the mean-

Scientific staff and students.

time, construction of an addition to the AGS Service Building has been completed.

A plan for a 14-ft cryogenic bubble chamber, on which some preliminary design work has been done, has been abandoned. However, Brookhaven and the National Accelerator Laboratory in Illinois will submit a joint request for fiscal 1970 proposing the construction of a 25-ft bubble chamber.

PERSONNEL

The total number of employees at the Laboratory on June 30, 1968, excluding temporary appointees, Research Collaborators, and guests, was 3337, a net increase of four from the 1967 figure. During the year the regular scientific staff (Ph.D or equivalent) increased from 464 to 476, Research Associates* decreased from 82 to 72, and salaried visitors* increased from 27 to 28, for a net increase in salaried staff of 3, from 573 to 576. The non-salaried scientific staff increased from 765 in 1967 to 830 in 1968 as of May 31 of these years. The latter visitors are not at Brookhaven on a full-time basis. About one-fourth to one-third of them are on site at any one time. A total of 644, as compared with 596 in 1967, visiting scientists and students worked at the Laboratory during the year; this number does not include Research Associates.

Summer visitors continue to play a significant role in the Laboratory's program. Arrangements have been made for 274 visiting scientists and students to work at Brookhaven during the summer of 1968. Of this number, 120 are staff members from various educational and research institutions, and 154 are students.

ADMINISTRATION

The organization of the Laboratory and the corporate structure, both as of July 1, 1968, are shown on the Organization Chart and in other material at the front of this report. At its annual meeting in October 1967 the AUI Board of Trustees re-elected all officers of the corporation, with one exception. Dr. Franklin A. Long was chosen Chairman of the Board for a two-year term, to succeed Dr. Ernest F. Johnson. Some changes were also made in the composition of the Board itself. Dr. Milton G. White succeeded Dr. Val L. Fitch

*These categories include students. For further details, see the section on Administration and Operations.

as University Trustee from Princeton University, and Dr. Carl C. Chambers returned to the Board as a University Trustee from the University of Pennsylvania, replacing Mr. Harold E. Manley, who resigned. Pursuant to action at the annual meeting, Provost Charles H. Taylor, Jr., on January 1, 1968, succeeded Dr. Arthur M. Ross as University Trustee from Yale University. Among the Trustees-at-Large, Dr. Herbert Friedman, of the Naval Research Laboratory, was elected for a three-year term, succeeding Mr. Theodore P. Wright, whose term expired at the annual meeting. Soon after January 1, 1968, the President of AUI, Dr. T. Keith Glennan, presented his resignation, to be effective July 1, 1968. Pursuant to subsequent action of the Trustees, Dr. Franklin A. Long, Chairman of the Board, was authorized to exercise all the powers of the President, pending selection of a successor to Dr. Glennan.

Three changes in Laboratory administration took effect on July 1, 1968: Dr. Gerhart Friedlander became Chairman of the Chemistry Department, replacing Dr. Richard W. Dodson, who returned to full-time research; Mr. Vincent R. O'Leary, Laboratory Budget Officer, was promoted to the newly created post of Assistant Director for Financial Planning; and Mr. Robert Chase became Head of the Instrumentation Division, replacing Dr. William Higinbotham, who will be spending full time as a member of the Safeguards and Materials Management Division in the Nuclear Engineering Department.

FINANCE

AEC-supported research at the Laboratory continued to be financed by the AEC Divisions of Reactor Development and Technology, Research (Physical Sciences), Biology and Medicine (Life Sciences), Training and Education, and Isotope Development. Operating costs for the work in each program and the major categories of operating expenditures are shown in the accompanying figure.

CONFERENCES

Eight major conferences were held at Brookhaven during 1968: the International Conference on Solid State Physics Research With Accelerators, September 25-28; the Woodland-Water Working Group of the International Biological

OPERATING COST DISTRIBUTION BY PROGRAMS

FISCAL YEAR	PHYSICAL SCIENCES	REACTOR DEVELOPMENT	LIFE SCIENCES	ISOTOPE DEVELOPMENT	TRAINING & EDUCATION	OTHER (NET)	TOTAL COST
1968	33,737,789	5,098,856	7,605,319	1,209,620	227,390	1,553,662	49,432,636
1967	33,584,030	5,947,334	7,258,843	1,212,747	288,148	1,226,859	49,517,961
1966	32,708,048	6,086,937	7,015,987	1,073,696	311,476	1,019,818	48,215,962

MAJOR CATEGORIES OF OPERATING EXPENDITURES

FISCAL YEAR	SALARIES & WAGES	MATERIALS & SUPPLIES, SUBCONTRACTS, TRAVEL & SPECIAL PROCUREMENTS	POWER	MISCELLANEOUS (NET)	OPERATING TOTAL
1968	36,229,083	9,476,341	1,828,578	1,898,634	49,432,636
1967	34,748,253	10,902,767	1,838,203	2,028,738	49,517,961
1966	33,738,859	11,409,512	1,756,098	1,311,493	48,215,962

BROOKHAVEN NATIONAL LABORATORY COMPARATIVE BALANCE SHEET

<u>Assets</u>		June 30, 1968	June 30, 1967
Cash		\$ 129,158	\$ 153,560
Accounts receivable		191,602	173,266
Advances, deposits, and prepaid expenses		68,042	82,154
Property, plant, and equipment (less reserves of \$87,502,666 at June 30, 1968, and \$80,202,277 at June 30, 1967)		161,286,582	155,853,029
Research materials and supplies		18,558,445	16,924,766
Total assets		<u>\$180,233,829</u>	<u>\$173,186,775</u>
<u>Liabilities</u>			
Accounts payable		\$ 4,780,094	\$ 6,964,582
Accrued vacation		3,225,824	3,031,150
Accrued payroll		271,750	249,059
Atomic Energy Commission		171,956,161	162,941,984
Total liabilities		<u>\$180,233,829</u>	<u>\$173,186,775</u>

NOTE: Although the Laboratory has custody and use of the assets, title remains vested in the United States Government.

Lecturers at BNL during fiscal 1968. André Maurois (upper left), Man of Letters, who was invited to deliver the 1967 George B. Pegram Lectures, had prepared three lectures collectively entitled "The Illusions." Death occurred as he was about to leave for Brookhaven, and his lectures were delivered by Dr. Jacques Barzun (upper right), University Professor at Columbia, on May 13 and 15. Ian L. McHarg (lower left), Chairman of the Department of Landscape Architecture and Regional Planning at the University of Pennsylvania, gave the fifth AUI Distinguished Lecture on February 5. His subject was "Values, Process, and Form." The sixth AUI Distinguished Lecture, entitled "Scientists and Politicians: A View From the Press Box," was delivered on March 26 by Daniel S. Greenberg (lower right), News Editor of *Science*.

Program, December 28-29; Future Bubble Chamber Processing Conference, January 24-25; the Organic Solid-State Chemistry Symposium, sponsored by BNL and the State University of New York at Stony Brook, March 25-28; the Conference on Industrial Needs and Academic Re-

search in Reactor Kinetics, April 8-9; the Proton Linear Accelerator Conference, May 20-24; Biology Symposium No. 21, entitled "Structure, Function, and Evolution in Proteins," June 3-5; and the Summer Study on Superconducting Devices and Accelerators, June 10-July 19.

PHYSICAL
SCIENCES
AND
ENGINEERING

Physics

The physics research program consists of experimental and theoretical studies of the structure and fundamental properties of matter. These characteristics of matter can most effectively be studied by observing the interactions of charged particles, neutral particles, and radiation with individual atoms, atomic nuclei, or nucleons, and conglomerates of atoms and molecules in bulk matter. The Alternating Gradient Synchrotron, 60-in. cyclotron, Van de Graaff Accelerator, Graphite Research Reactor, and the High Flux Beam Research Reactor at Brookhaven provide many types of particles and/or radiation as well as a wide range of particle energies with which to carry out experimental investigations. The researches reported here will be described under the categories of particle physics, medium energy physics, nuclear structure, neutron physics, solid state physics, and theoretical physics. The theoretical studies are pursued in conjunction with the experimental research and provide stimuli for development of new approaches to the problems.

The work of Brookhaven scientists is augmented by that of a number of visiting and guest scientists on leave from other institutions in this country and abroad. These visitors and guests are attracted to Brookhaven not only by the availability of its facilities but also by the opportunity to collaborate with Brookhaven scientists. The interchange of ideas and experience resulting from the presence of these visiting scientists is very important to the active research program.

PARTICLE PHYSICS

Most scientists believe that all phenomena of nature are based on laws that do not change with time and position and can eventually be understood. Quantum mechanics, which has been so successful in explaining atomic processes, is an outstanding example of this orderliness of nature. For phenomena involving nucleons no such complete understanding exists, despite the fact that these particles have been studied intensively for 20 years or more. Although a satisfactory explanation of particle physics still seems quite remote, the

field continues to be of great interest because it is a frontier in the understanding of one of the most fundamental aspects of nature.

This section of the annual report describes the work done here by theoretical physicists on this problem and the work of experimental physicists who have used Brookhaven's remarkable resources for exploration of this field. A great many facts are known about the nature and behavior of the many fundamental particles that have been identified, and some simplification of these facts has been achieved through the formulation of conservation laws and invariance principles. Much of the work reported here has been directed toward testing the validity and extent of these concepts, which may provide the basis for an essentially complete understanding of particle physics.

The number of universities and laboratories sharing in the particle physics research at BNL clearly demonstrates Brookhaven's national nature. About two-thirds of the work at the Alternating Gradient Synchrotron (AGS) is done by groups from these organizations. During fiscal 1968 more than 500 guest scientists participated in the program, including representatives of all the AUI institutions:

Columbia University
Cornell University
Harvard University
Johns Hopkins University
Massachusetts Institute of Technology
Princeton University
University of Pennsylvania
University of Rochester
Yale University

Scientists from the following academic centers also participated in the research:

Brandeis University
Brown University
California Institute of Technology
Carnegie-Mellon University
Case-Western Reserve University
Duke University
Florida State University
Illinois Institute of Technology
Indiana University
Iowa State University

Rockefeller University
 Rutgers University
 Stanford University
 State University of New York at Stony Brook
 Syracuse University
 Tufts University
 University of Arizona
 University of California at Berkeley
 University of California at Davis
 University of California at Irvine
 University of California at La Jolla
 University of California at Los Angeles
 University of California at Riverside
 University of Maryland
 University of Massachusetts
 University of Michigan
 University of Notre Dame
 University of Tennessee
 University of Wisconsin
 Vanderbilt University

Guest scientists also included representatives of the following foreign laboratories and universities:

University of Melbourne, Australia
 McGill University, Montreal, Canada
 University of Manitoba, Canada
 University College, London, England
 CEN, Saclay, France
 Weizmann Institute of Science, Rehovoth, Israel
 University of Bologna, Italy
 University of Milan, Italy
 University of Padua, Italy
 University of Pisa, Italy
 University of Rome, Italy
 CERN, Geneva, Switzerland
 Max Planck Institut, Munich, West Germany

No attempt has been made to cover all the work in particle physics completed at BNL during the past fiscal year. However, a list of publications describing this work is included in Appendix A. The material that follows presents the highlights and a typical cross section of the research activity for this period.

Introduction to AGS Research

The goal of research at the AGS is comprehension of the nature of matter in terms of its fundamental building blocks and their properties. This requires a continuing search for new particles and antiparticles, as well as investigations designed to gain understanding of the forces that give rise to interactions among particles. The primary proton beam of the AGS is available at energies up to 33 BeV. When allowed to strike various internal targets, this beam provides many beams of secondary particles, including high energy neutrinos. It can also be ejected to provide beams of very high en-

ergy for bubble-chamber and special experiments. These various beams are used in experiments designed to search for new particles, resonances, and other phenomena. Studies are made of elastic and inelastic collisions of various particles with nucleons and nuclei in order to gain insight into strong, weak, and electromagnetic forces and interaction mechanisms. Observations made of the production, scattering, and decay processes of the baryons, mesons, and leptons lead to a determination of the intrinsic properties of the particles, such as charge, rest mass, spin, lifetime, decay modes, isospin, strangeness, magnetic moment, and parity, as well as the properties of their interactions with other particles.

AGS research has led to significant progress in the field of elementary particle physics during the past year. The following paragraphs describe only partially the progress made.

AGS Research Activity

A recent experiment carried out in the AGS 30° neutral beam has provided new insight into the nature of weak forces. The experiment was performed by a research team from Columbia University, and the Brookhaven PDP-6 computer was used to evaluate the data "on line." Simply stated, this experiment has demonstrated that the forces by which an electron (e^-), a positive pi meson (π^+), and an antineutrino ($\bar{\nu}$) interact are not equal in strength to the forces by which a positron (e^+), a negative pi meson (π^-), and a neutrino (ν) interact when the directions of motion of the $e^+\pi^-\nu$ particles are opposite to those of the $e^-\pi^+\bar{\nu}$ particles.

For many years physicists expected that the forces among the $e^-\pi^+\bar{\nu}$ and the direction-reversed $e^+\pi^-\nu$ particles would indeed be equal. However, equality of these forces, which is known as CP (charge conjugation, parity) symmetry, had been in question since a Princeton University group, in an earlier AGS experiment, observed the decay of the long-lived neutral K meson (K_L^0) into $\pi^+\pi^-$. This $\pi^+\pi^-$ decay is forbidden if the forces governing the interaction are CP symmetric.

The new evidence for CP violation comes from the Columbia group's measurements, which show that the rate of decay of the K_L^0 particle into $e^-\pi^+\bar{\nu}$ is less than that of K_L^0 into $e^+\pi^-\nu$ and thus imply a difference between the $e^+\pi^-\nu$ and the $e^-\pi^+\bar{\nu}$ forces. The measured difference in the decay rates was $0.44 \pm 0.08\%$.

To achieve the required accuracy, 20 million $e\pi\nu$ events were recorded by an apparatus consisting of arrays of scintillation counters situated before and after a large magnet and Čerenkov counters which identified the e^+ 's and e^- 's. The identification of the e 's and the kinematic information provided by the scintillation counter-magnet system unambiguously separated the events of interest from other decay modes of the K_L^0 particle. Data from the experiment were continually analyzed by BNL's PDP-6 computer, which was electronically connected to the apparatus. Use of the computer made it feasible to collect the necessarily large number of events and to perform the required careful search for possible asymmetries in the apparatus which might have obscured the results.

In a separate experiment with the same detectors, this Columbia group also studied the conversion of K_L^0 particles into K_S^0 particles in a 12-in. copper target. The measured interference effects between the K_L^0 and K_S^0 states were found consistent with the predictions of the $\Delta Q/\Delta S$ rule (which relates the change in charge and the change in strangeness quantum number in decays) for the K^0 decays. The results are also consistent with the theoretical model in which the CP violation in K^0 decays arises from a superweak force between elementary particles. This suggested force is so weak that it would not have been detected in nearly all experiments studying elementary particle interactions.

In an excellent example of the cooperation among research teams working at Brookhaven, collaborators from Harvard, McGill, and Case-Western Reserve Universities also used the apparatus described above (slightly modified) to study the decay $K_L^0 \rightarrow \pi^+\pi^-\pi^0$. In this experiment a search was made for an asymmetry in the π^+ and π^- energy spectra of the K_L^0 , measured by detecting $\approx 500,000$ $K_L^0 \rightarrow 3\pi$ decays. The π^+ and π^- energy spectra were found equal to within an accuracy of 1%, which indicates that the CP violating part of the force responsible for the $K_L^0 \rightarrow 3\pi$ decay is $< \frac{1}{2}\%$ of the total $K_L^0 \rightarrow 3\pi$ force.

Total cross sections for collisions between elementary particles serve as a direct measure of the size of the colliding particles and as such are of great theoretical importance. With this as motivation, a Michigan-SLAC*-Princeton group carried out an experiment in which the neutron-proton ($n-p$) total cross section for neutron momenta

was measured up to 28 BeV/c. Use was made of a novel neutron detector consisting of a series of steel slabs interspaced with scintillation counters. The counters sampled the ionization produced at various depths in the steel by the neutron-initiated cascade and thus measured the energy of the detected neutron. The $n-p$ total cross sections measured in this experiment are found equal to the known $p-p$ total cross section at 28 BeV and lie below the $p-p$ results by 2.5% at 16 BeV. The $n-p$ and $p-p$ results, when compared with the $p-d$ (proton-deuteron) total cross section, give information on the behavior of the deuteron screening with energy. It is important to understand this screening effect so that "free" neutron cross sections can be reliably extracted from cross sections measured by using the bound neutron in the deuteron as the target particle.

A possible explanation of the CP violations observed in K_L^0 decays is that the electromagnetic interactions of strongly interacting particles are not symmetric under C . Since the decays of the η meson, $\eta \rightarrow \pi^+\pi^-\pi^0$ and $\eta \rightarrow \pi^+\pi^-\gamma$, proceed via the electromagnetic interaction and not via the strong interaction, this decay could in principle display sizable C -violating effects. A Columbia University group has carefully studied the energy spectra of the pions from the $\pi^+\pi^-\pi^0$ and $\pi^+\pi^-\gamma$ decays of the η^0 and finds a difference of $1.5 \pm 0.5\%$ in the π^+ and π^- spectra for the 3π final state and a $2.4 \pm 1.4\%$ difference for the $\pi\pi\gamma$ decay. The high sensitivity of the experiment results from detailed measurements of $> 45,000$ η decays made with a digitized spark chamber system in which the chambers were located inside a large magnet. These measured $\pi^+\pi^-$ differences strongly suggest a violation of charge conjugation symmetry in η^0 decays.

The experimenters are currently examining their data and planning future experiments to improve the reliability of the asymmetry measurements. Because this apparent evidence for C violation profoundly influences theories of particle interactions, the search for other evidence of C violation will continue here and at other laboratories.

During the past year physicists from more than 30 institutions analyzed photographs from the BNL 30-in., 31-in., and 80-in. cryogenic bubble chambers and obtained results that have led to improved understanding of fundamental particles. These results were mainly in the areas of strong and weak interactions.

*Stanford Linear Accelerator Center.

The work on strong interactions involved searching for new particles or resonances and determining their properties. Usually, a resonance is detected by plotting the mass spectrum derived from experimental data; if a sudden peak or "bump" appears in the mass spectrum it is often due to a resonance. For a system of particles comprising such a bump to be classified as a resonance, it must be describable in terms of a well-defined set of numbers (quantum numbers) which include spin, parity, isospin (I), G -parity, strangeness, charge conjugation, and baryon number. The experimenter determines as many of these quantum numbers as possible by investigating in detail how the resonances are formed and subsequently decay into other particles or resonances. It is important to determine the quantum numbers of the elementary particles, so that the particles can be classified into families or groups whose members have certain common properties. For example, the pi mesons (π^+ , π^- , π^0), K mesons (K^+ , K^- , K^0 , $\bar{K}^0$), and the eta meson (η^0) make up such a group. These eight particles have the same spin and parity quantum numbers but different isospin and/or strangeness quantum numbers and, according to the group theoretical symmetry scheme $SU(3)$, belong to the same family. Categorizing particles in such a way enables theorists to predict the masses of undiscovered particles and helps them to make other important calculations.

The experimenter is also concerned with the detailed mechanisms by which particles are produced. The collision process can be loosely described as either "peripheral" or "central." As the names imply, a central collision refers to the case in which the beam particle hits the target particle head on, whereas a peripheral collision occurs when the two particles hit each other a glancing blow. One way of visualizing what happens in a peripheral interaction is to picture the beam particle transferring a small amount of momentum to the target particle while the beam and/or target particle becomes excited to a higher mass state and subsequently decays into two or more particles. Thus, the result of a peripheral interaction is the production of a "beamlike" set of particles whose total momentum is nearly that of the beam, and/or a "targetlike" set of particles whose total laboratory momentum is very small. A central collision is thought to occur when many relatively uncorrelated particles are produced. Such reactions are analyzed in terms of statistical or thermodynamical

models. Experimentally, most reactions observed are peripheral in nature.

To obtain a quantitative measure of the degree to which a reaction is peripheral, the variable t (four-momentum transfer squared) is used. Continuing in the vein described above, t depends on the change in momentum and angle between a colliding particle and the higher mass state into which it transforms as a result of the collision. For a given final state, the more peripheral the reaction, the smaller the magnitude of t .

A summary follows of results of experiments performed during the past year to examine the phenomenon described above. These results come from bubble chamber studies of various kinds of enhancements or bumps.

Strangeness = 0, Baryon Number = 0 Systems.

Analysis of 6-BeV/ c $\pi^\pm p$ 80-in. bubble chamber photographs by a BNL group has revealed a new isospin-1 $K\bar{K}$ resonance in the reactions $\pi^\pm + p \rightarrow K^\pm + K_1^0 + p$ which has a mass of 1640 MeV and a width of the order of 100 MeV (see Figure 1a). The absence of any $K_1^0 K_1^0$ enhancement in this mass region from the final state $K_1^0 K_1^0 n$ as shown in Figure 1b suggests odd parity, odd charge conjugation, odd spin, and even G -parity for this resonance. This resonance may be associated with the isospin-1 dipion resonance $g_1(1630)$ discovered earlier by the same group.

A narrow enhancement at 960 MeV has been observed in a $K^- p$ experiment at 4.6 and 5.0 BeV/ c in the 80-in. chamber, analyzed by the BNL Bubble Chamber and Nuclear Interactions Groups and Syracuse University. This enhancement is seen in the ($\pi^- +$ missing mass) effective mass distribution from the reaction $K^- + p \rightarrow \Lambda + \pi^+ + \pi^- +$ missing mass and is suggestive of the $\delta^-(960)$ seen in a missing-mass spectrometer experiment performed by a group at CERN.

A possible $\rho-\rho^0$ resonance at 1710 MeV has been reported by the University of Notre Dame group from studies of the reaction $\pi^- + p \rightarrow p + \pi^+ + \pi^- + \pi^- + \pi^0$ at 8 BeV/ c in the 80-in. bubble chamber. In addition, evidence for resonances at 1630 and 1720 MeV has been reported by experimenters from the University of Rochester and Yale, Columbia, and Rutgers Universities from studies of 3 and 4-pion systems produced in $\pi^+ p$ interactions at 7 and 8.5 BeV/ c in the 80-in. chamber.

A BNL experiment with the 31-in. chamber was undertaken to study the nature of the en-

Figure 1. Effective mass plots of kaon plus antikaon systems ($K\bar{K}$) from the final states (a) $\pi^\pm + p \rightarrow K^\pm + K_1^0 + p$ and (b) $\pi^- + p \rightarrow K_1^0 + K_1^0 + n$.

hancement found by a BNL counter group in the isospin-1 $\bar{p}p$ total cross section at 1.3 BeV/c. Photographs of 88,000 $\bar{p}p$ interactions obtained at 1.12, 1.30, 1.32, 1.34, and 1.51 BeV/c indicate that the nature of this enhancement, instead of being strong in one combination of particles, is rather complex. A University of Wisconsin group, seeking to understand the same enhancement, obtained $\bar{p}p$ data in the same momentum range from the 30-in. chamber. They studied elastic and inelastic $\bar{p}p$ scattering, and preliminary results of this experiment indicate structure in the backward hemisphere. Such structure in $\bar{p}p$ elastic scattering suggests that narrow high-mass bosons (integer spin) exist.

A number of experiments were performed to study the production of the 3π systems in reactions of the type $\pi^\pm + p \rightarrow p + \pi^\pm + \pi^+ + \pi^-$. These included π^-p exposures at 13 and 20 BeV/c by

Harvard, at 8 BeV/c by Notre Dame, and at 25 BeV/c by Wisconsin, and π^+p exposures at 16 BeV/c by Stanford University and at 18.5 BeV/c by Notre Dame, all in the 80-in. chamber. These experiments all show a broad enhancement at the low end of the mass spectrum in the 3π , or more specifically $\rho\pi$, mass spectrum between 1.0 and 1.4 BeV. This structure is believed to consist of several resonances that have been resolved at some energies but not at others. Since the 3π system is peripherally produced, some of the structure in the 3π state can be understood as a kinematic effect. The Notre Dame group has interpreted the $A_1(1080)$ region of the $\rho\pi$ mass spectrum as a kinematic effect. Nevertheless, a report from Iowa State University of the reaction $K^- + p \rightarrow K^- + p + \pi^+ + \pi^- + \pi^0$ at 4.6 and 5.0 BeV/c indicates that there is an enhancement in the $\rho\pi$ system in the $A_1(1080)$ region that cannot be explained as a kinematic effect.

Strangeness $\neq 0$, Baryon Number = 0 Systems.

The $K\pi\pi$ system has been studied in K^+p and K^+d reactions. The situation is again a complicated one, since this is a peripherally produced system which characteristically peaks at low mass.

The K^+p exposures at 12.7 BeV/c for the University of Rochester and the K^+d exposures at 12.6 BeV/c for Johns Hopkins University in the 80-in. chamber reveal structures in the isospin- $\frac{1}{2}$ $K^+\pi^+\pi^-$ system in the final states $pK^+\pi^+\pi^-$ and $dk^+\pi^+\pi^-$ respectively. Both sets of data showed a Q meson at 1300 MeV with likely spin-parity 1^+ and an L meson at ≈ 1700 MeV with possible 2^- spin-parity.

Analysis by a group from the Lawrence Radiation Laboratory of a 9-BeV/c exposure has uncovered a $K^+\pi^+\pi^-$ resonance at 1250 MeV of 50-MeV width from the reaction $K^+ + p \rightarrow p + K^+ + \pi^+ + \pi^-$. In addition, the same LRL group discovered a $\bar{\Lambda}n$ resonance of mass 2240 ± 20 and width 70 ± 20 MeV.

Strangeness = 0, Baryon Number = 1 Systems.

An $N^*(1400)$ enhancement has been reported in two separate BNL experiments in final states in which the resonance interpretation is favorable. It was observed in the 3-BeV/c K^+p experiment of the Nuclear Interactions Group during a detailed investigation of the $K^+\pi^+n$ channel. The 6-BeV/c $\pi^\pm p$ Bubble Chamber Group experiments also reveal the $N^*(1400)$ in both $n\pi^+$ and $p\pi^-$ final states (see Figure 2).

A possible ΛK resonance of mass 1700 MeV and width 170 MeV is also seen in the same 6-BeV/c

Figure 2. (a,c) Sections of Chew-Low plot for $M(\pi^+n)$ vs $t_{p \rightarrow \pi^+n}$ in the reaction $\pi^+ + p \rightarrow \pi^+ + \pi^+ + n$ at 6 BeV/c, and for $M(\pi^-p)$ vs $t_{p \rightarrow \pi^-p}$ in the reaction $\pi^- + p \rightarrow \pi^0 + \pi^- + p$. (b,d) Mass projections for $M(\pi^+n)$ and $M(\pi^-p)$ with low $t_{p \rightarrow \pi^+n}$ or π^-p as indicated. There are two π^+n combinations for each event in the reaction $\pi^+ + p \rightarrow \pi^+ + \pi^+ + n$. In (b) there are 826 events in the histogram, and no event has both combinations in the $N_{1/2}^*(1400)$ region.

Figure 3. Effective mass squared of the $\Lambda\pi^+$ system from the $K^- + p \rightarrow \Lambda + \pi^+ + \pi^-$ final state at 4.6 and 5.0 BeV/c, showing the $Y_1^*(1385)$, the new $Y_1^*(1695)$, and possibly some contribution from the established $Y_1^*(1910)$.

experiments from a study of the reactions $\pi^- + p \rightarrow \Lambda + K^+ + \pi^-$, $\Lambda + K^0 + \pi^0$, and $\pi^+ + p \rightarrow \Lambda + K^+ + \pi^+$.

An interesting enhancement was seen in the $pp\bar{p}$ system by the Rutgers group investigating the reaction $\pi^+ + p \rightarrow \pi^+ + p + p + \bar{p}$ from their 8.4-BeV/c 80-in. chamber data. They find a mass of 3755 MeV and a width of 40 ± 20 MeV for this enhancement.

Strangeness $\neq 0$, Baryon Number = 1 Systems.

The only new result in this category comes from the BNL-Syracuse K^-p experiments at 4.6 and 5.0 BeV/c. They report a resonance at 1695 MeV with a width of 108 MeV which decays into $\Lambda\pi$. This comes from studies of the reaction $K^- + p \rightarrow \Lambda + \pi^+ + \pi^-$ by this group and others (see Figure 3).

Results from a number of very high energy experiments have been reported within the past year. Exposures have been taken in the 80-in. chamber with π^- and p beams of 20 BeV/c and higher. These are the π^-p experiments at 20 BeV/c (Harvard) and 25 BeV/c (Wisconsin), and the pp experiments at 22 BeV/c (Iowa State), 25 BeV/c (Columbia and Rutgers), and 28.5 BeV/c (BNL).

These high energy experiments are of interest in that they represent a transition region between the familiar lower energy (< 10 BeV) experiments and the yet unexplored region that will become accessible for systematic investigation with the completion of the 200-BeV/c accelerator at Weston, Illinois.

Events with as many as 16 particles in the final state have been seen by both the BNL and Wisconsin groups. Extremely high energy (up to ≈ 1000 BeV) cosmic-ray experiments, with small amounts of data, seem to indicate the production of clusters of heavy objects or "fireballs" which decay isotropically in their centers of mass. The high energy (≈ 25 BeV) bubble chamber experiments show no clear indication of "fireball" production.

The reactions at high energy with few particles produced can be compared with the same channel at lower energies. To illustrate the behavior of final states at high energy, consider the reaction $p + p \rightarrow p + n + \pi^+$. A plot of $n\pi^+$ mass-squared vs $p\pi^+$ mass-squared (Dalitz plot) reveals several interesting facts (see Figure 4). Only the low mass regions in $p\pi^+$ and $n\pi^+$ are occupied, and the $n\pi^+$ band is populated more heavily than the $p\pi^+$ band. At lower energies the $p\pi^+$ Dalitz plot is more uniformly populated and the $p\pi^+$ band is

Figure 4. Dalitz plot for the reaction $p + p \rightarrow p + n + \pi^+$ at 28.5 BeV/c. Plotted along the vertical axis is the effective mass squared of $n\pi^+$, and along the horizontal axis, that of $p\pi^+$.

more heavily occupied than the $n\pi^+$ band. The prominence of low mass enhancements indicates that the reaction is highly peripheral. The final state with the low mass $n\pi^+$ is favored over that with low mass $p\pi^+$ because it can be produced with the proton becoming "excited" into an $n\pi^+$ state as a result of the peripheral interaction. The low mass $p\pi^+$ final state requires that the proton pick up an extra unit of charge, and this appears to be more difficult as the beam energy is increased. This effect is also evident in the π^-p data in, for example, the reaction $\pi^- + p \rightarrow n + \pi^+ + \pi^-$, in which low mass enhancements are seen in $n\pi^+$ and $\pi^+\pi^-$, the low mass $n\pi^+$ being favored over low mass $\pi^+\pi^-$.

The high energy π^-p experiments reveal the production of ρ^0 , f^0 , and low mass 3π enhancements as well as low mass structure in other systems. The pp experiments also show low mass enhancements in nucleon + pion(s) systems, with copious production of the $\Delta(1236)$ isobar. The only boson resonance clearly identified in the pp experiments is the $\omega^0 \rightarrow \pi^+\pi^-\pi^0$ from the reaction $p + p \rightarrow p + p + \pi^+ + \pi^- + \pi^0$.

Other interesting results have been reported in the area of strong interactions. Some groups have carried out calculations fitting their data according to predictions of the one-pion-exchange (OPE) model. This is based on the picture of a nucleon as surrounded by a cloud of π mesons (pions). The OPE mechanism refers to the process wherein the

collision takes place between the beam and one of the pions in the pion cloud of the target particle. Physicists at UCLA, using a modified OPE model, were able to examine πK scattering by analyzing the reaction $K^+ + p \rightarrow \Delta^{++}(1236) + K^+ + \pi^-$ observed at 7.4 BeV/c. The group at Vanderbilt University employed another version of the OPE model to compare in detail single and double N^* production from 2.8-BeV/c pp and $\bar{p}n$ reactions. They observe that the pp reaction is more peripheral than is predicted by the model.

The University of Rochester group, in K^+p experiments at 12.7 BeV/c, have observed anti-hyperon production with a cross section of $\approx 200 \mu\text{b}$ compared with $\approx 400 \mu\text{b}$ for hyperon production.

A large exposure of stopping $\bar{p}$ events in the 30-in. chamber filled with deuterium was analyzed by a University of Rome-Syracuse University team. They measured 200,000 events and obtained 10,000 $\pi^-\pi^-\pi^+$ events and 2000 $K^+K^-\pi^-$ events. A careful analysis of these events showed a great deal of structure in the final state, but no clear interpretation can as yet be given to describe this structure.

The BNL Nuclear Interactions Group made some precise measurements of masses and mass differences of stable and quasi-stable particles. From their 600-MeV/c K^+d film, 47 events were extracted to yield a precise measurement of the $K^0 - K^+$ mass difference. The value obtained was 3.95 ± 0.21 MeV, where the error includes both statistical and systematic errors. This can be compared with the $\bar{K}^0 - K^-$ mass difference, measured by other experiments, of 4.05 ± 0.12 MeV. From K^-p data at 4.6 and 5.0 BeV/c, precise measurements of the Ω^- and Ξ^0 masses were made. A total of eight Ω^- events have yielded a value of 1673.3 ± 1.0 MeV for the Ω^- mass. With this accurate value, a critical test was made of the $SU(3)$ equal mass spacing rule for the baryon decuplet, and this rule was found to be satisfied for a spacing of 141.5 ± 2.5 MeV.

A BNL experiment was performed with 28-BeV/c protons incident on the 80-in. bubble chamber filled with a 50% neon and 50% hydrogen mixture. The coherent reaction $p + \text{Ne} \rightarrow \text{Ne} + p + \pi^+ + \pi^-$ was compared with the reaction $p + p \rightarrow p + p + \pi^+ + \pi^-$ from 28.5-BeV/c pp data. Shown in Figure 5 is the four-momentum transfer to $p\pi^+\pi^-$ for both cases. This shows that in the $p(\text{Ne})$ reaction the peripherally produced $p\pi^+\pi^-$ system is peaked much more sharply forward than

in the $pp \rightarrow pp\pi^+\pi^-$ reaction. The steeper slope in the $p\text{Ne}$ reaction is a consequence of the radius of neon being much larger than that of hydrogen.

In the area of weak interactions, results from several experiments were reported from exposures taken in the 30-in. chamber. When a particle decays via the weak interaction, the quantum numbers that characterize the particles in the final state are not necessarily the same as those that described the decaying particle. Therefore the purpose of these experiments is to determine what changes in quantum numbers can occur and to what extent the rules that govern weak decays are obeyed. From these experimental results, existing theories describing weak interactions can be tested and modified if necessary.

From an exposure of 500,000 pictures of stopping K^- mesons in the 30-in. chamber filled with hydrogen, the University of Maryland group studied the properties of hyperon leptonic decays and

Figure 5. Top curve, plot of the distribution $t'_{p \rightarrow p\pi^+\pi^-}$ (t' is defined as $t - t_{\min}$) for the reaction $p + p \rightarrow p + p + \pi^+ + \pi^-$ at 28.5 BeV/c, with the effective mass of the $p\pi^+\pi^-$ system < 2.0 BeV. Bottom curve, the same distribution for the reaction $p + (\text{neon}) \rightarrow (\text{neon}) + p + \pi^+ + \pi^-$ at 28.0 BeV/c. Since the radius of the neon nucleus is much larger than that of the proton, the slope for the $p + (\text{neon})$ reaction is much steeper than that for the pp reaction.

measured the branching ratio $(\Sigma^- \rightarrow \Lambda e^- \nu) / (\text{all } \Sigma^-) = (0.64 \pm 0.12) \times 10^{-4}$. This result shows that $\Sigma^- \rightarrow \Lambda e^- \nu$ decays are comparable in strength to $n \rightarrow p e^- \nu$ decays. Secondly, this group reports the most rigorous upper limit for the strength of $\Delta S = -\Delta Q$ hyperon leptonic decays $\Sigma^+ \rightarrow n l^+ \nu$, namely, $(\text{rate of } \Delta S = -\Delta Q) / (\text{rate of } \Delta S = +\Delta Q) < 0.034$ at the 90% confidence level. Another experiment in which a search was made for decays occurring with a change in quantum numbers of $\Delta S = -\Delta Q$ was conducted by the BNL Nuclear Interactions Group. They investigated the distribution in time of 400 leptonic decays of the neutral K mesons from the interaction $K^+ + d \rightarrow K^0 + p + p$ at 600 MeV/c. These data display a two-standard-deviation effect which is interpretable as evidence for $\Delta S = -\Delta Q$ decays. From the same data, a study of nonleptonic decays of K^0 mesons was completed. Measurement of 9600 such decays yielded a branching ratio $(K_L^0 \rightarrow \pi^+ \pi^- \pi^0) / (K_L^0 \rightarrow \text{all charged modes}) = 0.161 \pm 0.005$. This value and the rate for $K^+ \rightarrow \pi^+ \pi^0 \pi^0$ agree with the $\Delta I = 1/2$ predictions for nonleptonic K decays.

A study of the decay $\Sigma^- \rightarrow n + \pi^-$ was made from an exposure of the reaction $K^- + p \rightarrow \Sigma^- + \pi^+$ near 410 MeV/c by a group from BNL, the University of Massachusetts, and Yale. This yielded ≈ 6000 $\Sigma^- \rightarrow n + \pi^-$ events, of which about 1000 had a subsequent $n + p \rightarrow n + p$ elastic recoil. From the measured decay parameters, it is concluded that the Σ^- decays via s -wave, and, combining this with information regarding the Σ^+ decay, the $\Delta I = 1/2$ rule is found valid for these decays.

Finally, a result was reported bearing on an electromagnetic decay process. Columbia University in collaboration with the State University of New York at Stony Brook and Brandeis University completed a study of the $\eta^0(550)$ branching ratios. The η^0 data were collected in a 400,000-picture exposure of the 30-in. chamber, filled with deuterium, to an 820-MeV/c π^+ beam. No evidence was found for $\eta^0 \rightarrow \pi^0 \gamma \gamma$ decay, and the branching ratio $[(\eta^0 \rightarrow \pi^0 \pi^0 \pi^0) / (\eta^0 \rightarrow \pi^+ \pi^- \pi^0)] = 1.58 \pm 0.25$ was measured.

During the year a BNL counter group completed the analysis of high precision (0.3%) pion-nucleon and proton-proton total cross-section measurements made at high energies. These data allow a much better prediction of the energy at which the Pomeranchuk theorem will be obeyed. This asymptotic theorem states that the total cross section for a particle (e.g., π^+) incident on a target

(e.g., p) will become equal to the total cross section of the corresponding antiparticle (π^-) at a high enough energy. This is a basic theorem for most strong interaction theories. These measurements were obtained with an apparatus (shown partially in Figure 6) consisting of a system of hodoscopes connected on line to a computer.

Figure 7 shows two fits (5 parameters) using a power law for each of the π^+p and π^-p total cross sections. The precision measurements of the real amplitudes carried out by these same experimenters and the theoretically derived forward dispersion relations were used to select between the two fits. Only the solid line fit gave reasonable agreement between the prediction of D - [the unsubtracted forward dispersion relation which depends on the behavior of the difference $\sigma(\pi^- + p) - \sigma(\pi^+ + p)$] and the measurements of the real amplitude. For this fit the Pomeranchuk theorem $\sigma(\pi^+ + p) = \sigma(\pi^- + p)$ would become true within the best estimated attainable experimental precision (0.1%) at 25,000 BeV. The Pomeranchuk theorem for the $p-p$ and $\bar{p}-p$ pair would correspondingly become true at about 35,000 BeV. Considering the uncertainties involved, it is estimated that at least 20,000 BeV is required for this most basic asymptotic theorem to become true.

Figure 6. Part of the counter hodoscope and on-line computer system used in measuring the total cross sections for ultrahigh precision. The trailer in the right background contains the fast electronic and digital data handling equipment. The PDP-6 on-line computer is located in trailers behind the trailer shown.

Figure 7. Power law fits to the total cross-section data and the predicted higher energy behavior of the total cross sections (y scale) for π^+p interactions (σ_{π^+}) and for π^-p interactions (σ_{π^-}) versus the reciprocal of the incident laboratory momentum (P) in BeV/c (linear x scale) or alternatively the incident laboratory energy in BeV (the lower nonlinear scale). For the solution selected by the dispersion relations (solid line), the two cross sections become equal within experimental precision (i.e., the asymptotic region is reached) at about 25,000 BeV.

A Brookhaven group used the long branch of the separated beam for counter experiments to extend measurements of K^+ - and K^- -meson total cross sections on protons and deuterons to 3.3 BeV/c. Two resonances were discovered in the K^- -meson-nucleon system with masses of 2455 and 2595 MeV, widths of 140 MeV, and isotopic spins $I=1$ (Figure 8). Nothing is known about their spin-parity assignments as yet. If, however, the Regge pole theory is invoked, the two resonances could be classified as $^{1/2}+$ and $^{3/2}-$, respectively, if they are recurrences of other well-established resonances. In the K^+ -meson-proton and K^+ -meson-deuteron total cross-section measurements, two new structures have been discovered with masses of 2190 MeV and 2505 MeV, widths of 120 MeV, and isotopic spins $I=1$ (Figure 9). The two structures could be due either to threshold effects or to strangeness $+1$ resonances. It will take considerable effort to understand them. Should a resonance between a K^+ meson and a nucleon be definitely established, it would seriously complicate the quark model. In the quark model all known particles and resonances can be formed from three or fewer quarks. A K^+ -meson-nucleon resonance would require five quarks.

The same BNL counter group has completed the data-collecting phase of an experiment to measure the magnetic moment of the Ξ^- hyperon. The

Figure 8. The K^- -meson-nucleon total cross sections in the $I=1$ state. The solid curve is obtained on the assumption that there are no new structures in $I=0$ above 2.5 BeV/c. The broken curve is the best fit with two $I=1$ and two $I=0$ structures.

experiment used a high-intensity, partially separated K^- beam at 1.80 BeV/c and a solid hydrogen target for Ξ^- production. The forward-produced Ξ^- passed through a superconducting magnet operated at a peak field of about 118 kG. The subsequent decays of the Ξ^- were photographed so that its magnetic moment could be determined by the precession of the decay distributions as a function of the magnetic field strength. Some 890×10^3 pictures were taken with the field on; they are about equally divided between the two field polarities. All pictures were scanned twice. From a sample of 17×10^3 possible Ξ^- events, 3668 events were found in which the Ξ^- decayed after the magnet ("after" event). All pictures of the "after" type were hand-measured with use of an image plane digitizer and analyzed with the CDC 6600 computer. The distributions of these events are being studied and compared with results from Monte Carlo calculations in order to extract the Ξ^- moment from the data.

A Cornell-BNL group completed its experiment on elastic pion-proton scattering at large angles. Much emphasis was placed on scattering at backward angles where previously a sharp rise had been observed in the differential cross section near 180° (the "backward peak"). A systematic study was made of this phenomenon in the angular range 135° to 180° c.m.s. at a number of incident pion momenta between 6 and 17 BeV/c. The experimental method was to detect, after magnetic

Figure 9. The total cross section of K^+ mesons on protons. Errors represent statistical standard deviations.

analysis, both the scattered and recoil particles in scintillation counter arrays and optical spark chambers. The height of the backward peak in both π^+ and π^- scattering was found to decrease with increasing pion momentum, with the π^+ peak (Figure 10) being both narrower and higher than that for π^- (Figure 11). As angles decreased from 180° , a dip and secondary maximum were ob-

Figure 10. Results for π^+p elastic scattering near 180° c.m.s.

Figure 11. Results for π^-p elastic scattering near 180° c.m.s.

served in the π^+ angular distribution, but not in the π^- case. A number of features of the data are in agreement with the predictions of the Regge pole model. Measurements were also made of elastic scattering of π^- , K^- , and $\bar{p}$ from protons in the angular range 20° to 120° c.m.s. for incident momenta between 6 and 14 BeV/c. Although the results are not yet fully analyzed, much more structure is present in the differential cross sections than anticipated.

A BNL-Rochester group has been studying the backward scattering of $\pi^\pm$ mesons and $K^\pm$ mesons from protons in a wire spark chamber experiment at the AGS. The experiment on $\pi^\pm p$ backward scattering in the momentum interval of 1.5 to 3.0 BeV/c was completed in November 1967, and the results have been published (see Figure 12). The differential cross sections indicated the very strong influence of the nucleon resonances at high momenta and striking similarities between the 180° structure of the π^+ and π^- cross sections. A similar

Figure 12. The π^+p elastic scattering cross section at 180° as a function of incident pion momentum. The solid curve is the prediction of a resonance model calculation. The broken curve indicates the π^-p elastic cross section at 180° multiplied by a factor of ten from the earlier work of Kormanyos et al. at Argonne National Laboratory.

Figure 13. A missing-mass spectrum in π^-p at 16 BeV/c; the high energy proton at $\theta_{\text{LAB}} \sim 1.5^\circ$ is detected. This represents the first observation of backward ρ^- and A_2^- production at AGS energies.

experiment which includes magnetic analysis is being performed for K^+ and K^- in the 1.0 to 2.3-BeV/c separated $K^\pm$ beam of the AGS. The influence of both direct and exchange amplitudes is expected to be seen.

A Brookhaven group in collaboration with a group from Carnegie-Mellon University carried out an extensive study of elastic and inelastic π^-p , K^-p , and $\bar{p}p$ interactions at 8 and 16 BeV/c. A missing-mass technique was employed in which use was made of a high-resolution wire spark chamber spectrometer connected on line to the BNL PDP-6 computer. Special care was taken in the design of the incident negative beam to achieve both high intensity and resolution, e.g., at 16 BeV/c a π^- intensity of 10^6 per pulse was attained with use of only 25% of the internal proton beam. An indication of the versatility of this apparatus is the fact that both forward and backward π^-p interactions could be studied by simply reversing the field of the spectrometer magnets.

In this experiment, cross sections for 23 two-body reactions not previously observed or accurately determined were measured at each of the two beam momenta (8.0 and 16.0 BeV/c), with data rates of up to 100 events per AGS pulse. An example of the missing-mass spectrum (proton detected) in backward π^-p interactions at 16 BeV/c

is shown in Figure 13. The peaks at the ρ^- - and A_2^- -meson masses represent the first observations of backward production of these particles at high energy. When completely analyzed, the large amount of data from this experiment will provide critical tests of present theoretical models. For example, the Regge pole model predicts that the cross sections for the reactions $\pi^- + p \rightarrow p + \pi^-$, $p + \rho^-$, and $p + A_2^-$ near 180° should be comparable in magnitude and display the same angular dependence. This model also predicts a relation between the cross sections measured at 8 and 16 BeV. These predictions are in dramatic agreement with present analysis of the above data. The extensive data on differential cross sections for production of strangeness 0 and -1 baryon states in two-body inelastic channels (15 channels were observed), together with similar data from the pp experiment performed by this group in 1965-66, are expected to provide new insight into the dynamics of strong interactions at high energy. Additional information on backward scattering will be extracted, including much improved upper limits for K^-p and $\bar{p}p$ elastic scattering.

Cosmic-Ray Research

In the quark model all strongly interacting elementary particles (hadrons) are pictured as composites of quarks in much the same sense that nuclei are composites of neutrons and protons. With this model, many empirical facts of elementary particle physics have been successfully explained, but in no experiment have particles with the predicted quark properties been observed. The search for these basic building blocks of matter in the cosmic rays was continued by a BNL-Yale group during fiscal 1968. Recent results follow.

1. An upper limit was established of $1.3 \times 10^{-10} \text{ cm}^{-2} \text{ sr}^{-1} \text{ sec}^{-1}$ on the flux of charge $\frac{2}{3}$ or $\frac{1}{3}$ or $\frac{2}{3}$ particles in the cosmic rays.
2. A mass spectrometer was used to search for heavy integrally charged particles (heavy triplets) reaching sea level. Again, no evidence for such particles was found.
3. Very low limits were also placed on the fluxes of charge $\frac{2}{3}$ particles in the cosmic rays.

These null results place severe upper limits on the fluxes of quarks (or heavy triplets) and imply that either the simple models that picture elementary particles as quark (or heavy triplet) composites are incorrect, or the quark (or triplet) masses are >20 BeV.

Theory

During the past year, the work of the high energy theory group has covered a wide variety of topics.

A unified and simple method was developed for calculating the kinematic singularities and constraints of helicity amplitudes for high spin scattering processes. In the S -matrix approach to strong interactions the equations to be solved are assumed to deal with scattering amplitudes that are analytic functions of energy and momentum transfer except for singularities associated with physical intermediate states (dynamical singularities). In some cases, especially for particles with spin, these amplitudes differ from the physical scattering amplitudes by a factor that cancels additional singularities which would otherwise occur (kinematical singularities). Furthermore, the experimentally related amplitudes for scattering of higher spin particles are not linearly independent but satisfy certain constraints which can cause apparent singularities for certain choices of amplitude which actually are cancelled when the constraints are taken into account. The problem of finding a general procedure for determining the constraints and kinematic singularities has received considerable attention over the past few years. Various schemes have been suggested, but the one referred to here is considerably simpler and more general. A knowledge of these constraints and singularities is essential in making reasonable phenomenological parameterizations for processes involving higher spin resonances.

Some consequences of the $O(4)$ symmetry of scattering amplitudes at zero four-momentum transfer have been examined for an off-shell model of $N\bar{N}$ scattering via the exchange of a pseudo-scalar meson. This symmetry groups together a number of different angular momenta, just as three-dimensional rotational symmetry groups together $(2l+1)$ different magnetic quantum numbers into a single total angular momentum state. When the exchange of Regge poles, corresponding to a whole family of angular momenta, is considered, this symmetry would group different trajectories as degenerate components of a "Lorentz pole." For the $N\bar{N}$ problem three different kinds had been previously known from the on-shell discussion; this off-shell calculation shows that there are, in fact, six. It was further shown that the pion cannot correspond to the type of pole ($M=1$) to which it has been assigned by previous authors;

such a pole does not couple to physical amplitudes for zero angular momentum.

A one-dimensional model has been used to study, in detail, the problem of three particles that interact because at least one of the three forms a compound state alternately with each of the other two. By using a new method of treating the resultant scattering integral equation it was shown that, when the compound states of the pairs of particles are resonant states, a three-body metastable state develops (subject to certain stated conditions) in the neighborhood of a predictable energy. Specifically, for three identical particles the three-particle resonance has an excitation four times that of the two-particle resonance. The low energy excitation of three alpha particles serves as a good example of this effect. All the significant features of the model are also present in the relativistic three-dimensional case. There are potential examples of such effects among the baryonic resonances.

The decay of both long- and short-lived components of the neutral K meson has been described phenomenologically in the context of CP nonconservation. Estimates of some of the parameters describing these decays were made by using mainly CPT invariance and unitarity, and a discussion was presented on possible measurements that have a bearing on the question of CP nonconservation. Relations were obtained between various possible decay rates of $(K^0, \bar{K}^0)$, Σ^+ , and Ξ^0 particles in modes with $\Delta S = -\Delta Q$. A connection between $\Delta S = -\Delta Q$ decays and $\Delta S = 2$ leptonic decays was suggested.

An investigation is being made of the angular correlations occurring in the cascade decay of a three-body boson resonance via a quasi two-body state, such as $K^*(1420) \rightarrow K^*(890) + \pi$ followed by $K^*(890) \rightarrow K + \pi$. These correlations can be used to help determine the spin and parity of the parent resonance. For comparison with experiment, estimates must be made of the effects of background and competing decay modes producing the same final states [$K^*(1420) \rightarrow K\rho \rightarrow K\pi\pi$, for example]. Such estimates are made analytically when possible and numerically if necessary.

An analysis is being carried out of the interactions of K^- mesons with protons at very low energies, the data being parameterized by means of a K -matrix model. The phase shift analysis of K^+p scattering is being extended to 2 BeV/ c , and data at present being produced by the BNL-

Rochester group, who are collaborating in the analysis, are being incorporated.

In the field of quantum electrodynamics the contribution of the fourth-order vacuum polarization to the sixth-order term in the difference between electron and μ meson (muon) anomalous moments has been obtained. This is part of a larger program to obtain, with the aid of a computer, many previously unknown higher order contributions to various Q.E.D. processes. A calculation is in progress of the scope of the electric form factor of the electron to fourth order.

The contributions to the muon anomalous moment due to possible couplings of scalar and vector bosons to lepton pairs have been calculated to second order. The results obtained provide stringent tests of several recently proposed theories.

The use of phenomenological Lagrangians to calculate the consequences of assumptions about symmetry properties of currents and their commutation relations has been clarified. It has been shown that the method developed by Schnitzer and Weinberg for relating various processes in which pions of nonnegligible energy are emitted cannot be extended to include $SU(3)$ symmetry effects without a very specific model of the way in which $SU(3)$ symmetry breaks down. By constructing a Lagrangian invariant under the general chiral group $U(n) \times U(n)$, many results of Weinberg, Schwinger, and others were shown to be special cases of a more general scheme and to depend on the rather arbitrary choice of certain parameters.

80-in. Bubble Chamber

During the year the 80-in. chamber produced a total of 1.5 million pictures, distributed among 11 experiments by as many experimental groups. Of these pictures, 60% were taken with a chamber filling of hydrogen, while 20% used deuterium. For the remaining 20%, a mixture of 50% neon and 50% (atomic) hydrogen was used. Operating characteristics for this mixture were found to be well within the capabilities of the chamber, and excellent pictures were obtained. This firmly established the technique as completely practical for use in large bubble chambers.

Several experiments are now in progress using a neon-hydrogen mixture (up to 50% neon, 50% hydrogen) in the 80-in. bubble chamber. Use of neon mixed with hydrogen or deuterium provides a variable density liquid. For some experiments

Figure 14. An example of the detection of a γ ray from an event in the BNL-Michigan 2.2-BeV/c K^-p experiment in the BNL 31-in. hydrogen bubble chamber. Two tantalum plates and two leaded glass windows were installed in the chamber for the detection of single photons. One tantalum plate is downstream and the other at the right-hand side (as shown in the sketch). The end plate is viewed edge on, and a shower is seen. The event is being viewed through the main window and the front leaded glass. The many large X fiducial marks are on these two windows, while the four smaller X marks are on the rear leaded glass. The small dark areas are caused by bubbling from the clamps holding these plates. This bubbling has largely been eliminated in a second installation. The event sketched is $K^- + p \rightarrow \Lambda + \pi^+ + \pi^0 + \pi^-$, in which apparently one of the two γ rays from the π^0 produces a pair of electrons ($e^+ + e^-$) in the downstream tantalum plate. The mass of the $\pi^+\pi^0\pi^-$ system is 1200 MeV, the π^0 momentum is 980 MeV/c, and the space angle between the π^0 and the γ shower is 35° in the laboratory system (142° in the π^0 rest frame), which corresponds to a solid angle probability of 20%.

this can be a new and powerful technique. For example, denser liquids make possible the conversion of high energy γ rays (from the decay of the π^0 meson, for instance) into electron pairs and thus allow measurements of γ -ray energy. In low-density liquids, such as hydrogen, this conversion is so infrequent as to be relatively unimportant from the experimentalist's point of view. In addition, interactions of a complex nucleus, in this case neon, can be studied.

Figure 15. The 10½-ft-diam stainless steel vacuum vessel for the 7-ft test facility. At the top are three portholes for viewing the chamber and a manhole entrance for servicing the coil and chamber to be installed inside the vessel. All piping and instrumentation portholes are in the bottom section. The device is supported by three 12-in.-diam legs bolted to a heavy foundation.

30- and 31-in. Bubble Chambers

During fiscal 1968, 1.4 million pictures were taken for 12 groups for 11 experiments with use of hydrogen, deuterium, and liquid neon-liquid hydrogen mixtures in the 30-in. bubble chamber. An array of plates consisting of two concentric, truncated cones was mounted in the chamber. For this experimental arrangement, Scotchlite was installed as the retrodirector and the optical system was changed from a three- to a four-camera system to insure that all parts of the chamber would be viewed by at least two cameras.

With liquid hydrogen in the 31-in. bubble chamber, 2.1 million pictures were taken for 8 experiments by 7 research groups. An array of tantalum and lead glass plates was installed in the chamber to convert γ rays for an extensive study of rare decay modes of boson and hyperon resonances produced from K^-p interactions near 2.2 BeV/c. A sample event is shown in Figure 14, which illustrates the production of an e^+e^- pair as a result of conversion in the tantalum plate of a γ ray from a π^0 decay.

Figure 16. Fisheye window, lens, and film platen for the 7-ft test chamber. The large, 2-in.-thick, 12-in.-diam, spherical surface window at the bottom is mounted in the chamber vessel. The next fisheye window reduces thermal radiation striking the chamber window and is called a heat shield window. The smallest window, made of fused quartz, seals the vacuum tank. The nondistorting 90° lens is used for photographing on film which is held optically flat by the special film platen.

Particle Physics Apparatus

Reappraisal of the Brookhaven 14-ft cryogenic bubble chamber project was brought about by failure to obtain the inclusion of this project in the budget for fiscal 1969. Ideas for design improvements and simplifications and cost reductions are constantly being explored. The suitability of oblong rather than circular chambers for research with high energy particles is being investigated. Some efforts of the Brookhaven Bubble Chamber Group have been devoted to updating the design concepts for large cryogenic bubble chambers along these lines. In parallel with this activity, the research and development program associated with the 14-ft chamber project is being continued. Most of the work in this area is directed toward construction of a 7-ft. test chamber facility. This half-scale, fully working model of the Title I design of the 14-ft cryogenic bubble chamber project will be used in tests of new large bubble chamber concepts pioneered at BNL, i.e., wide-angle photography using fisheye windows; a fully stabilized, face-cooled superconducting magnet without an

Figure 17. Cross section of the conductor for the 7-ft test facility superconducting magnet. Six superconducting filaments are embedded in and metallurgically bonded to copper. The conductor is 2 in. wide by 0.100 in. thick.

iron yoke; and a Fibreglas-reinforced plastic piston and flexible bellows. Major equipment delivered during the year included the 10½-ft-diam stainless steel vacuum tank, the helium Dewar for the superconducting coil, the chamber body (7 ft in diameter, with a volume of 9000 liters), and 42,000 ft of 6000-A stabilized superconducting strip. The equipment for winding the 16 double-layer pancakes required for the superconducting coil was assembled and the coils were completed. In Figure 15 the large vacuum tank that houses the superconducting coil and the 7-ft test chamber is shown installed in a work area that will be used for the magnet test. The energizing of this large superconducting magnet is expected to mark a major advance in the practical utilization of superconductivity. This magnet with its stored energy of 72 megajoules will be by far the largest tested to date. The test will verify the total stabilization and the cooling provisions and will allow extrapolation of these unique magnet design features to larger chambers, to be proposed in the future, and to other large magnets required by government and industrial programs. After initial testing of the 7-ft test chamber, several hundred thousand photographs of beam particles from the AGS will be taken to provide information regarding reliability of performance, consistency of control, and accumulation of data for initiating development of data-processing methods for use with large-volume bubble chambers. These photographs will be made with the wide-angle fisheye window and lens assembly, whose parts are shown in Figure 16.

The use of superconductors in magnets makes the generation of high magnetic field intensities over large volumes economically feasible. The construction and safe, reliable operation of large superconducting magnets were made possible by the in-

roduction of the concept of superconducting stabilization. Stabilization of superconductors may be achieved by paralleling with the superconductors appropriate amounts of normal conductors, such as copper or aluminum, in good thermal and electrical contact with the superconductors. Enough normal conductor and sufficient cooling are provided so that, when transient instabilities cause the superconductor to make momentary transitions to its normal or resistive state, the full magnet current can transfer to and be carried by the normal conductor without raising the temperature at the superconductor beyond the critical value above which it is no longer superconducting. The amount of normal conductor must also be sufficient to prevent the magnet coils from suddenly "going normal" if the current in the superconductors is increased above that which they can carry in the magnetic field at the superconductors.

Stabilized superconductors were first developed in cable configurations in which superconducting wires and copper wires were stranded together and then bonded with low-resistivity materials such as indium. With use of such cables an 8-in.-bore, split-pair superconducting magnet was completed. One section of this magnet was shown in Figure 11 of the Physics section of the 1967 Annual Report. This magnet, which is used for tests on new superconducting materials, generates a central magnetic field of 60 kG. It has been cycled frequently and run continuously for long periods of time.

For large magnets in which the electromagnetic forces on the conductor may be substantial, the mechanical support of a stranded cable conductor is complex and difficult. For such magnets, a stabilized superconducting conductor configuration with a rectangular cross section is more appropri-

Figure 18. Components of the 7-ft test facility magnet coil.

Figure 19. Magnet coil and helium Dewar, 7-ft test facility.

ate because flat surfaces are available for support. In such configurations, superconducting filaments or ribbons are bonded in or between strips of normal conductor. The conductor being used in construction of the superconducting magnet for the 7-ft bubble chamber test facility is shown in Figure 17.

Samples from 32 lengths of this conductor, totaling 42,000 ft, were tested carrying a current of 6000 A and mounted in the 8-in.-bore magnet. These tests as well as others concerning mechanical strength and other important properties turned out very satisfactorily.

The stabilized superconductor is in direct contact with liquid helium; this is achieved by winding in with the 42,000 ft of conductor a machined spacer strip that leaves 75% of one conductor face exposed to liquid helium. In addition, a stainless steel strip is wound in to help support the very large forces on the magnet conductor. Finally, Mylar tape provides turn-to-turn insulation. Figure 18 shows a cross section of the components of the 7-ft test facility magnet coil windings. The magnet consists of 16 double-layer coils, each layer having 44 turns.

The air-core magnet, which is 7 ft high and has an inner diameter of about 8 ft, is shown in Figure

19. At 6000 A the magnet should generate a magnetic field intensity of 30 kG. Full-scale magnet tests employing a 240-W helium refrigerator system have begun.

Other types of conductor configuration are also being considered for use with large magnets. Hollow stabilized superconductors are being evaluated with particular attention to the heat transfer rates attainable with supercritical helium as the coolant. The use of hollow conductor may permit the design and fabrication of magnet coils in compact, integral structures and will eliminate the need for a helium Dewar.

The magnetic-finger device that focuses both π and K mesons over a broad momentum band and thereby provides a high intensity ν beam is still undergoing electrical and mechanical tests. All components have been successfully operated at full power and are now undergoing life tests.

The double-vee magnetic spectrometer system under construction by a BNL counter group is nearing operational status; in the fall it will be used at the AGS to study double-vee high energy interactions of the types $\pi^\pm + p \rightarrow \gamma$ (or γ^*) + K (or K^*), as well as other reactions, at data rates two orders of magnitude higher than formerly and with much better precision of measurement than was afforded by the visual techniques previously used.

As part of this program, new methods of construction were developed to build, at relatively low cost, spark chamber hodoscopes much larger than those previously built. So far, 13-ft-long spark chamber hodoscopes have been constructed, and the equipment is capable of building instruments 23 ft long by 23 ft wide. The special coil winding technique used is shown in Figure 20. A complete magnetostrictive readout system has been developed, as well as a data-handling system allowing automatic on-line computer analysis of the data from the double-vee magnetic spectrometer.

Data Analysis

During calendar 1967 the BNL Bubble Chamber Group analyzed 15 experiments. The scanning section found 210,000 events that were measured for these experiments. Guidance roads for later track-finding programs were also made by the scanners for 160,000 events that were measured by the two flying-spot digitizers (FSD's). In addition, 50,000 events were measured on four measuring projectors running on line to a small data acquisi-

Figure 20. The Mark II wire spark chamber hodoscope winder, built in the high bay area of the Physics Building and now in operation. This device has the capacity to wind a wire chamber discharge plane up to a size of 24×24 ft, with the wire spacing (adjustable to any desired distance) from 0.020 in. and up. The wire chamber frame rotates around its vertical axis while positioned on ground steel beds. The wire feed point is driven by a lead screw along the vertical slide. The tension on the wire is controlled to within better than 5% by use of a vacuum column.

tion and checking computer. The events are extracted from the film in batches of 500 to 1000 for efficient processing by the subsequent geometry, kinematics, and fit-selection programs.

The data analysis system is now applied to a broad range of experimental conditions. Since FSD data extraction increases the efficiency of the scan-measuring technicians, whose number is fixed, the experimentalists prefer FSD measurements to conventional ones. FSD measurements have been successfully extracted from all three Brookhaven bubble chambers for events that include short charged decays and short stopping protons and complex events with up to 3 neutral vees, 7 charged vertices, and 15 tracks. The FSD high-quality bubble density measurements continue to find favor with the experimentalists.

The conventional measuring machines continue to be used for special situations that require careful operator control or would require too much development work on the FSD programs for the number of events involved. In addition, the conventional machines remain the best standard for evaluation of the FSD measurements. Installation of an "on-line" PDP-5 computer and incremental magnetic tape recorder has resulted in great improvement in the measuring efficiency of these machines as well as a reduction in the manpower required to handle their output.

The decline in usage of the conventional measuring system is indicative of the transfer of manual operations and operators to the "road-guided" FSD system, with a consequent increase in the output per operator among other merits of the system. Eight "road-makers" capable of digitizing pictures from any of the Brookhaven bubble chambers are now operational.

The rejection rate by the three-view geometry programs varies from about 7% for simple events to about 20% for complex events for *both* conventional and FSD systems. For common events, a subset of the rejects is remeasured to evaluate possible biases; for rare events, all rejects are remeasured once, which leaves a residue of $<1\%$ geometry rejects. The track-matching capability of the geometry program rescues a few percent of the multiprong events whose track labels have been interchanged by the measuring technicians.

The capability of the kinematics program to analyze events automatically is very useful to the experimenters. Equipment for manual analysis of events is available and is used in special situations.

The automatic program saves the experimentalist the often time-consuming task of writing down all the possible reactions. It also saves computer time by trying first those tests that will most limit the number of remaining interpretations to be tried. For FSD measurements, a bubble density test has been added. The kinematics program is also able to process a collection of possible parent vertices for several neutral vees under the cluster classification. The cluster is automatically divided into the correct events. Thus more beam tracks can be followed per picture as long as scanning efficiency does not deteriorate.

As the data analysis system continues to develop, more physicists are freed for work on experiments. In fact, no physicist is now required to devote full time to data analysis development or maintenance. Important here is the capability of the staff of computer analysts to respond to changing experimental conditions on a reasonable time scale, as well as the system design that covers a broad range of experiments. While most of the analysts are engaged in development and maintenance, a few are assigned to experiments to relieve the physicists of required computer programming jobs.

Although the data analysis system is processing more events, the same number of computing aides are able to direct the operation of the computer programs. The outstanding success of the Applied Mathematics Department's two CDC 6600 computers is the key factor here. Another contributing factor is the more efficient extraction of conventional measurements by the on-line computer.

Figure 21. Human interaction with computers is being investigated at Brookhaven National Laboratory with use of a general-purpose TV display of a computer's output. A user can "talk back" to the computer by pointing to the picture or typing on a keyboard.

A project to connect nine FSD road-making machines to the SDS Sigma-7 computer of the Data Terminal Network, via a 16-station interface, is in an advanced stage. With this connection, the advantages of on-line control and data acquisition will be extended to the road-making system. The initial control program is being coded, and the possibility of scanning (as distinct from measuring) aid from the computer to the operator is being studied.

The hardware construction and programming of the Data Terminal Network have been completed, and four terminals, two with television-style visual displays, are operational. Further development of the facility awaits connection of the Sigma-7 to the CDC 6600 computer in the Applied Mathematics Department. In the meantime the system will be used via a magnetic-tape data transfer system which will allow meaningful simulation of the final system and will provide a useful new facility for physicists to interact with their data. In Figure 21 a display terminal is shown in use.

The data analysis system of the Nuclear Interactions Group now encompasses eight high-precision image plane digitizers, all routinely operational and connected on line to an SDS 920 computer. Event rates for this type of device are experiment dependent, since the scanning and measuring are done together. However, rates of 12 events/hr have been achieved over long periods of time for experiments in which an event occurs every few pictures. The measuring accuracy of the image plane digitizers has been shown to be equivalent to that of Frankenstein film plane measuring devices by comparing the results of measurements of identical events with both devices. The overhaul of the SDS 920 software, for the purpose essentially of converting all programs to FORTRAN, has been completed. This modification will enable all physicists to write programs for the system as well as to alter existing ones with ease. In addition, the incorporation of a million-word drum has greatly increased the power and flexibility of the whole system.

During the year the research resulting from use of the on-line data facility, which provides and maintains the digital data-handling and on-line computer equipment used in AGS counter experiments, exhibited phenomenal growth. To accommodate this growth, the PDP-6 computer system has been very successfully used in a time-sharing

mode to service the needs of six university groups (Columbia, Harvard, Yale, Princeton, Rochester, and Carnegie-Mellon) and four BNL counter groups, in a combination of simultaneous time-sharing and rotational use. Five groups have actively used the computer during a single calendar period, two on-line simultaneously and three off-line, with rotation between off-line and on-line use. In addition, the core has been increased to 80,000 36-bit words (1.0- μ sec cycle time), a 450,000-word disk has been ordered and will soon be installed, and a remote-user station consisting of a line printer, dectapes, and several teletypes has been installed in the Physics Department. Figure 22 shows the trailer-housed PDP-6 computer system in actual use at the AGS. This system has been essential to researches at the AGS which resulted in the publication of 28 papers during the year.

MEDIUM ENERGY PHYSICS

During fiscal 1968 the bulk of the nuclear structure data obtained at the Cosmotron before it was shut down was analyzed. The results demonstrated the development of a new and powerful technique for obtaining nuclear structure data heretofore unavailable by other experimental means. Because of the fine energy resolution (1.6 MeV at 1 BeV), it was possible to separate the elastic from the inelastic scattering of 1-BeV protons on light nuclei. Analysis of the elastic data showed that there were pronounced maxima and minima caused by multiple scattering of the incident proton by the individual nucleons in the nucleus. The exact nature of the multiple scattering clearly depends on the nucleon-nucleon correlations inside the nucleus, the double scattering depending on the pair correlation, the triple scattering on three-body correlations, and so forth.

In the limit of high energy incident particles, the formal theoretical framework for analyzing the experimental results becomes particularly simple. The theory as developed by R. J. Glauber shows that the first minimum is a result of interference between single and double scattering, the second minimum between double and triple scattering, and so on. Furthermore, the form of the single scattering is available from the electron experiments of the Hofstadter group. Therefore, by a combination of proton and electron data, some information about the pair correlation can be

extracted. A detailed analysis of this kind on helium data was carried out and yielded the parameters of a repulsive Gaussian pair correlation function. This is the first direct experimental information on the nature of the nucleon-nucleon correlation.

The understanding of nuclear correlations inside the nucleus is a frontier problem in nuclear physics. The Brookhaven results have shown that high energy techniques are particularly well suited to experimental investigations of the effects of correlations.

NUCLEAR STRUCTURE

Experimental work in the field of nuclear structure entails the study of nuclear levels and their

Figure 22. The on-line data facility complex in the experimental area at the AGS. The trailer and experimental equipment in the foreground are part of the apparatus used by a BNL group in checking microscopic causality and in precise total cross-section measurements. The computer facility is located in the next two trailers.

properties, such as spin, parity, lifetime, electromagnetic moment, and energy. These nuclear parameters are determined from measurements of nuclear transition properties that involve γ rays and particles emitted from relatively long-lived radioactive nuclei or from short-lived nuclei produced during the measurement with neutrons or charged particles from reactors and accelerators. It is important to emphasize the need for detailed knowledge of all such properties for individual transitions, for such information often makes it possible to design and execute tests of physical principles and ideas of general interest in physics, not merely in nuclear structure physics. A few of the outstanding experiments carried out during the past year with radioactive nuclei and measurements at the small Van de Graaff accelerator and the High Flux Beam Research Reactor (HFBR) are described briefly below.

The use of magnetically perturbed γ - γ angular distributions in measurements designed to yield either gyromagnetic ratios of excited nuclear states or, if such ratios are known, information about

internal magnetic fields in materials is a well-known experimental technique. In particular cases it often cannot be applied because the nuclear cascade involves a low energy, highly internally converted transition.

A series of experiments has been performed in which low energy internal conversion electrons have been successfully used in magnetically perturbed γ - e angular correlation measurements. The case involved was that of the 123-keV $2+$ first-excited state of Gd^{154} . The source, Eu^{154} , was implanted in an iron foil by bombarding the foil with Eu^{154} ions at an energy of about 50 keV. The foil was magnetized by placing it across the pole tips of a small C-yoke electromagnet. The directional correlation patterns between a 1274-keV γ ray and either the 73-keV K -conversion electrons or the 115-keV L -conversion electrons of the 123-keV transitions were rotated by the action of the strong internal magnetic field on the magnetic moment of the 123-keV state. Absolute particle parameters were evaluated by comparing the γ - e rotations with the rotation of the 1274-keV - 123-keV γ - γ correlation pattern. The measured particle parameters, together with the theoretical point nucleus values (finite size corrected) are summarized in the following tabulation.

E2 Particle Parameter	Theoretical Value	Measured Value
b_K	1.88	1.73 ± 0.13
b_L	1.25	1.12 ± 0.13
b_K/b_L	1.51	1.55 ± 0.15

The relative effect on the two correlations involving the K - and L -conversion electrons demonstrates that no significant nuclear structure effects appear in the $E2$ particle parameters in the strongly deformed Gd^{154} nucleus.

The availability of γ -ray sources that display essentially natural line width (recoil-free emission), together with the corresponding sharp absorption lines, has made it possible to investigate the probability of decay of a nuclear state as a function of time when it is populated in some manner giving an energy distribution different from that implied by the natural line shape.

Experiments have been performed with a source of Co^{57} in an iron lattice. The distribution of time intervals between formation of the 14.4-keV excited state of Fe^{57} (announced by detection of the preceding 122-keV γ ray) and the detection of 14.4-keV photons scattered by a thin cylindrical iron

scatterer has been measured for four different frequency shifts between the radiation from the source and the central frequency of the scatterer. The frequency shifts were introduced by imparting a chosen constant linear velocity to the source by means of an appropriately driven electromechanical transducer.

Incoherent resonant scattering processes in which either one nucleus in the scatterer or the lattice of the scatterer is left in an altered quantum state were found to contribute significantly to the observed results. The time dependence of such processes has not been accessible to measurement in transmission experiments of this type, since their contribution in exactly forward scattering is negligible.

A theory based on a classical model in which the scattering nuclei are randomly situated harmonic oscillators has been developed. Experimental results are generally in reasonable agreement with computed theoretical curves. Discrepancies occur for the time distributions measured at frequency shifts ($\Delta\omega$) which correspond to two and three line widths for the case of the natural iron scatterer. These time distributions are shown in Figure 23. The "filled-in" minima in the experimental distributions imply the presence of frequencies in the scattered radiation that were absent in the radiation incident upon the scatterer.

A long-lived isomer of high spin ($T_{1/2} = 171 \pm 11$ days; $I \geq 10$) has been discovered in Ir^{194} . This isomer was produced by neutron irradiation of enriched samples of both Ir^{191} and Ir^{193} in the Materials Testing Reactor in 1962. A comparison of the activities of these samples indicates that the Ir^{194} isomer was produced preferentially by successive capture of three neutrons in Ir^{191} ($I = \frac{3}{2}+$), through successively higher spin states in Ir^{192} (74 days; $I = 4-$) and Ir^{193m} (12 days; $I = \frac{1}{2}-$). The mass number of the new isomer was established through identification of γ rays that depopulate the well-known $4+$ and $2+$ states in Pt^{194} . Chemical separation of platinum from the iridium sample established that the new isomer is in Ir^{194} rather than in Pt^{194} .

A detailed investigation of the disintegration scheme has been carried out by performing both γ - γ coincidence studies with $\text{Ge}(\text{Li})$ detectors and γ - e coincidence studies with a $\text{Si}(\text{Li})$ electron detector and both $\text{Ge}(\text{Li})$ and NaI γ -ray detectors. A state at 2438 keV in Pt^{194} , populated by β decay of the isomer, decays by two parallel cascades.

Figure 23. Time spectra of resonantly scattered γ rays obtained with the 4.53×10^{-3} -mm-thick natural iron scatterer. In parts a, b, and c, the data were collected at source velocities corresponding to average frequency shifts ($\Delta\omega$) of 0, $2/\tau$, and $3/\tau$, respectively. Random coincidences and contributions due to Rayleigh scattering have been subtracted. The solid curves have been computed from the theory. The broken curves, which have the functional forms $t \cdot e^{-t/\tau}$ and $t^2 \cdot e^{-t/\tau}$, are normalized to the area of the experimental points and are shown for purposes of comparison.

The more intense cascade, representing about $\frac{2}{3}$ of the decays, proceeds by successive transitions through states with energies (and probable spins) of 2099 keV ($8+$), 1411 keV ($6+$), 811 keV ($4+$), and 328.5 keV ($2+$) to the $0+$ ground states. A weak γ ray of the 1012-keV state in coincidence with the 600-keV γ ray and not with the 688-keV γ ray establishes the order of these transitions.

The second cascade from the 2438-keV state represents about $\frac{1}{3}$ of the decays and proceeds to the $4+$ state by four cascade transitions. Two of these transitions are indistinguishable in energy (562.4 keV). The energies of the remaining two transitions are 390.8 and 111.7 keV, respectively. The 111.7-keV γ ray is about $\frac{1}{4}$ the intensity of the remaining γ rays in the cascade. Its total conversion coefficient of about 3 indicates a multipolarity which is mainly $E2$. The order of the remaining 562-, 390.8-, and 11.7-keV transitions has not yet been determined.

From the known properties of collective bands in even-even platinum nuclei, it is probable that the 339-keV transition takes place from an intrinsic state to the $8+$ state of the ground-state band. Although the level energies of this band deviate appreciably from the $I(I+1)$ interval rule, they may be readily fitted by a semiempirical analysis of collective bands recently proposed by M. Mariscotti and G. Scharff-Goldhaber. The band parameters obtained in this analysis show that Pt^{194} is both reasonably deformed and very soft. A level scheme consistent with all information known at present about the Ir^{194m_2} decay is shown in Figure 24.

In the Van de Graaff research program, two experiments have been carried out which were motivated by interest in the nuclear structure of O^{16} . Of particular theoretical interest are the ground state and the 6.05-MeV first-excited state of O^{16} , both having a spin-parity of 0^+ . In one series of experiments the 13.1-MeV, $T=1$ state of O^{16} was excited by the $\text{N}^{15}(p,\gamma)\text{O}^{16}$ reaction, and the γ -ray branching intensities to the ground and first-excited states were measured. The $E1$ fractional branch to the 6.05-MeV state was found to be only 5.8×10^{-3} , corresponding to an inhibited transition having a $B(E1)$ of 0.037 relative to that of the $E1$ ground-state transition. In the other experiment the 7-sec activity N^{16} was formed in the $\text{N}^{15}(d,p)\text{N}^{16}$ reaction, and the β -ray branching to the 6.05-MeV state was investigated by measuring the positron-electron nuclear pair emission from

the 6.05-MeV state with a magnetic pair spectrometer. An unsuccessful search for this branch had been made with the spectrometer at Brookhaven some years ago, but this time a new spiral baffle system was used which increased the relative sensitivity of the measurement by a factor of 5. The N^{16} β -ray branch to the 6.05-MeV level was established to be about 10^{-4} per decay, with a corresponding $\log ft$ value of about 10. Compared with the known β -ray branch to the ground state of O^{16} , the branch to the 6.05-MeV level is inhibited by a factor of 10. Both the above experiments are consistent with a description of the 6.05-MeV state of O^{16} as being predominantly deformed but with an 8% admixture of a spherical component. The ground state is thought to be predominantly spherical with a small deformed component.

The doubly magic nucleus Ca^{40} is thought to have a structure analogous to that of O^{16} . In particular, the 3.35-MeV 0^+ first-excited state and the 3.90-MeV 2^+ state of Ca^{40} are thought to be similar to the 6.05-MeV 0^+ and 6.92-MeV 2^+ states of O^{16} . The radiative width of the O^{16} 6.92→6.05-MeV transition is known, as is the lifetime of the 3.90-MeV state of Ca^{40} . A study of the γ -ray decay of the 3.90-MeV level of Ca^{40} was made by exciting the state in the $\text{K}^{39}(p, \gamma)\text{Ca}^{40}$ reaction with the Van de Graaff accelerator. The 3.90→3.35-MeV radiation (550 keV) was looked for in triple coincidence with annihilation γ rays

which result from the $0^+ \rightarrow 0^+$ decay of the 3.35-MeV state. The 550-keV γ ray was not observed, and it was shown that the reduced transition probability for the 3.90→3.35-MeV $E2$ decay in Ca^{40} is at least three times smaller than that for the corresponding $E2$ decay of the 6.92-MeV state in O^{16} , whereas theory says that they should be the same. The discrepancy may be very difficult to explain according to present theory.

There has been recent theoretical interest in the possible coupling of analogous channels of (d, p) and (d, n) nuclear reaction processes. In view of the tentative experimental identification of such coupling reported at other laboratories, a search for this effect was undertaken by the Van de Graaff Group at Brookhaven. A B^{11} target was bombarded with deuterons, and the cross section for the (d, p_0) reaction leading to the ground state of B^{12} was measured as a function of bombarding energy in the energy region for the formation of the 15.1-MeV, $T=1$ state of C^{12} in the (d, n) reaction. In spite of the high statistical accuracy of the measurements, no anomalies were observed in the (d, p_0) cross section. The results suggest considerable doubt that such coupling effects occur.

While the neutron is electrically neutral, it may still contain equal parts of both positive and negative electric charge because it is a magnetic particle. If the centers of these two charge distributions were slightly displaced from each other, the result

would be an electric dipole moment equal to the product of each charge multiplied by the displacement distance. Since a neutron is always spinning, any observation of a moment would involve a charge displacement along the spin axis. If there were an electric dipole moment, it would change sign if the spin axis were reversed 180° or if the direction of rotation of the neutron were reversed. Either of these changes of rotation would be equivalent to a change in sign of physical time. One of the foremost questions in physics today is whether or not the laws of physics remain unaltered if the sense of physical time is reversed. A measurement of the neutron dipole moment would test the symmetry in the laws of physics with respect to time reversal.

A search was made for a possibly existing electric dipole moment of the neutron around 1950 by Smith, Purcell, and Ramsey with the limited techniques and facilities then available. A null result was reported, showing that any existing dipole moment was less than that corresponding to the displacement of an electron and a proton by a distance of 5×10^{-20} cm. Present developments in

physics have stimulated a renewed interest in this search, and a similar experiment has been performed at Brookhaven (a schematic arrangement is shown in Figure 25). The results are again null, with an upper limit of about 10×10^{-22} cm.

The conversion of the 60-in. cyclotron to variable-energy spiral-ridge operation has been completed. The nominal energy range is from 40 MeV down to 5.5 MeV for protons, from 20 to 12 MeV for deuterons, from 40 to 24 MeV for He^4 , and from 57 to 18 MeV for He^3 . These limits can be extended downward considerably by use of third-harmonic acceleration, and upward a small amount by pushing the design limit to higher fields. A switching magnet is in place, and three beam pipes will be available. A negative ion extraction facility is also available for small beams of hydrogen ions. The machine is undergoing performance tests at present, and the deflector to provide external beams of positive ions in the target room has not yet been installed. Its use, both current and projected, involves isotope production with some emphasis on particularly short-lived species, molecular scattering organic chemistry, direct irradiation of biological systems, and especially charged-particle reaction and scattering.

A considerable enlargement in the scope of the nuclear structure program is in the planning stage in anticipation of the initiation of operations at the new 30-MeV Tandem Van de Graaff facility within the next two years, as well as full operation of the modified and rebuilt 60-in. cyclotron within the coming year. Construction progress on the Tandem Van de Graaff facility is reviewed in the introduction to this annual report.

Figure 25. Neutron electric moment experiment. The first cobalt polarizer in the neutron beam produces a polarized beam in which all the neutrons have their spin axes in the same direction. In the central section of the apparatus, the spin axis of each neutron precesses about the direction of the applied magnetic field. A strong electric field is applied alternately to each pole of the magnet. If there were any interaction between the neutron and the electric field, the rotation frequency would change periodically with reversal of the electric field and would be observed by means of the BF_3 detector and second polarizer. This experimental arrangement can detect changes in the precession frequency of one part in 10^5 .

Figure 26. The 45-m flight path and counting station for the HFBR fast chopper experiment.

NEUTRON PHYSICS

Neutron physics research at Brookhaven is concerned with the properties of the neutron, its interaction with nuclear matter, and its utilization as a probe for investigating certain properties of liquids and solids. The neutron experiments, carried out at the HFBR, employ both crystal-spectrometer and time-of-flight techniques. A significant portion of the work requires extensive use of cryogenic equipment. Adjunct research is carried out in low-temperature physics, including superconductivity and ultralow-temperature techniques. Some examples of work during the past year are outlined below.

In April 1968 a new 45-m flight path station was completed for the HFBR fast chopper facility (see Figure 26). With this equipment the time-of-flight method is used to investigate the radiative capture of neutrons by nuclei. The resulting γ -ray energies are routinely measured with a precision of 1 part in 1000, and information is gained about

Figure 27. The direct capture effect for the 4059-KeV γ ray from $U^{238}(n,\gamma)U^{239}$. The relative strength of this γ ray in the neighborhood of the 6.7-eV resonance shows interference between the direct and compound nucleus reaction amplitudes.

the properties of neutron resonances and levels in the residual nucleus. These studies fall into four principal categories: (1) investigation of the nature of the neutron capture reaction mechanism by measuring the variation of the transition strength to an individual final state as a function of neutron energy, (2) determination of nuclear structure through population of the final states of the residual nucleus, (3) statistical distributions of (n,γ) reaction widths, and (4) investigation of p -wave neutron capture by measuring the resulting angular distribution of γ rays.

A study of correlations in (n,γ) partial widths was undertaken with particular emphasis on correlations between neutron widths and radiative widths. The existence of such correlations would provide evidence for the importance of "channel" or "external" capture in which that portion of the initial-state wave function outside the nuclear boundary $r \gg R$ contributes to the dipole matrix element. Results of earlier experiments on thulium, tungsten, and uranium were examined for such correlations. Positive evidence for correlation was obtained for $Tm^{169}(n,\gamma)Tm^{170}$, $W^{182}(n,\gamma)W^{183}$, and $W^{186}(n,\gamma)W^{187}$, while for uranium the correlation was shown to be consistent with zero. A mathematical technique was devised for the study of correlated χ^2 distributions with one and two degrees of freedom.

The direct capture mechanism, first demonstrated in cobalt, was shown to exist in $U^{238}(n,\gamma)U^{239}$ and in $Tm^{169}(n,\gamma)Tm^{170}$. The interference between a direct amplitude and the compound nucleus resonance amplitude is clearly seen in these nuclei, particularly in uranium. Additional data below 21 eV, supplementing earlier uranium measurements, showed that direct capture was necessary to explain the anomalous strength of the 4059-MeV γ ray (see Figure 27).

The proposed existence of additional quantum numbers characterizing the capturing state was studied in the isotopes of Hf^{178} and Hf^{180} . In order to explain the anomalous weakness for transitions to final states with Nilsson quantum number $\Lambda = 2$ in thermal capture for a wider range of deformed nuclei, a Λ selection rule has been proposed. The results for hafnium showed that in resonances no such selection rule was obeyed. Hence the effect, if it exists, must be characteristic of nonresonant capture only.

A study of the capture of neutrons in $Mo^{98}(n,\gamma)Mo^{99}$ showed that the resonance at 12

eV was produced by p -wave neutron absorption. The asymmetric angular distribution of γ rays from this resonance established its spin as $\frac{3}{2}$, and from the parameters of the distribution the spins of eight low-lying states in Mo^{99} were obtained. The capture at higher energies (≈ 450 eV) revealed the presence of anomalously strong $M1$ γ rays and thus supported the proposed $M1$ giant resonance in this region of the periodic table.

Because Fe^{56} is important as a structural and shielding material at nuclear reactors, the partial capture cross sections for the stronger radiative transitions in it were measured with use of a boron monitor. Cross sections were measured up to several keV. In addition, the partial widths for de-excitation of the 1167-eV resonance were measured. From angular distributions and the study of the partial widths, this resonance was shown to have spin $\frac{1}{2}$. An extremely small resonance was found in iron at 46.0 eV.

The slow chopper apparatus began to produce information during the year. A serious problem with the lifetime of bearings has been solved with use of a new full-flow oil lubrication system devised by Brookhaven engineers. Newly developed scintillation and multiple-wire, high-pressure He^3 detectors were employed in the first experiment to record low energy neutrons scattering from a Cu-Ni alloy. The Cu-Ni system possesses an almost totally incoherent scattering amplitude. A high-temperature oven was constructed to permit study of this sample in the liquid form. For both fast and slow chopper time-of-flight experiments, a sophisticated, time-shared, on-line computer system, developed over the past five years, is used.

A new crystal spectrometer was placed in operation at the HFBR. This high-precision instrument will be used to continue experiments of the type formerly carried out at the Brookhaven Graphite Research Reactor with polarized neutrons and polarized target nuclei. Initial measurements with the new spectrometer were designed to calibrate the system and explore its capability. Various neutron cross sections were determined, particularly those needed for improved standards, e.g., those of He^4 , C^{13} , Ne, and Ar and those requested for engineering application in nuclear power plant design.

Thermal neutrons offer unique advantages for the study of mixtures of liquid He^3 and He^4 . Since the thermal cross section of He^3 is 5300 barns, while that of He^4 is only 0.85 barns, a beam of

Figure 28. Phase diagram for He^3 - He^4 liquid mixtures at saturated vapor pressure.

neutrons passing through a liquid mixture interacts in effect with the He^3 alone. Thus a measurement of the neutron transmission serves to determine the He^3 number density, which gives the ratio of the He^3 concentration x_3 to the molar volume V . At temperatures below 0.87°K , mixtures of liquid He^3 and He^4 separate into an upper He^3 -rich phase and a lower He^4 -rich phase. This phase separation has been observed directly by scanning a narrow neutron beam along a cell containing a mixture of the two liquids. The boundary between the phases shows up clearly as an abrupt drop in the transmitted intensity when the beam passes into the He^3 -rich phase. From measurements of the neutron transmission, x/V was determined for each phase with a high degree of accuracy in the temperature range from 0.87° down to 0.045°K .

The molar volumes are known only at 1.2°K ; therefore, to determine x , an approximate correction must be made for thermal expansion. The phase diagram, or x vs T plot, is shown in Figure 28. The points represent raw measurements. The solid line for $x < 15\%$ represents the smoothed dielectric constant measurements of Edwards and co-workers at Ohio State University. That part of the solid line from 15% to 90% is a consensus of a number of previous results, while the part for $x > 90\%$ is a theoretical result of Daunt and Edwards. The agreement over the whole range is excellent. From extrapolation, a limiting concentration at $T=0$ of $6.84 \pm 0.06\%$ He^3 in He^4 was determined. The upper phase is pure He^3 within the 1% accuracy of the measurement.

The first successful investigation of the phonon dispersion relation for solidified He^4 (hcp phase) was carried out at Brookhaven. This work, in which the largest single crystals yet reported were used, was carried out at the HFBR. The results of this investigation are of fundamental importance because the classical Born-von Karman theory of lattice dynamics fails to give an adequate description for solid helium. The zero point motion in solid helium has an amplitude of about one-third of the interatomic distance, in accord with quantum mechanical theory. For this reason helium does not solidify under its own vapor pressure at any temperature; a pressure of >23 atm must be applied to form the solid. Thus solid helium is often called a "quantum" solid.

The lattice dynamics of quantum solids has been a subject of theoretical interest for a number of years. Some of the more recent theories have shown considerable promise, but many approximations and *ad hoc* procedures were involved. Further progress has required reliable experimental data to test these assumptions. In the Brookhaven experiment, eight of the ten dispersion branches along symmetry directions in hcp He^4 were determined at the low molar volume of $21.1 \text{ cm}^3/\text{mole}$ and $T = 1.0^\circ \text{K}$. Comparison with the latest calculations of Koehler, Werthamer, and Gillis is generally good, the theoretical predictions being about 10 to 15% too high. There appear to be lifetime effects in the longitudinal-optical branch along the a -axis, an effect not yet studied in detail by theorists.

Although many studies have been made of static physical properties near magnetic critical temperatures, the transport properties have received little attention. Since valuable information on interactions may be extracted from measurements of these properties, a general study of transport phenomena was begun by investigating the electrical resistance or critical magnetic scattering of conduction electrons near the ferromagnetic transition in metallic nickel. The data were shown to disagree with all extant theories, but the derivative of the temperature coefficient of the resistance was found to obey simple power laws similar to those of the static properties. This investigation is being extended in a study of thermal conductivity in nickel.

The Cryogenics Group has designed, built, and tested a low-temperature refrigerator utilizing the dilution of liquid He^3 into liquid He^4 . This refrig-

erator, based on a concept proposed by London and Mendosa, is now operating and can attain temperatures below 0.050° absolute. This limiting temperature will be further reduced by improved low-temperature heat exchangers which are now being built. The apparatus will be used for investigations on magnetism and on He^3 - He^4 solutions.

The Cryogenics Group participates actively in a program on superconductivity in cooperation with members of the Solid State Physics Group and of the Metallurgy and Materials Science Division of the Nuclear Engineering Department. Research in this area is reviewed this year in the section on Nuclear Engineering.

SOLID STATE PHYSICS

The research in solid state physics is concerned with the understanding of the physical nature of condensed systems, with emphasis on crystal imperfections and the structure and dynamics of solids. Some representative accomplishments are described briefly below.

Theory

The Heisenberg model of ferromagnetism has been thoroughly investigated and many approximate solutions have been devised. Computer calculations have extended the usefulness of the model by permitting investigation of properties not derivable analytically. In this model each lattice point has a spin which interacts with neighboring spins. It would be desirable to calculate the average magnetization and the time-dependent fluctuations of the system as functions of the temperature. Although these quantities have not been calculated exactly, they have been evaluated numerically for lattices containing as many as 8000 spins by treating the spins as classical vectors of fixed magnitude but variable direction. The equations of motion for the system were solved numerically on a computer and the averages evaluated. The computer output has been displayed on a cathode-ray tube, and the correlated behavior of the spins as they move under the influence of the Heisenberg interaction was demonstrated vividly in a motion picture sequence. Several surprising power-law behaviors emerged from these calculations for the three-dimensional system. For example, the magnetization appears to follow a $(T - T_c)^{1/3}$ dependence with considerable accuracy for the full range of temperatures below T_c .

A simple one-band model of the electronic structure of a ferromagnetic metal was examined to determine the existence and properties of polar spin-wave states, i.e., "optical" spin waves due to the finite range of the electron-electron interaction. The model Hamiltonian is an extension of the Hubbard-Hamiltonian, and the equation of motion method was used in the random phase approximation. Polar spin waves were found to exist in the case of an approximately half-filled, totally polarized ground state and to merge with the continuum with decreasing occupancy of the bands. Near wave vector $q=0$, inelastic neutron scattering by the acoustic spin-wave mode dominates all other modes; however, a finite polar-mode scattering cross section does exist away from $q=0$.

Work continued on the Mössbauer line-shape in the presence of randomly varying electric field gradients and magnetic fields. Two specific cases were considered. First, the case of a fluctuating magnetic field perpendicular to the axis of a fixed electric field gradient was evaluated. The line-shape shows a number of differences in comparison with the previously considered fluctuating magnetic field parallel to the axis of a fixed electric field gradient. These differences are due to so-called nonadiabatic effects in which the fluctuating field induces transitions between the eigenstates of the gradient. Second, the line-shape was calculated in the presence of an electric field gradient which jumps at random between the x , y , and z axes. This is a model for a nucleus in an ion undergoing a dynamic Jahn-Teller effect. In each case the agreement with available experimental data is excellent.

The basic properties of azide compounds are under detailed investigation in a cooperative project between Brookhaven National Laboratory and Picatinny Arsenal. The azide ion, N_3^- , forms compounds with potassium, sodium, silver, and lead. Lead azide is technically important, since large quantities are used in munitions. The alkali metal azides are of scientific interest, since they are among the simplest crystals containing both ionic and covalent bonds. In an attempt to predict and understand the properties of azides, a calculation of the electronic structure of an isolated azide ion was carried out. A set of molecular orbitals for the ion was calculated by a method particularly well suited to computer calculation. In this calculation, Gaussian functions centered on each of the nitrogen nuclei were used as atomic functions. Application

of the variational principle to molecular orbitals with an assumed set of coefficients leads to a secular equation which in turn yields new coefficients. This procedure is repeated until a self-consistent set of parameters is reached. The entire calculation is then repeated, with variations in the positions of the nitrogen nuclei and also the exponents in the Gaussian functions so as to minimize the total energy. From these data the vibrational frequencies were computed, and it was shown that the equilibrium azide configuration is linear and symmetrical. The electron distribution around the nitrogen nuclei was also calculated. Some typical results are illustrated in Figure 29, which shows contours of the constant electron density in a plane containing the three nitrogen atoms.

In close-packed solids, interstitial or vacancy condensations onto a plane can lead to the formation of a new defect, the prismatic dislocation loop. The atomic displacements from such a "penny-shaped" defect can be approximated by determining the displacements in a semifinite elastic medium bounded by the plane of the loop, $z=0$, with boundary conditions: the z displacement is $\pm\epsilon$ for values of r less than the radius of the

Figure 29. Isodensity contours for a symmetry orbital of N_3^- . The distribution of electron density of a particular symmetry orbital in a plane containing the nitrogen nuclei is represented by the contour lines. The nitrogen nuclei of the N_3^- molecule are positioned at the "+" signs; the axes represent distance in atomic units.

loop, C , and zero outside of C , and the shear stress T_{rz} vanishes for all r . Solutions were obtained for all space in terms of an absolutely convergent series. For distances large compared with the radius of the loop, the displacement field converges to the sum of two well-known solutions to the elasticity equation, the point singularity and the doublet singularity. For small values of r and z the displacements remain finite and converge to the boundary conditions. These results suggest that the elastic strain energy of a loop is considerably less than that of the isolated point defects before they condensed into the loop. The behavior of the displacement field at large distances allows the image field to be calculated so that the over-all lattice dilatation can be determined. There is no dilatation in the plane of the loop, and the dilatation normal to the plane is exactly the fraction of atoms present or missing in the form of loops. This is of the order of 1.5 to 3 times less than the dilatation produced by the same fraction of isolated defects.

A method for the calculation of the relaxation of ions around a defect in an ionic crystal was developed in which the polarization of ions neighboring the defect (out of the 30th shell) is treated by a self-consistent matrix method. The induced dipoles on the ions due to the fields of the defect, relaxed ions, and other dipoles are evaluated, and a continuum is joined on by the determination of an effective dielectric constant for use at an ionic position in the crystal. Calculations were performed for KCl, in which the Schottky pair energy is obtained at 2.2 eV, and for LiH, where the corresponding value is 2.9 eV. The activation energy for the migration of helium interstitial ions in LiH was calculated to be 0.3 eV.

Recent advances in experimental biology have created the need for quantitative descriptions of cell proliferation. A stochastic theory for cell kinetics was developed based on a realistic model of cell proliferation. A characteristic transit time, $\bar{t}_i$, was assigned to each of the four states of the cell cycle. The actual transit time, t_i , for any cell was represented by a distribution around $\bar{t}_i$ with a variance of σ_i^2 . Analytic and computer formulations were used to describe such characteristics as age distribution, labeling experiments, and response to perturbations of the system by, for example, irradiation and temperature. The decay of synchrony was analyzed in detail and was shown to proceed as a damped wave. From the first few peaks of the

synchrony decay, the distribution function for the cell-cycle time can be obtained. The later peaks decay exponentially with a characteristic decay constant that depends only on the average cell-cycle time and the associated variance.

Crystal Imperfections

The study of defects in crystals continued as a major research activity. Basic investigations of charged-particle interactions with crystals and of the formation and subsequent behavior of color centers in inorganic solids are in progress. The program concerned with electron transport properties of organic crystals has become an important part of the over-all research effort.

The diffusion of triplet excitons in single crystals of anthracene, phenanthrene, and pyrene was investigated at room temperature by use of two techniques. In the first, the time dependence of delayed fluorescence as a function of crystal thickness is determined; surface quenching of the triplet excitons decreases the triplet lifetime from the bulk value. In the second, the diffusion length is obtained from a study of the delayed fluorescence intensity as a function of absorption coefficient. In pyrene single crystals, the two methods give diffusion lengths at 18 and 15 μ , respectively. In anthracene a diffusion length of 30 μ is obtained. In phenanthrene crystals, maxima in the delayed fluorescence intensity as a function of wavelength occur at the same wavelengths as maxima in the uv absorption spectrum, which implies that the diffusion length is smaller than the penetration depth at the diffusion length in phenanthrene. The triplet lifetime in phenanthrene is much longer than in anthracene or pyrene, having a value between 60 and 15 msec, depending upon the crystal quality. The diffusion coefficient is therefore at least two orders of magnitude smaller than in anthracene or pyrene. If it is assumed that the thermal velocity and mean free path of the triplet excitons are roughly comparable in all three crystals, then it may be concluded that the phenanthrene triplet excitons spend a large fraction of their lifetimes in traps.

Radiation-induced processes were investigated in KCl containing known amounts of thallium impurity ions. The room-temperature absorption spectra of KCl crystals, both very pure and doped with Tl^+ at levels ranging from ≈ 2 to 120 ppm, were determined as functions of γ -ray dose. For all doping levels, the absorption bands associ-

ated with Tl^+ decrease, while the F -, M -, and V -bands increase monotonically with dose. Other unidentified bands not found in pure KCl were also observed. In all samples the M -center concentration is proportional to the square of the F -center concentration, but the proportionality constant is a function of thallium content. Chemical studies indicated that γ irradiation converts some Tl^+ to an oxidized form, most likely Tl^{2+} . A comparison of the electron and hole center concentrations shows that these do not balance. At low thallium concentration there are hole centers, and at high thallium concentration, electron centers that have not yet been identified and measured experimentally. Thermal annealing showed that the Tl^+ absorption bands are regenerated at high temperatures, well above that required for the annealing of F -centers. This suggests that after irradiation a large fraction of the electrons are trapped in defects other than F -centers.

Measurements were made of the cluster-diffuse neutron scattering from a polycrystalline sample of $Cu_{0.475}Ni_{4.525}^{62}$. This isotope and its composition are ideal for such measurements, since the effective scattering length for the Bragg reflections and for temperature-diffuse and Huang scattering is zero, while that for the cluster scattering is 0.821×10^{-12} cm. The short-range-order parameters, α_1 through α_9 , representative of the system at $\approx 550^\circ\text{C}$ were determined by a least-squares fit to the scattering data; $\alpha_1 = 0.128$, while all other α 's are $< \frac{1}{4} \alpha_1$. By using an approximate theory of Clapp and Moss relating the short-range-order parameters and pair-wise interaction energies, first- and second-neighbor interaction energies of -0.0118 eV and $+0.007$ eV were determined. From this a critical temperature of 210°C was predicted, which is in reasonable agreement with that extrapolated from thermodynamic data.

The nature of defects in irradiated MgO and BeO was investigated. Theoretical analysis showed that the peak of diffuse x-ray scattering due to point defects is located at the reciprocal lattice points of the undistorted crystal, whereas the Bragg peaks reflect an expanded lattice. The Bragg peaks are attenuated by a static distortion factor but the diffuse scattering is not. This theory predicts that, for low defect concentrations, the diffuse scattering intensity increases linearly with defect concentration. When defects aggregate into loops, the intensity is proportional to the square of the loop radius at any total defect concentration.

Both effects were observed in neutron-irradiated MgO. A combination of these theories for point defects and loops removes the conceptual difficulty in relating macroscopic and x-ray volume measurements in crystals containing dislocation loops. For large loops the x-ray lattice parameter is measured from broadened diffuse peaks located at the undistorted positions, whereas the Bragg peak has been so attenuated that it is not observed. Thus, the measured lattice parameter is not the average distance between atoms. The latter is obtained by macroscopic volume measurements, and no real discrepancy exists between the two measurements. The dilatation produced by a dislocation loop was calculated, and it was shown that all components except those normal to the loop vanish. The well-known extreme anisotropy of the irradiation-induced growth in BeO was thus explained.

The Brookhaven dynamitron was modified completely for low-frequency operation during the summer of 1967. The major alterations in the machine consisted of replacement of the toroidal coil, rf electrodes, and all 64 rectifiers. In addition, a rectifier cooling system, new Zener modules, and autotransformers for the rectifiers were installed. The dynamitron is now capable of attaining a voltage slightly in excess of 3 MeV during beam-tube conditioning and operates routinely and reliably at 3 MeV. Moreover, power consumption has been reduced by about 40%. The first set of experiments using the dynamitron, on electron-irradiated tungsten wires, was completed. Samples of 99.999% purity were irradiated at $< 20^\circ\text{K}$ with 2.5-MeV electrons. Defect behavior was studied by simultaneous resistivity, internal friction, and dynamic modulus measurements on two identical specimens. During isochronal annealing to 45°K , a large resistivity recovery peak at 31°K and five minor peaks between 26° and 42°K were observed. Dislocation pinning indicated long-range interstitial migration for the resistivity peaks above 20°K . Reorientation of the 31°K resistivity defects was observed as a 30°K internal friction relaxation peak. In irradiated single crystals this peak was largest for a $\langle 100 \rangle$ stress, which implies $\langle 100 \rangle$ orientation for the anisotropic defects. Analysis yields a reorientation energy of 0.065 ± 0.010 eV and annihilation in about one jump with an activation energy of 0.11 ± 0.01 eV. Modulus vs dose at 20°K showed an initial increase attributed to dislocation pinning. After complete pinning at 16°K , further irradiation pro-

duced a linearly decreasing modulus characteristic of vacancy creation. Upon annealing, the modulus recovered in a manner similar to that of resistivity.

Structure of Solids

Another major experimental activity is the use of neutron diffraction in studies of the dynamical and structural properties of solids. The HFBR has proved to be an excellent facility with a high neutron flux combined with a low experimental background. The principal emphasis has shifted to inelastic scattering problems and the precise determination of spin-density distributions.

A property common to all magnetic materials is the disappearance of their magnetism as they are heated to high temperatures; i.e., such materials undergo a transition from a state in which the atomic moments of the individual atom are ordered to one of disorder. The purpose of investigating the scattering of neutrons from magnetic materials in their transition region, termed critical scattering, is twofold: (a) to obtain an improved picture on an atomic scale of the nature of the transition itself, and (b) to investigate the way in which this picture is affected by the kinds of magnetic material involved. Recent investigations have centered on iron, a ferromagnetic metal, and on rubidium manganese fluoride, RbMnF_3 , an antiferromagnetic inorganic compound. In iron the individual atomic moments are aligned parallel to one another, whereas in RbMnF_3 the manganese atomic moments are coupled in an antiparallel array. The neutron-scattering measurements have revealed a number of important new features connected with the transition in these materials: (1) The essentially low-temperature description of the magnetic excitation, known as spin waves, is valid in the antiferromagnetic system up to and beyond the temperature at which the long-range order vanishes. In iron, on the other hand, these spin-wave excitations appear to collapse at the transition temperature. (2) In the antiferromagnetic material a new collective mode has been observed just below the transition temperature. This diffusive mode had been predicted by theory, but this is the first experiment in which it has been detected. Careful measurements in iron demonstrated the absence of this same mode. (3) The slowing-down of the correlated fluctuations in the magnetization, again predicted by theory but not heretofore observed, has been demonstrated in the antiferromagnetic crystal. In

iron, however, the effect is either much smaller or outside the range available to neutrons.

The effects of high hydrostatic pressures on the magnetic properties of several metals were investigated in neutron diffraction experiments. This type of experiment provides a powerful method for studying basic magnetic interactions in metals. The metals chosen for study were chromium, terbium, and holmium, which have certain similarities in their patterns of magnetic ordering and in their magnetic interactions. By studying pressure-induced changes in the periodicities of the ordering patterns and the shifts in the temperatures at which ordering occurs, it was possible to provide a good check on recent theoretical work. The theory indicates that magnetic ordering in these and similar materials originates in an indirect interaction via the delocalized electrons available for electrical conduction. The high-pressure experiments permit a straightforward interpretation, in contrast to alloy studies, since the electronic number of the specimen is unchanged and no irregularities are introduced in the potential energy function for the crystal lattice. The high-pressure data for chromium, consisting of changes in spin-flip temperature, wave vector of the spin-density wave, and spontaneous magnetic moment as a function of pressure, were found to be in agreement with the Lomer two-band model. The pressure dependence of the helical turn angle of terbium and holmium single crystals agreed satisfactorily with a calculation based on the theory of Miwa.

The study of spin-density distributions and magnetic structures has continued. The basic objectives of this aspect of the neutron diffraction program are to obtain information about electronic configurations and covalency effects in various compounds; to investigate magnetic properties and transitions as a function of such variables as temperature, applied fields, pressure, and composition; and finally to carry out exploratory work on the nature of the magnetic ordering in new types of magnetic material. An example of work in this area is provided by the detailed study of $\text{CuCl} \cdot 2\text{D}_2\text{O}$ which was completed during the year. Fourier maps showed that the spin-density distribution in this antiferromagnet is markedly aspherical. Calculations based on a ground-state wave function consisting of an admixture of $d_{x^2-y^2}$ and $d_{3z^2-r^2}$ orbitals in the ratio of about 10:1 account satisfactorily for the observed results. In ad-

dition, the transition known to occur in this compound in an applied field of about 7 kOe was shown to correspond to a simple spin flop from the a - to the b -axis, without a change in the basic scheme of antiferromagnetic order and without any substantial alteration in the spin-density distribution.

As part of a systematic program in collaboration with Princeton University, the dynamical properties of the rare-gas crystals, krypton and neon, have been measured. These crystals are simple in their interatomic interactions, and therefore precise theoretical calculations of their fundamental properties can be made with a minimum number of assumptions. Particularly important are their lattice dynamical properties, which can most effectively be studied experimentally with a triple-axis neutron spectrometer. Extensive measurements have been carried out on a krypton crystal, which should be regarded as a typical classical solid because of its large mass. The experimental results for crystalline krypton are in very good agreement with the theoretical model. Detailed measurements have been made on the lighter neon crystals in which quantum effects are expected to

play an important role. The crystals were grown in an aluminum container under various pressures, and thus the density was varied. Since the thermal expansion of aluminum at low temperatures is much smaller than that of neon, the crystals were maintained essentially at constant volume, the best but seldom realized experimental condition for theoretical considerations. The frequency as a function of wave number has been measured along the symmetry directions, as illustrated in Figure 30. The temperature dependence of selected frequencies was also studied in the 5° to 25° K range. Comparison of these experimental results with theory indicates that the simple model adequate for krypton is not satisfactory for neon.

Like the Cryogenics Group, the Solid State Group takes an active part in a joint program on superconductivity involving members of the Metallurgy and Materials Science Division of the Nuclear Engineering Department. Research in this area is reviewed in the section on Nuclear Engineering.

THEORETICAL PHYSICS

Research activities in theoretical physics range over nuclear structure theory, nuclear models, nuclear reactions, many-body systems, and atomic physics. Close liaison is maintained with the experimental groups. Some typical studies are described briefly below.

A major effort in nuclear physics is directed toward computing nuclear properties directly from the force between individual neutrons and protons. One approach is the Hartree-Fock-Bogoliubov method. In the nuclear case this method runs into a seeming block because at the outset fundamental symmetries of the exact problem are broken. Isospin invariance is one of the most important of these symmetries. It is restored by including the remainder terms omitted in the first step. These terms are treated in the quasi-boson approximation which guarantees exact maintenance of symmetries. It was shown for a simple case (the pairing-force problem) that the broken isoinvariance is restored, within the approximation, when the remainder terms are included. A method was worked out which leads to this end result simply and also is extendable to other problems. A simple version of the pairing-force problem was treated exactly to demonstrate the technique.

In shell-model calculations performed for nuclei with $A = 15, 16$, and 17 , it was assumed that $3, 4$,

Figure 30. Phonon dispersion curves for neon at 4° K along the principal crystallographic directions. L and T are the longitudinal and transverse vibrational modes, respectively.

and 5 particles interact within the shell $1p_{1/2}$, $2s_{1/2}$, and $2d_{5/2}$. The two-body interaction was taken from reaction matrix calculations. The resulting level schemes are satisfactory. In O^{16} the low-lying negative parity states, the $T=1$ states, and the rotational band based on the second + state all agree well with experimental values. Computation of the transition rates is in progress.

The investigation of the relevance of free-space two-nucleon forces to finite nuclei was continued. In one line of this study, the $T=0$ internucleon force was applied to the F^{18} nucleus. The residual interaction was expanded in terms of the free reaction matrix, with special attention given to a proper treatment of the off-energy shell behavior of the reaction matrix. In related work, particle-hole spectra of doubly magic O^{16} and Ca^{40} were examined by using the reaction matrix. A careful study of the validity of expanding the residual interaction in this way includes finding out how well the two-particle ladder approximation has been solved and how large are possible corrections due to core breakup.

A detailed analysis of the Brookhaven experiments on elastic scattering of 1-BeV protons from H, D, He^4 , C^{12} , and O^{16} was carried out with use of the Glauber multiple scattering formalism. For He^4 the fit to the elastic scattering data is good. The nuclear model describing the proton data describes the electron scattering data as well. The fit for the more complex O^{16} nucleus is also very good. The analysis is insensitive to the nucleon correlations. The agreement for C^{12} is relatively poor, however; it seems clear that further analysis in this case must proceed from the assumption that C^{12} is aspherical. An extension of the theory along this line has been started.

Pion-nucleus scattering data in the energy range 24 to 153 MeV were analyzed by using the velocity-dependent optical model proposed by Kisslinger. This leads to a determination of nuclear density parameters and of the rms charge radius of the pion, r_π . The nuclear radii obtained are consistent with electron-scattering radii. The sensi-

tivity of the elastic $\pi^\pm$ - He^4 scattering to the form factor of the pion was also examined by using calculations made with this model. The region around 60 MeV offers the greatest sensitivity to the pion radius, but shapes of the pion form factor are not easily distinguished. The use of deuteron and mass-3 targets was examined.

In connection with interpretation of the spectra of rare-earth salts (e.g., $PrCl_3$), the shielding of the $A_4r^4P_4(\cos\theta)$ and $A_6r^6P_4(\cos\theta)$ terms of the crystal field at the location of the $4f$ shell was evaluated for the cases of Pr^{3+} and Tm^{3+} . Shielding of the $4f$ electrons is produced by the external $5s$ and $5p$ shells. It was found that the appropriate shielding factors σ_4 and σ_6 are quite small (e.g., $\sigma_4 = +0.091$ and $\sigma_6 = -0.040$ for Pr^{3+}), in contrast to the large results previously obtained for σ_2 .

The effective interaction between He^3 atoms in dilute mixtures of He^3 in liquid He^4 was determined from measurements of specific heat, susceptibility, sound attenuation, and spin diffusion. It was shown that ordinary effective range theory is not useful, but a modified form (applied to the attractive interaction only) gives a good description of s -state phase shifts up to quite high momenta. It was found that mixtures should undergo a fermion superfluid phase transition, but the transition temperatures are $< \approx 10^{-6}^\circ K$. However, evidence for the transition should be found in a 5% decrease in the limiting value of the spin diffusion in a currently accessible temperature range.

Within the framework of Landau's Fermi liquid theory, the leading corrections to the transport mean free times were shown to come mainly from quasiparticle scattering with small energy and momentum transfer, and to be of relative order T/T_F rather than T^2/T_F^2 , as had been expected. (Here T_F is the Fermi temperature.) The changes in the energy and damping of a quasiparticle were calculated from the same point of view, and it was shown that a $T^3 \log T$ term appears in the specific heat. In the special case of a nearly ferromagnetic Fermi liquid, the results are similar to those already known from Green function calculations.

High Energy Accelerators

The Accelerator Department is responsible for the operation, maintenance, and improvement of the Alternating Gradient Synchrotron (AGS), the planning and setting up of apparatus required for the experimental program, a conversion program to increase the intensity of the AGS, and research and development of new ideas in accelerator design and exploitation. The present status and program of the Department are detailed in the following sections.

ALTERNATING GRADIENT SYNCHROTRON

The AGS Division has the dual responsibility of efficiently operating the synchrotron for high energy physics experiments and engaging in the research and development required to modify the facility as necessary. Some 60 members of the Division are employed on a rotating shift basis to man the machine during continuous round-the-clock operation. The development effort is directed toward improving AGS operating efficiency, achieving a better understanding of accelerator physics, and providing new or improved facilities for the experimenters.

The year was marked by continued increases in the peak and average intensities of the accelerated beam. At the same time the desirable trend of reducing the radiation levels of AGS personnel has been maintained. A major addition to the facility, the slow extracted beam system, has been successfully tested and is scheduled for limited operational use in the summer of 1968. It has taken about 2½ years to develop and install the equipment for this beam.

Operation

This year, for the first time, the AGS was required to run for extended periods with the proton intensity intentionally reduced. The peak intensity reached was a 20% increase (2.6×10^{12} protons/pulse) over last year, and shift averages $> 2.2 \times 10^{12}$ were realized. This intensity was well above that required by experimenters. This fact, coupled with the need to avoid excessive increases in residual radiation levels, has caused the intensity to be held to an average of 1.7×10^{12} . Figure 1 shows the slow

growth of the biweekly average intensity during the last 18 months.

Although machine reliability increased slightly compared with last year, the time used for high energy physics remained about the same because of the increased amount of time required for studies involved in commissioning the slow extracted proton beam. Figure 2 shows the biweekly operations efficiency, and Figure 3 is a yearly breakdown of AGS utilization. Figures 4 through 6 show, for the last four calendar years, the efficiency of operation, the amount of scheduled time preempted by equipment failures and maintenance, and the relative amounts of experimental setup time and requested downtime. Significantly, the failure rate continues to decrease. The total utilization of the AGS is greater than is indicated by the small increase in efficiency because of the increase in the number of experiments running simultaneously (from an average of 3.2 in 1964 to 4.0 in 1967). Figure 7 shows the total experimental time for each of the last four calendar years.

A winter shutdown was scheduled from Nov. 12, 1967, through Jan. 11, 1968, primarily to install phase I of the slow extracted beam system. This included the installation of the septum and ejector magnets, three target airlocks (one automatic), two of the four powered backleg windings, steering and focusing magnets in the external beam line, and all attendant vacuum chambers and components. Major changes in the shielding of the F-10 area were effected. Most of the cabling for this equipment was installed, including that for the slow extracted beam console and security system. Other work completed during this shutdown included major rearrangement of the AGS main control room to accommodate more equipment; installation of part of a new closed-circuit television system, three additional airlocks (two automatic), and a fast kicker system with a wider aperture magnet; and surveying and adjustment of the level of the main magnets.

The present operating schedule calls for a 12- to 16-hr period for maintenance of the synchrotron every two weeks. This period can also be used for minor improvements and modifications of equipment normally inaccessible during AGS operation.

Figure 3. AGS utilization during fiscal 1968. Sum of enclosed areas represents scheduled operation time. Percentages refer to scheduled time, which is 86% of maximum possible running time.

Figure 4. AGS efficiency, calendar years 1964-67.

Figure 5. Equipment failure and maintenance, calendar years 1964-67.

Figure 6. Experimental setup time and requested downtime, calendar years 1964-67.

Figure 7. Total experimental time, calendar years 1964-67.

On eleven occasions during the year synchrotron operation was interrupted by failures lasting 10 hr or longer (see Table 1).

The linear accelerator (linac) performed well during the year; a significant reduction has been made in synchrotron downtime due to linac troubles. During the major shutdown, the coupling loops in the output of the two final FTH 515 tubes were replaced by capacitive elements, which made tuning adjustment much easier and reduced arcing. A new beam-current monitoring system was installed. At the end of the shutdown the preinjec-

tor accelerating column was found to be contaminated; it would not hold off the 750 kV necessary for normal injection into the linac. It was replaced by a spare column that had been kept under vacuum. This column required relatively little conditioning to withstand full operating voltage and has since run without failure.

The motor-generator set that energizes the main magnets was pulsed about 8×10^6 times during the year. Operation was entirely satisfactory, with little downtime. A new motor speed control system was installed during the winter shutdown.

Figure 8. Location of major components and beams at the AGS.

A continuing effort at the AGS is the replacement of organics in high radiation areas with more radiation-resistant materials. Such materials as metal "C" rings for vacuum seals and ceramics for insulation are being introduced into the AGS machine whenever possible.

Sputter-ion-type vacuum pumps continue to be used on the AGS to supply additional pumping speed when required. Two evapor-ion pumps at the F-17 and L-17 straight sections were replaced with sputter-ion pumps. This will reduce the radiation exposure to personnel in these areas, since such pumps require little maintenance. In addition, to reduce AGS downtime for target changes, fast pumping systems have been installed on a number of the target airlocks. These pumps are used for quick pump-downs and to provide lower ultimate pressures.

The installation of the slow extracted beam imposed a heavy load on the Mechanical Services Group because of the complexity of the water-cooling and refrigerator systems. Three wells were shock-treated with phosphate during the winter shutdown. Several large iron water pipes were replaced by copper pipe because of the accumulation of iron deposits inside them. Provision was

Table 1

Cause of failure*	Duration, hr
Rectifier problems, motor-generator set	54
Water on main magnets, caused by broken hose on experimental magnet near G-10	42
Beam 5 separator breakdown	35
Repair of warped plate in beam 5 separator	20
Power shutdown due to snowstorm	19
Failure of multiturn injection equipment	16
Failure of A-10 septum magnet	11
Power shutdown caused by Long Island Lighting Co. power dip	11
Loss of vacuum due to I-10 ejector leak	11
Loss of vacuum due to leak in F and G superperiods	10
Failure of beam 2 power supplies	10

* Beam numbers and locations are shown in Figure 8.

made for back-flushing and acid-cleaning of the new pipes if necessary.

The magnet enclosure has experienced an increase of about 35% in residual radiation compared with an increase of about 15% in total accelerated beam.

The total 1967 radiation exposure of accelerator personnel was about 532 Rem. This figure is 12%

lower than that for 1966, partly because of a lower incidence of damage in high radiation areas.

Accelerator Studies

The major program carried out in the past year involved the testing of the slow extracted beam system. Initially it was shown that a reliable third integral resonant spill could be obtained on an internal target during a high energy flat-top. Although some ripple appeared on this spill, methods for reducing it are available. After installation of the F-5 and F-10 septum magnets, some beam was extracted on the first attempt. Tuning and adjustment of this beam will continue for some time. The measured extraction efficiency of 80% compares favorably with the calculated value.

Another important program was the reduction of orbit distortions at injection. As part of this effort, magnet-gap shields consisting of $\frac{1}{16}$ -in. steel sheets were installed on 238 of the main C-magnets. These shields reduce the effects of the earth's field, as distorted by the ring girders, on the injection orbits. Operation at injection was affected in three ways as predicted. The twister magnet correction fields were reduced by 45%, the 12θ vertical orbit correction currents were reduced by 25%, and a reduction was effected in the sensitivity of the machine intensity to stray magnetic fields produced by experimental apparatus close to the machine.

Early in 1968 additional quadrupoles on the ring were connected to give both vertical and horizontal 17θ gradient corrections for reducing the $\nu = 8\frac{1}{2}$ resonance stopband widths. In addition, wiring errors in the sine and cosine 8θ and 9θ backleg windings were eliminated. These windings are now regularly used to provide horizontal orbit corrections at injection.

As a result of these efforts, $>2 \times 10^{12}$ protons/pulse can be accelerated in a routine manner, and peak intensities of 2.6×10^{12} have been obtained.

During the year, investigation of vertical and horizontal coherent instabilities was continued. An improved version of the narrow-band feedback damping system for suppressing vertical coherence was installed and tested in the fall of 1967.

Other programs include a detailed investigation of the half-integral stopbands and a study of the interaction rate in beryllium oxide and tungsten targets as a function of position along the target for different targeting conditions. The purpose is to obtain a realistic picture of the source sizes for

secondary particles and to determine the nature of nonuniform heating of the targets.

In addition, some time was given to each of the following topics: adiabatic rf capture, bunch shape oscillations and longitudinal space-charge effects, multiturn injection with 20 turns from the linac, and clean-up target studies.

The Health Physics Group continued its studies on radiation characteristics and hazards of the synchrotron. A plastic phantom man filled with a solution containing all the common elements found in man was exposed in the G-10 target area. The activation and decay scheme of the phantom was compared with the measured exposure. Thus a rapid estimate of dosage received in the "active" magnet enclosure can be made by measuring the exposed person's residual radiation and comparing it with results on the phantom.

Technical Development

Linear Accelerator. The high-gradient accelerating column, under development for several years, will shortly be operational. It consists of a stack of 15 ceramics, each 2.5 in. thick and having an outside diameter of about 28 in., separated by metal disks. In operation the inside of the column is at vacuum, the outside is at normal atmosphere, and the assembly is cantilevered.

Prior to construction of the first operational column, investigations were carried out to ensure the mechanical integrity of the unit. Epoxy tests of the metal-to-ceramic bond were made and a suitable epoxy and assembly technique was found. A full cross-section mechanical test unit, $\frac{1}{2}$ the length of the final column, was constructed to study the adequacy of the materials and methods to be used in the final column. Loads were applied that were up to a factor of three greater than normal working loads. The temperature was varied by 40°F to test the integrity of the joints under stresses caused by thermal expansion.

Finally, the first operational column was constructed with use of the techniques developed on the test unit. A "clean" 200-mA pulsed beam of 120 μsec has been accelerated without the dilution so often observed in present operational low-gradient machines. A fast beam-loading compensation scheme reduces the voltage droop during the beam pulse to $<300\text{ V}$.

A new linac-tank end cover valve and beam stopper have been installed at the low energy end of the linac. The beam stopper allows the prein-

jector to accelerate a beam to this point without damage to the valve or subsequent drift tubes.

A new medium-power amplifier for 100-W input to 300-kW output at 200 MHz has been completed. Besides improving reliability, this amplifier is sufficient to drive the rf final stages when the three-port modification is installed. This change is designed to minimize beam-loading and field distortion when the beam from the new short preinjector column is accelerated. This equipment is in the final stages of completion. Added to the components is a coupler for the FTH 515 power amplifiers which will facilitate rf matching with the output transmission lines. Instead of using fixed loops, rf coupling is achieved via an 8-in.-diam movable disk that penetrates the wall of the output cavity of the FTH tube. The degree of coupling can be varied to achieve matching conditions by manually adjusting the depth of penetration. A prototype of the coupler was fabricated, tested, and found to operate satisfactorily.

The hard tube modulator installed last year has improved the stability of the linac beam. It is now connected in a closed loop in order to provide automatic high-speed correction of the effects of beam loading and other disturbances. The measurement of beam stability has been improved by installing a monitoring system that is self-calibrating.

Synchrotron Components. A simple, phase-sensitive demodulator working within the AGS radio-frequency band of 1.3 to 4.5 MHz has been developed. The circuit has many applications in the accelerator and has led to an improved low-level rf system which permits stable AGS performance at lower intensities than could formerly be accommodated. Low intensity is often required for radiochemistry experiments.

A second PDP-8 computer has been added to the main control room computer complex. Thus a computer is available for use as a real-time on-line data acquisition and control device, and the original computer can be used in program development and research applications. The selection of an identical PDP-8 computer allows extensive reductions in the programming effort required for effective system operations, since programs already written are usable without changes.

An equilibrium orbit measurement technique that relies upon the computer system is a particularly successful application of computer technology to accelerators. Formerly, accelerator equilibrium orbits were attainable only after hours of oscillo-

scope photography, data reduction, and plotting. Often the process took so long that the phenomenon under study had changed before data collection and tabulation were completed. The new technique permits measurement of both radial and vertical orbits, at several selectable times within the cycle of acceleration, in <30 sec. The computer can then also type or display the orbits for immediate study. (See Figure 9.)

A high-definition closed-circuit TV system was introduced this year. The new cameras are less sensitive to stray magnetic fields and more radiation-proof than those used previously.

Improvements made in the firing circuits of the main rectifier bank of the AGS motor-generator (MG) set have led to less ripple in the main magnet field. The liquid rheostat used to control the speed of the MG set has been replaced by an all-electronic system which uses a high-power triode to control dissipation in the rotor winding of the MG set. The exciter power supply of the generator has also been replaced. These changes in the main magnet power supply have resulted in marked improvement in the stability and ease of operation of the AGS when it is operating with a complex cycle of extraction and multiple internal targeting. The successful operation of the slow extracted beam is particularly dependent on a closely repeatable AGS cycle with as little flat-top ripple as possible.

Figure 9. Computer-generated display of horizontal equilibrium orbit. Top: Normal beam position and dispersion. Bottom: Beam shifted to outside of vacuum chamber for targeting purposes.

Three new airlocks that are controlled by an electronic logic unit have been placed in operation. A complete sequence of target withdrawal and insertion can be initiated by the operator. Each step of the sequence is actuated by the automatic controller only when certain mechanical, vacuum, and security system requirements are met. This system will minimize the possibility of accidentally releasing the main AGS vacuum and will also reduce exposure of operating personnel to radiation.

An automatic airlock of this type has been installed for chemistry experiments at straight section G-20. It will allow experiments to be performed in the direct proton beam, well away from the high radiation area at G-10. A target box with two target and airlock systems has been installed. A remotely controlled, pneumatic transport system, designed for use in conjunction with one of the airlocks, is ready for bench tests. This system will enable experimenters to remove thin foil targets immediately after exposure without shutting down the AGS.

The radiation monitoring system within the accelerator has been redesigned to function also as an in-ring spill monitor on a pulse-by-pulse basis. Each detector is linked to its own electronic alarm sensor. The sensor is automatically adjusted by any five possible AGS operating modes, either singly or in any combination.

Figure 10. Control console of the slow extracted beam system in the main control room of the AGS.

Extracted Beams. The fast beam to the 80-in. bubble chamber in the North Experimental Area can now extract two bunches in one AGS cycle separated by about 0.1 sec. The fast kicker system has been modified by the introduction of deuterium thyratrons. This change has permitted the kicker magnet aperture to be increased. A new fast kicker, to be used after the AGS conversion is completed, is being designed. The ejector power supply that forms part of the fast beam to the Southwest Experimental Area is to be moved, pending reactivation of that area.

During the year the slow extracted beam system was successfully operated for the first time. All the equipment in the ring, such as septum magnets, vacuum chambers, and instrumentation, was installed during the shutdown at the end of 1967, and the first beam was extracted in March. Intensive studies were carried out to improve extraction efficiency, reduce spill modulation, and improve beam quality so that the first experiment using this facility could begin in 1968. The slow extracted beam is one of the most complicated single systems ever installed in the AGS. More than ten special, highly regulated, high-current power supplies are required. The beam transport line, after leaving the ejector, divides into an analysis and an experimental channel, and the total length of vacuum pipe is >230 ft. The slow extracted beam vacuum system is under complete remote control from the vacuum laboratory. Sputter-ion pumps are used both on the septum and ejector boxes and on the beam transport system. The operating pressure range is 10^{-6} to 10^{-7} torr.

The special septum magnets developed for this project were described in last year's report. These magnets, with their respective vacuum boxes and remotely controlled moving and sensing mechanisms, were installed in the F-5 and F-10 straight sections. The ejector magnet will allow an exciting current of 6400 A for a duration of 600 msec, equivalent to a duty cycle of 25% at the present AGS repetition rate. It has a magnetic field that can bend the primary proton beam 20 mrad at 30 BeV.

Extensive instrumentation, analysis equipment, and TV pickups are located on the transport pipe. In addition there are bending and focusing magnets. When development is complete, it will be possible to focus the slow extracted beam to dimensions of about $\frac{1}{16} \times \frac{1}{32}$ in. (See Figure 10.)

Figure 11. Experimental setup in the West and East Experimental Areas of the AGS, summer 1968.

EXPERIMENTAL PLANNING AND SUPPORT

Resident Brookhaven groups and research groups from universities throughout the United States used the AGS for research in high energy physics during the year. Bubble chambers or electronic counters were used as detectors. The bubble chamber program involved three chambers, and >5 million pictures were taken for 40 groups. In addition, 14 counter experiments collected research data during the year. Materials and services for this research are supplied by technical groups within the Experimental Planning and Support Division. These groups design, construct, and operate the equipment used in the particle beams at the AGS.

Experimental Facilities and Program

The three bubble chambers are served by four separated beams. These beams span the particle momentum region from <1 BeV/c to 30 BeV/c. The lowest energy beam supplies particles to the 30-in. bubble chamber. The beam is capable of purifying a beam of K mesons to 900 MeV/c, and by a suitable use of material in the beam the energy of the particles can be degraded so that they stop in the chamber.

Operation of the low energy separated beam and the 30-in. bubble chamber continued throughout the year. About 1.5 million pictures were taken for experiments done with a variety of incident particles and chamber fillings. Low-momentum and stopping beams of π^- , $K^\pm$, and $\bar{p}$ were used in conjunction with liquid hydrogen and deuterium fillings. The longest run of 0.5 million pictures was made for Princeton University, with shorter runs of 25,000 to 220,000 pictures for groups from Stanford, Vanderbilt, Yale, Brandeis, Syracuse, and Tufts Universities, Illinois Institute of Technology, the Universities of Rome, Melbourne, California, Massachusetts, and Florida, and Brookhaven National Laboratory. A run was also performed for University College, London, with K^- mesons stopping in emulsions.

Medium energy separated particle beams were obtained from beam No. 1A for use in the 31-in. bubble chamber. During the year experiments were done by groups from the Lawrence Radiation Laboratory, the University of Kansas, Iowa State University, Syracuse University, the Atomic Energy Commission of Argentina, and Brook-

haven National Laboratory. About 1.8 million pictures were taken this year employing π^- , K^- , and $\bar{p}$ beams in liquid hydrogen and, for one long run, in a liquid hydrogen-neon mixture.

The rate at which satisfactory pictures can be obtained in beam No. 1A has been improved recently by the installation of a "shutter" magnet, a device that can be pulsed to terminate the particle beam after a preset number of particles have entered the chamber. The instrumentation for tuning and monitoring this beam has been improved by the installation of a remotely programmed and operated scanning device at the second mass slit.

This year the AGS North Experimental Area and the 80-in. bubble chamber provided exposures for 11 experiments with a total of 1.3 million pictures. About one million of these were taken in the electrostatically separated beam No. 3, with the chamber filled with liquid deuterium. These included exposures with K^- mesons at 5.0 BeV/c and near 3.8 BeV/c (101,000 and 284,000 pictures) and with protons, π^- mesons, and antiprotons and protons at 7.0 BeV/c momentum (87,000, 96,000, and 97,000 pictures, respectively). In the rf separated beam (No. 4) the chamber, filled with a hydrogen-neon mixture, was exposed to K^- mesons at a momentum of 12.8 BeV/c and to protons of 28.5 BeV/c momentum (242,000 and 67,000 pictures, respectively). After being shut down all winter for extensive modifications, the 80-in. bubble chamber was filled with hydrogen and experiments were resumed in beam No. 4 with a K^+ -meson exposure at 7.4 BeV/c for a total of 137,000 pictures. Early in the fall the rf separators failed as a result of arcing damage and the deflectors were repolished. An extensive program of about 18 experiments for a total of about 1.8 million pictures is planned for the 80-in. bubble chamber and beam No. 4 in the coming year.

Two target areas are used to produce secondary beams for counter experiments, most of which are accommodated at the G-10 area. Three beams radiate from the target within the G-10 target box, and each beam is split into two branches on the experimental floor. In this manner some experiments can be set up while others are running. This increases the efficiency of operation and smooths out the work load associated with changing experiments. Figure 11 illustrates the beams to be set up during the summer of 1968.

On the inside of the AGS ring the beam from G-10 is split into a neutral beam and a charged particle beam. The latter was used by a large number of groups to test their apparatus before their experimental equipment was installed in the final location. At any one time two or three groups could be using the particles from the test beam.

The bending magnet that directed particles down the test beam channel swept all charged particles from the straight-ahead neutral channel. This was then used by a Columbia University group for a total of 1228 hr to study certain decay characteristics of K_2^0 mesons. A similar experiment for Harvard University followed. After 300 hr of data-taking, this group finished work on another aspect of K decay. The beam area is now being rebuilt for additional and more sophisticated experiments on K_2^0 decay.

The 4.7° beam from the G-10 target on the outside of the ring provided μ mesons (muons) for an extensive run by two groups from Harvard, both studying inelastic muon interactions; data were collected for 1214 hr. Between the two muon runs the other branch of the beam was used for 1795 hr for an experiment on large-angle scattering of π mesons (pions) by protons for a Cornell University group. In an experiment for a University of California group the scattering of K mesons on heavy nuclei was studied. The 4.7° beam is now being rebuilt to accommodate two new experimental setups. The University of California group will study another aspect of K -meson decay, while the other branch will be used by a group from the State University of New York at Stony Brook. The latter group will be studying the associated production of K and Σ particles by pions.

The other beam from G-10 is at 10° on the outside and is purified by the use of electrostatic separators. After a total of 953 hr the experiment of a BNL group measuring the magnetic moment of the cascade hyperon was completed. The other branch of the beam had two experiments in it. The first, for Columbia University, was an experiment on the production and decay characteristics of η particles. The possible asymmetries in the spectrum of charged pions emitted in the decay were studied for 664 hr. In the second experiment, a University of Rochester group collected data on the decay of neutral K mesons for 184 hr.

After the winter shutdown of the AGS, experiments in both branches of the beam were changed.

The short branch now contains an experiment to measure the large-angle scattering of K mesons in hydrogen for a group of physicists from Brookhaven, CERN, and the University of Rochester. In the other branch a large magnetic spectrometer is being used by a group from MIT to measure the energy of particles from the decay of K^0 mesons.

The remaining target location for counter experiments is at F-10. A secondary beam from a target in that area has been used for a long sequence of such experiments. The area is now being rebuilt for use in experiments with the slow external proton beam. Before rebuilding began, a large experiment on isobar production by pions and K mesons was completed in 1074 hr by physicists from Brookhaven and Carnegie-Mellon University. The use of internal targets at F-10 was then suspended, and components for the new proton beam were installed.

The massive shields to stop the slow extracted proton beam were constructed in the East Experimental Area during fiscal 1968. The cores of the backstops in which the residual beam will be degraded to a tolerable radiation level used about 0.75 ton of tungsten and 2 tons of depleted uranium on the beam analysis channel and 1 ton of tungsten and 4 tons of depleted uranium on the experimental channel. In addition, some 1000 tons of steel were used in the shielding. The large amount of shielding is dictated by the intensity and energy of the beam and the attendant muon shielding problem.

Construction is progressing on the phase II backstop for the experimental channel. Made of steel, the backstop is about 18 ft wide $\times$ 10 ft high and extends 33 ft along the beam direction, having a re-entrant cavity some 13 ft deep to contain the residual proton beam after targeting. Channels for the extraction of experimental beams are provided at -5.36° and 0° .

The first experiments to utilize the slow extracted beam are being installed. These have been chosen with a view to the interests of the physicists and their beam requirements. They can utilize the beam in the earliest stages, before the optimal qualities of beam and spill are achieved.

Experimental Equipment

During the year there were, on the average, ten beams either in operation or under construction in the East, West, and North Experimental

Areas. The scheduling and use of these areas was so arranged that construction of new beams could proceed concomitantly. Thirty-six man-years of effort were expended on new beam construction by members of the Experimental Division and the Laboratory's Plant Engineering and Planning Division.

A summary of the inventory and usage of major experimental service items is given below.

Item	Inventory	Usage, %
Magnets	211	86
Power supplies	185	79
Beam separators	12	83
Shielding	90 tons	80
Experimental power	37 MVA	92
Experimental cooling water	3550 gal/min	96

Miscellaneous Items

The Power Supply Group has purchased twenty 450-kW SCR controlled power supplies. These units are now competitive in cost with magnetic-amplifier controlled units. They have a higher over-all efficiency and require less maintenance. Work continues on power supply improvements, with the major improvement this year in the current regulators. New regulation units, using field-effect transistors rather than inverters and choppers, have a much better reliability record than the old ones.

About 8 MVA of new power will be made available along the outer wall of the East Experimental Area via 16 distribution boxes. This power was provided by purchasing a 3750-kVA outdoor transformer and transferring a transformer of the same capacity from the Cosmotron. The electrical power to these transformers will be provided by splicing into an existing feeder cable.

An effort has been made to reduce the downtime on the machine due to magnet failure and to improve the radiation resistance of certain magnets in the G-10 area. Eight of the magnets, those closest to the G-10 target, have been provided with wooden skirts to deflect any water spray (from leaks) away from adjacent components and down to water detectors that register in a central control room. In addition, the coil jumper hoses have been fitted with quick-disconnect fittings to facilitate a regular replacement program with minimum exposure of personnel to radiation. Plans are now being made to replace these coil jumper hoses with ceramic spacers. In addition, all magnets in the G-10 area have been fitted with flexible

bronze water hoses. These replace the neoprene rubber hoses used previously.

Two special types of C-magnet were designed for use with primary and secondary beams in the slow external proton beam facility. One is a large C-magnet, designated 18C72, that will be used to direct the proton beam onto production targets. Another is a small C-magnet that will be used to split off secondary particles produced on such a target from the unused proton beam. A 48D48 magnet was modified to provide an unusually large gap (see Figure 12).

A large magnet-transporting device, capable of lifting, moving, and positioning a 100-ton spectrometer magnet within the necessary alignment tolerances, has been designed and is being fabricated. This device could possibly be used to transport and align other large magnets in the experimental area.

The efforts of the Magnet Study Group were divided between research and development of

Figure 12. One of the large spectrometer magnets for use in an experiment at the AGS to measure the momenta of particles emitted in the decay of K mesons. The magnet has been modified to include a gap of 78 in. between the magnet poles. The larger volume of magnetic field will allow many decays to be studied simultaneously.

magnet hardware and provision of certain precision calibration services.

A harmonic coil was constructed for analysis of the new high-gradient 3-in.-diam quadrupoles. An existing 12-in. harmonic coil has been modified for use in the analysis of the new 18-in.-diam quadrupoles. Harmonic aberrations and absolute calibration curves are provided for all types of magnet in use at the AGS.

A large number of Hall probes are routinely maintained and precisely calibrated for use by experimental groups. When modifications of large solid-angle magnet assemblies are proposed, design assistance as well as computer field studies is provided.

An effort of appreciable significance has been that of describing the complex fields of the 120D36 and the 48D48 spectrometer magnets. Computer programs for precise momentum calculation are now available to experimental groups. A very simple method of momentum analysis capable of producing precision momenta almost instantaneously has been successfully applied to wide-angle spectrometer-spark-chamber arrays.

Design of magnets both for beam handling and for accelerators has been pursued. Emphasis in beam transport has been shifting to septum-type configurations for use in the critical areas where beams are split. Models have been made and computations carried out for both window-frame and septum dipole iron magnets with high current density coils that are cryogenically cooled. Fields approaching 40 kG appear practical in certain designs.

The Beam Separator Group operated 12 electrostatic separators in four beams and the rf separated beam. In November, six dc separators comprising two triplets were removed from the 80-in. bubble chamber beam for modification to reduce the electrode spacing. Four separators have been installed in the same beam in the form of two doublets; the doublets are expected to produce the same separation as the triplets. The remaining two separators will be installed later in the slow external proton beam facility.

Six 400-kV power supplies were purchased to replace obsolete units and to power separators in new beams. In addition, two turbine molecular vacuum pumps have been installed on separators in the G-10 + 10° beam, with an improvement in over-all operation.

A series of tests was conducted on the test separator this past year. The most significant test in-

volved the addition of a grounded shield in the tank to decrease the electrical volume of the vacuum enclosure. The results showed that there was no longer an interaction between the electric and the magnetic fields, that the separator operated longer between conditioning periods, and that a higher electric field might be feasible. The tests will be continued, and modifications based on the results will be made to beam-line separators as the separators become available.

The rf separators ran successfully until late in the fall, when internal arcing occurred in one of the deflectors. On inspection, the other deflector also showed evidence of arcing, and both units had to be burnished and cleaned. It is thought that the cause of the arcing was organic contamination. A program has been initiated to improve the deflector vacuum systems by replacing most of the organic seals with metallic seals.

The Cryogenic Group's major efforts have been directed toward the design, fabrication, and operation of liquid hydrogen or liquid deuterium targets. Seven targets were operated at the AGS and five new targets were designed. These targets consist of a Mylar flask surrounded by superinsulation and a vacuum vessel. Associated equipment includes a liquid hydrogen reservoir, a liquid-level indicator for the reservoir and target, a vacuum-jacketed transfer line, vapor vent lines, vacuum electronics, and an electrical power control chassis.

Of the magnet systems operated, the solid hydrogen superconducting magnet system is certainly the most sophisticated. The system includes a closed-cycle 4.2°K helium refrigerator, appropriate purification equipment, a superconducting magnet Dewar, and a solid hydrogen target system. Problems encountered with the magnet recharging techniques were resolved as more experience was accumulated. The refrigerator performed well, with >1600 hr of operating time.

Liquid-hydrogen and liquid-helium transfer lines were constructed and maintained for the various experimental setups. The associated equipment for targets, including liquid reservoirs, liquid-level indicator, gaseous vent lines, vacuum electronics, and electrical power control centers, has been maintained by the Cryogenics Group.

The High Energy Electronic Equipment Pool (HEEP) is a section of the Experimental Planning and Support Division. It supplies a large part of the electronic equipment used in counter experiments at the AGS, and this year provided equip-

ment for 28 experiments. Equipment utilization has been about 85%, due largely to the group's policy of lending equipment to users outside the high energy research groups on a short-term basis.

HEEP is running extensive tests to evaluate 200-MHz logic modules in an effort to provide the best and most reliable equipment for general use.

AGS CONVERSION

Fiscal 1968 was the first full year during which construction funds (as distinct from design funds) were available for the AGS conversion project. The project is well into the construction phase. Preliminary design for the entire project is essentially complete, and detailed design of buildings and major machine components is far advanced. Construction of buildings and facilities has commenced, orders have been placed for many of the major machine components, and delivery of some equipment has been made. By the end of the year, about 40% of the project funds had been committed.

Construction work is advancing most rapidly, since construction of the buildings and facilities for the project must precede the installation of accelerator components. The contract for Improvements to Land is essentially complete. This contract involved relocating Fifth Avenue, installing storm drainage and sewers, leveling the East Experimental Area yard, and clearing the site of the 200-MeV linac complex. Work on the extension of the utility system is well advanced. Water and steam mains and electrical duct banks are largely completed. Work on the new 50-MW substation is well along, and installation of the electric distribution cables is in progress.

The steel piles to support the new linac are all in place. The concrete work for the linac complex is nearing completion. This includes the 500-ft-long linac tunnel and the 400-ft-long tunnel between the linac and the AGS, as well as the foundations for the Preinjector Building and the equipment bay. The structural steel and siding for the Linac Building are almost ready for delivery.

The foundations and structural steel frame of the addition to the East Experimental Building are complete and the structure will soon be closed in. The foundations for the new motor-generator set and its building and for the new Rf Power Building, all inside the AGS ring, are well advanced. The 21 large service sleeves that penetrate

the AGS magnet tunnel are all in place. The precast concrete arches that will support the additional shielding of the magnet tunnel in certain areas have been fabricated and delivered.

The linac complex, the East Experimental Building addition, the Motor-Generator Building, and the Rf Power Building should be ready for occupancy during the spring of 1969.

To increase the pulsing rate and flat-top capabilities of the main AGS magnet, it had been planned originally to acquire another set from the manufacturer of the existing motor-generator-rectifier set. However, when prices were established for this equipment, it was decided to solicit bids for an entirely new motor-generator-rectifier set of twice the size of the existing unit. This decision allowed for competition in obtaining prices and also permitted the introduction of some beneficial design features. The existing set will serve as an operating spare. An order has been placed with Siemens of West Germany for a complete motor-generator-rectifier set of the full required capability at a price lower than that for the equipment to augment the existing set.

A second prototype of higher power output for the ring rf amplifiers has been built and tested. Procurement of the 14 units for the new ring rf system is being initiated. The new four-gap accelerating cavities are nearing the prototype stage. A new, more efficient method has been developed for powering the 240 ion pumps that will develop the high vacuum in the main ring. These pumps are being delivered and the power supplies and auxiliaries are on order. The new main-ring vacuum chambers which will incorporate quick-disconnect, metallic gasketed seals have also been ordered. The various components for the modularization of the main magnets are on order or in the final stages of design. A remotely operated alignment theodolite employing televised viewing has been delivered.

Theoretical studies of the 200-MeV linac's performance have centered on dynamics with space-charge effects and on the interaction of the beam with the cavity fields. The results confirm earlier estimates that peak currents of 100 and probably 200 mA can be accelerated with good emittance. In addition, improved techniques of accelerating field phase and amplitude control have been developed. The understanding of accelerating field stabilization by the multistem drift-tube method has been extended and refined.

A 750-kV Cockcroft-Walton generator has been ordered for the first preinjector, and a high-gradient accelerating column is under construction. An order has been placed for the fabrication of the nine accelerating cavities. The first 56 drift tubes with their quadrupoles are being fabricated by members of the Conversion Division. Orders have been placed for the fabrication of the balance (220) of the quadrupoles and other drift-tube parts. Final assembly of all drift tubes will be done at the Laboratory. Electron beam welding will be used to make the final closure of the drift tubes, and a large electron beam welder has been purchased.

The cavity circuits for the 5-MW final rf amplifiers have been ordered. The 5-MW prototype rf system has operated successfully in excess of 7 MW. Some problems encountered with the modulator series switch tube appear to have been solved. Major components for the heavy electronics of the rf system have been ordered. Concepts of the linac control and monitoring system have been reviewed and updated, and detailed design of the system is under way. Detailed design work is continuing on the beam analysis and transport system between the linac and the AGS.

ADVANCED ACCELERATOR DEVELOPMENT

Superconducting Synchrotrons

During the past several years most of the basic design problems associated with superconducting synchrotrons have been solved. Such a synchrotron should clearly be a separated function machine; this means that the function of bending the particle beam into its circular path should be performed by pure dipole magnets, and that of focusing the beam should be performed by pure quadrupole magnets. This is in contrast to combined-function machines like the AGS, where both operations are performed by the same magnet. Superconducting dipoles and quadrupoles have been designed, built, and tested.

The chief problems remaining are associated with the necessarily rapid changes in magnetic fields that take place during beam acceleration. The magnets, which display no losses in steady operation, show intolerably high losses when they are pulsed. Moreover, at low fields the field frequently rises in discontinuous "flux jumps." These phenomena have been under active study during the past year at Brookhaven. Many measurements have been made on coils of various shapes and on

short samples of superconducting materials. Some understanding of the phenomena is now being gained, and with it there comes some optimism that the undesirable effects can be controlled or effectively eliminated. The experiments are difficult to perform and to interpret, and it seems likely that another year of work will be required before a superconducting synchrotron can be designed with confidence.

A type of synchrotron developed at the MURA Laboratory and known as an FFAG (fixed-field, alternating-gradient) synchrotron operates with no variation of the magnetic field. Design of such a machine with a superconducting magnet has been given some study. The magnet structure is complex but seems quite feasible. Although less economical than a conventional synchrotron, such a machine might be considered if the problems of pulsing are not solved soon.

Superconducting Rf Particle Separators

Rf separators for eliminating unwanted particles in experimental particle beams have been limited to use with bubble chambers, since they can be turned on for only very short pulses. For separated beams to supply counter experiments, longer pulses are required. It is possible that cavities coated with a superconducting material will allow rf separators to be pulsed for the required length of time. A year ago a program of development on superconducting cavities was initiated at Brookhaven. Copper cavities plated with lead were constructed and their behavior was observed at liquid helium temperatures. Quality factors $>10^{10}$ were observed at the lowest temperatures. At 4.2°K the quality factor was not quite high enough to permit continuous operation with adequate cooling. When the temperature was reduced below 2°K, the losses dropped to tolerable values. At this temperature liquid helium makes the transition to a superfluid, which enhances its characteristics as a coolant. Work is now in progress on niobium cavities, since niobium is not attacked by air as rapidly as lead. Losses in niobium will probably be about the same as those in lead.

Summer Study on Superconducting Devices

A six-week summer study on superconducting devices began at Brookhaven on June 10, 1968. More than 160 visitors from other national laboratories, universities, and industry were invited to attend. A number of invitees came from Europe; a

large delegation came from CERN, where there is now much interest in superconducting magnets and rf systems. Topics discussed included superconducting rf separators and linear accelerators, superconducting materials, cryogenic equipment and techniques, effects of varying fields on superconductors, superconducting magnets, and accelerators and storage rings using superconducting magnets. The Proceedings of this summer study will be published.

RESEARCH

The program of searches for quarks and other heavy triplets that might be the fundamental particles from which the $SU(3)$ symmetry is derived was completed for the most part during the year. Very low limits were placed on the fluxes of quarks of charge $\frac{2}{3}$ in the cosmic-ray flux.

The possibility remains that combinations of quarks of nonintegral charge may have a mass smaller than that of single quarks, although still so large that they are not easily produced. Single quarks would then decay into these composites with short lifetimes. Although the composites would have nonintegral charge, it seems probable that the lightest stable members of these multiplets

would generally have large values of charge: $\frac{4}{3}$ or $\frac{5}{3}$ or $\frac{7}{3}$. Apparatus was arranged to detect such particles in a sensitive manner above the ordinary cosmic-ray background; very low limits have been established for the flux of these particles in cosmic rays.

It is also possible that the fundamental triplets have integral charge. A mass spectrometer was used to measure the masses of cosmic-ray particles reaching sea level; no evidence was found for such triplets.

This spectrometer was also used to measure the muon energy spectrum and the muon charge ratios at high energies. The energy range covered by the spectrometer extended to about 500 BeV, high enough to provide information on nucleon-nucleon interactions at energies near 5000 BeV. These results are particularly interesting, since analyses of measurements made in deep mines have suggested that the muons produced at very high energies are derived from a very short-lived particle which is not otherwise known – perhaps the intermediate vector boson. These measurements apply, in particular, to muon energies >900 BeV. The present measurements seem to show no anomalous effect for the integral spectrum above 125 BeV.

Instrumentation

The Instrumentation Division designs and builds special-purpose research and test instruments for the other departments of the Laboratory, provides consultation, calibration, and repair services, and operates a vacuum technology shop, a glass-blowing shop, and an electron microscopy facility. In addition, some independent research is carried on, particularly in the areas of radiation detector technology and associated circuitry. Considerable effort is also devoted to the design and construction of computer interface systems and to programs for the automatic collection and processing of data and for control of scientific equipment. Some of the more interesting problems the Division has been concerned with in the past year are discussed below.

GERMANIUM DETECTORS AND SYSTEMS

Germanium junction radiation detectors translate the energy of incident γ rays to proportional electrical signals with considerably less statistical uncertainty than scintillation or proportional counters. The excellent energy resolution of which they are capable has given impetus to a substantial amount of work on the development of new detector production techniques, new detector configurations, and electronic systems designed to degrade the inherent detector performance as little as possible.

Several germanium detectors have been fabricated by using the γ -ray compensation method rather than lithium ion drifting. Devices 8 mm in diameter and 2.5 to 3 mm thick have been given line widths of 6 keV at 1.3 MeV, which is only twice that obtained with the best lithium-drifted detectors. The γ -ray-compensated detectors are more convenient to use because they do not have to be stored and used at low temperatures. When problems of material selection and uniformity have been solved, it may be possible to produce arrays of moderately good small germanium detectors much more cheaply than can be done by lithium drifting.

In addition to the full energy pulses corresponding to total absorption of the incident γ -ray energy

in the detector, there are a large number of smaller pulses resulting from the escape of Compton-scattered γ rays. This continuous distribution of pulse amplitudes tends to obscure the much more interesting full energy peaks. The ratio of counts in the peaks to counts in the continuum can be improved somewhat by surrounding the detector with an anticoincidence shield. An interesting alternative arrangement was developed this year; it increases the "peak-to-leak" ratio by about a factor of 10 in the energy range from 300 keV to 1.3 MeV. The detector is divided into two contiguous segments. Three preamplifiers are used, the first deriving a signal from the first segment, the second from the second segment, and the third, a sum signal from both segments. The sum signal is recorded only when signals have been generated in both detector segments. This implies that at least two interactions have taken place within the compound detector's sensitive volume. After two Compton scatterings, very few γ rays in the energy range below 1.3 MeV retain enough energy to escape from the detector, so that most such events contribute to the full energy peak.

The precision with which γ -ray energies can be measured with germanium detectors is limited by statistical fluctuations in the production and collection of charge in the detector or by noise generated in the associated electronic amplifier, or by both. Efforts to identify the various noise sources and to reduce their effects have continued, with two objectives in mind: to improve over-all system resolution under optimum conditions at low counting rates, and to permit operation at high counting rates with as little loss in resolution as possible.

To achieve the best possible resolution, nearly all the preamplifier components must be selected with care. Dielectric losses in insulating materials can be a significant noise source (Teflon is trouble-free in this respect), and the unavoidable detector load resistor can be much more troublesome than originally anticipated. It has been found that many high-value carbon film resistors (in the range of 1000 to 5000 M Ω) exhibit a substantial variation of resistance with frequency, which greatly

enhances their noise contribution. Methods for selecting good resistors have been developed, and an effort is being made to determine whether high-value resistors made from single semiconducting crystals will have better noise properties.

Operation at high counting rates leads to some losses in system performance. Filters conventionally used to improve the signal-to-noise ratio lead to pulses with long tails on which subsequent pulses are superimposed. A study has been made to determine the effectiveness of using time-variant parameters (such as switches, variable resistors, and multiplying circuits) to shorten the pulse tails without degrading the signal-to-noise ratio. A general approach to the analysis of the problem has been developed in which the systems, both time-variant and invariant, can be characterized by a "weighting" function and by an effective measuring time. This permits comparison of the various systems, prediction of their noise performance and counting rate limits, and an understanding of the compromises that are possible. A system based on the results of this analysis is now being designed.

Decay schemes and the lifetimes of excited nuclear states are often studied by observing time correlations of signals from two or more detectors. Very precise timing has been achieved by using scintillation counters with fast organic scintillators. However, organic scintillators give very poor energy resolution. An investigation has been undertaken to determine whether timing accuracy comparable to that obtained with organic scintillators can be obtained with germanium detectors without sacrificing energy resolution.

The problem is somewhat complicated by the fact that the charge collection time in large germanium detectors is long (of the order of 100 nsec) and variable, depending on the location of the interaction within the detector's sensitive volume. In addition, the noise in a wide-band amplifier, suitable for preserving the speed of fast rising signals, introduces timing errors determined by the ratio of the noise to the signal slope. Other errors may arise if signals of different amplitude reach the triggering threshold of the timing circuit at different times.

A system has been built based on a variation of a "constant fraction of pulse height" trigger which compensates, approximately, for variations in signal amplitude and rise time. Time resolutions (full width at half maximum of a prompt coincidence curve) of 3 nsec at 500 keV and 0.8 nsec at 2.7

MeV have been achieved, with an energy-dependent time variation of only 1 nsec over this range.

COMPUTER SYSTEMS

The major effort of the Division's computer systems group this year has been the development of an operating system in which the supervision of bubble-chamber film scanning and measuring tables and the collection of data from them are integrated with a set of display consoles, all under a single time-shared system on an SDS Sigma-7 computer. The system can service up to 32 data terminals, each including a teletypewriter and a data source, which may be either a measuring table or an interactive display. The system is oriented to the execution of user programs called tasks, which are stored in a high-speed disk memory and executed, when called, according to a pre-assigned priority. It is expected that continuous computer supervision of each of the measuring tables will catch errors as they occur, and thus a substantial amount of recycling and remeasuring time will be saved.

The multiconsole display called BRAD (Brookhaven Raster Display) makes use of a rotating magnetic memory with a number of independent read-write heads. Picture information is stored as a series of "ones" and "zeros" in a format consistent with a standard television raster, so that inexpensive commercial television monitors can be used at each terminal. Detailed, flicker-free pictures containing up to a quarter of a million individual spots or as many as 4000 α -numeric characters can be realized. Two-way communication between the user and the computer is available via a teletypewriter and a "track ball" which intensifies a selected spot on the display and transmits its coordinates to the computer.

Recently, some striking three-dimensional displays have been generated by using the raster display system with a color television monitor. Two stereo projections of the object to be displayed are computed and presented, superimposed, in two colors (red and green) on the television monitor. The display is viewed through eyeglasses with one red and one green lens. The result is a convincing three-dimensional picture similar to that obtained with a stereopticon. An interesting improvement in the three-dimensional presentation of line drawings was realized when the bright and dark parts of the display were reversed (accomplished by a

Figure 1. Color stereo representation of a three-dimensional object produced, under computer control, on a color TV monitor. The viewing glasses in the pocket inside the back cover of this report should be held at normal reading distance to obtain a stereoscopic three-dimensional view of the object.

simple change in program) so that the lines were presented as dark lines on a bright field. The subjective reconstruction of the object in space was substantially enhanced because the lines to be superimposed in the mind were then seen as the same color (black) by both eyes rather than as red by one eye and green by the other. (See Figure 1.)

Another project of the computer group this year was the addition of an interface to the Sigma-2 computer in the Medical Department to allow it to take data directly from an electron paramagnetic resonance apparatus. The computer can be used both for spectrum analysis and for signal-to-noise ratio enhancement by digital filtering and averaging of multiple measurements.

OTHER INSTRUMENTS

Several pieces of apparatus were constructed for low-temperature nuclear magnetic resonance (NMR) studies. NMR measurements are frequently made with a frequency swept oscillator consisting of a tuned circuit, a high-gain broadband amplifier, an amplitude limiter, and a feedback voltage divider. This classical system (usually referred to as a Robinson circuit) was redesigned: a low-noise field-effect transistor was used as the input element, with bipolar transistors for the remaining circuits. Operation over a frequency range of 10 kHz to 20 MHz has been achieved, with input voltage levels from as little as 100 μ V up to

several hundred mV. The circuit includes provision for sweeping and modulating the operating frequency, an adjustment for eliminating the associated amplitude modulation, and a mechanism for simulating resonances for calibration purposes.

A programmed rf pulse burst generator was built for NMR measurements using the spin-echo technique. An interesting feature of the system is an arrangement by which the phase of the initial rf burst is remembered during the interval between bursts so that the echo can be detected synchronously. No rf is generated anywhere in the system during the interval between bursts at either the exciting frequency or any of its subharmonics. The rf signal, at a frequency f , is derived from a continuously running oscillator at a frequency equal to $6f$. Signals at $2f$ and $3f$ are derived by dividing the $6f$ signal by 2 and 3 in digital scalars. When a reference signal at the frequency f is desired, the $2f$ and $3f$ signals are gated into a nonlinear mixer and the difference frequency is extracted. When extreme quiet is desired at the frequency f , the inputs to the mixer are switched off. An additional feature of the spin-echo system is a very low noise preamplifier that uses a field-effect transistor at its input.

Some biologically interesting materials can be recognized and measured quantitatively by virtue of the fact that they absorb right circularly polarized light at certain wavelengths to a different extent than left circularly polarized light. A stable and sensitive device for recording this property, called circular dichroism, has been built. It makes use of a commercial ultraviolet monochromator to which has been added a mechanical light chopper which synchronizes and stabilizes the operation of a servo loop. This servo loop maintains a constant signal, at the chopper frequency, at the output of a photomultiplier sensing the light transmitted by the sample. Thus the calibration is automatically normalized, independent of changes in light intensity or sample absorbance. An electro-optic plate is driven at a different frequency, which causes the sense of rotation of the light polarization to alternate at this frequency. The output of the photomultiplier is amplified and synchronously rectified, the output of the synchronous rectifier being a stabilized, normalized measure of the circular dichroism.

Fast chemical reactions can be studied and their rates measured by observing the change in light transmission at suitably selected wavelengths fol-

lowing the rapid mixing of reagents. A circuit has been built for sampling, integrating, digitizing, and storing the measured value of the anode current of a photomultiplier tube at 40 selected times with intervals ranging from 500 μ sec to 500 msec. After each measurement the results are printed and punched on tape by a teletypewriter. The device is composed almost entirely of digital integrated circuits and operational amplifiers.

It is desirable to know the minority carrier lifetime of the semiconducting materials used in the manufacture of semiconductor radiation detectors. A simple device for measuring this quantity has been built. Minority carriers are generated in a sample of the material by photoexcitation from a pulsed neon lamp. A constant current is maintained throughout the sample, while the voltage across it, which is a measure of the minority carrier concentration, is monitored on an oscilloscope as a function of time. Lifetimes as short as 2 μ sec (the decay time of the light pulses) can be measured with this apparatus.

METEOROLOGY

Wind and Turbulence

The steadiness of the wind, as reflected by the ratio of the vector mean to the scalar mean speed over a given time period, is a valuable indicator of the air pollution potential of a site. It provides a simple means of determining how persistent the wind may be and what dispersion conditions are likely to accompany long periods of nearly constant winds. After surprising difficulty in obtaining wind records of acceptable quality, the first wind steadiness map of the United States has finally been completed. In addition to the standard wind observations obtained at ≈ 30 ft above ground, data from 200 to 300-ft elevations have been selected from other National Laboratories and nuclear power plant sites for comparison.

Dispersion and Deposition

Experimental study of particulate dispersion and deposition from a low-level line source was made to supplement previous studies from point and area sources. Castor bean (*Ricinus*) pollen released naturally from an 80-m line of 240 potted plants served as the tracer. The line was placed within a square grid of sampling instruments placed at 10-m intervals. For each test the plants were moved to one of eight preselected line locations, chosen to

be nearly normal to the mean wind direction and upwind of the sampling array. In all, 24 tests from 2 to 6 hr in length were made; they are expected to provide unique data, since no similar experiments elsewhere are known.

The study of particulate penetration into and through a forested area was continued. In 1967, 10 point source tests were made, in each of which particulates were released from 3 separate locations. Of the 30 release sites, 14 were in the open field at various heights and distances upwind of the forest edge, 13 were within the forest, and 3 were above the trees. Several additional tests were made with an area source upwind of the forest.

Samples are still being counted and analyzed in both of these programs, but partial results indicate considerable transport of particulates both upward and downwind through the forest crown under stable atmospheric conditions.

The difficulty of obtaining reliable samples of large (3 to 100- μ) particles in the varying natural wind has plagued researchers for years. The par-

ticles tend to deviate from the air-flow streamlines because of gravitational and inertial forces, and the collection efficiency of typical samplers depends upon their physical characteristics, their orientation, and the existing wind structure. An automatic grab sampler intended to collect particulates of all sizes with equal efficiency at any wind speed was designed and constructed. The sampler (Figure 2) periodically encloses a known volume of air and traps the particulate and gaseous contaminants, which are then sampled by an internal collecting device. The cycle is repeated as desired. The contaminants removed are accumulated on the collecting medium for later analysis. A unique feature of the system is the closed-cycle purging of the collector section. After a sample of ambient air is enclosed, clean air is introduced into the top of the collector at the same rate that the trapped air is pulled through the filter in the base. This flow circulates until several times the volume originally trapped has been moved through the system, which ensures complete removal of all contaminants. In the present model, a fresh sample of ambient air is trapped every 30 sec to give a total sample of 0.65 m³/hr. The Atomic Energy Commission has applied for a patent on the device.

Manual on Atmospheric Dispersion

Three members of the Meteorology Group have made major contributions to a guide for the assessment of atmospheric dispersion. This manual, which provides a simple system for deriving first approximations of most conventional dispersion problems, will be published soon by the American Society of Mechanical Engineers.

Laser-Radar Development

The development of the pulsed ruby laser system started during fiscal 1967 continued. Considerable effort was devoted to establishing and refining the characteristics of the pulses and to experimentation with various *Q*-switch solutions. The system is now ready for use as a detector of atmospheric tracer concentrations.

Atmospheric Sulfur Program

This program, involving the use of the natural variations in the abundance of sulfur isotopes as a tracer technique, is being conducted in cooperation with the Nuclear Engineering Department, and details will be found in that section of the report.

Figure 2. Automatic grab sampler. The large cylinder is rapidly lowered pneumatically at selected intervals to trap a volume of air containing particles. When the cylinder is closed, the vacuum pump draws air through the filter in the base and returns it after further purification through the tube in the top of the assembly. Particles of virtually all sizes are thereby sampled with almost 100% efficiency.

Chemistry

HIGH ENERGY NUCLEAR REACTIONS

The program of study of the reactions of high energy protons with complex nuclei has been continued and extended to new areas in experiments with protons from the Alternating Gradient Synchrotron (AGS). Refined computer analysis is being completed of a large amount of data accumulated in fission investigations carried out in the Cosmotron external beam.

Studies of Fission Using Semiconductor Detectors

The analysis of experimental data on 2.9-BeV proton interaction with uranium, bismuth, and silver, obtained at the Cosmotron with a 1-m scattering chamber, solid-state detectors, and time-of-flight equipment, progressed during the year, and the computer programs needed for analysis of the experiments were completed. From the one set of experiments now completely analyzed, the major conclusion is that in all events in which a pair of heavy fragments is observed the velocities of the fragments correspond to what is expected from a fission mechanism essentially the same as that describing low-energy fission. However, highly asymmetric breakup with a light fragment having mass $< \approx 35$ was not observable in this set of measurements.

Analysis of the data from an experimental study of uranium and tantalum fission by 156-MeV protons performed at Orsay was carried to completion. The fission probability was determined as a function of the angle between fission fragments, and kinetic-energy spectra of fragments were measured. The measured angular correlations shown in Figure 1 are seen to be in good agreement with the predictions of Monte Carlo calculations of the intranuclear cascades, provided that reasonable pre- and postfission particle emission is included. The experimental mean total kinetic energy and the full width of the kinetic-energy distribution for tantalum agree with values calculated with use of a simplified liquid-drop model.

Rare-Earth Yields From Uranium and Tantalum

The investigation of cross sections for the formation of rare-earth nuclides in the interaction of 30-

BeV protons with uranium was expanded. In this work chemical separations and electromagnetic isotope separations were used in combination so that individual nuclides could be isolated for measurement. Incidentally, new results on the radioactive characteristics of a number of nuclides are being obtained. The initial results (summarized in Figure 2) indicate that the double-humped charge dispersion curves previously found at BNL in the mass 130 to 140 region persist at higher mass numbers, and in fact the peak-to-valley ratios become greater, values of about 10 being attained at $A \approx 145$ to 150. At still higher mass numbers, neutron-excess yields are found to drop off rapidly, just as in low-energy fission. This finding corroborates the conclusion previously reached at BNL that these neutron-excess products result from the deposition of small amounts of energy in the target nuclei.

In conjunction with the above study, similar measurements were begun with tantalum targets. In contrast to the uranium case, practically no neutron-excess nuclides are produced, which confirms the conclusion that these arise from low-deposition-energy fission processes. The formation cross sections of neutron-deficient species are similar for tantalum and uranium targets.

Angular Distributions and Differential Ranges Studied With Catcher Foils

A comprehensive study was completed of angular distributions and differential ranges of a number of medium-mass products (Sr^{91} , Mo^{99} , Pd^{103} , Ba^{131} , and Ba^{140}) formed in the interaction of U^{238} with 2.2-BeV protons. It was concluded from this work that the dominant process leading to formation of products in this mass range is binary fission, but that a spallationlike process contributes somewhat to the formation of products with a neutron-proton ratio $< \approx 1.35$. This latter contribution was found to increase with increasing product mass number. Comparisons with data obtained at other laboratories indicate an increase in the spallation contribution with increasing proton energy above 2.2 BeV. The same simplified liquid-drop model that has been applied successfully at lower bombarding energies predicts mean velocities, shown in Figure 3, which agree with

Figure 1. Fission probability as a function of the angle-in-plane ϕ for U, Bi, and Ta targets irradiated with 156-MeV protons. In the cases of U and Bi, the circles refer to measurements from another experiment. The broken curves are the results of Monte Carlo calculations with neglect of contribution from pre- or postfission particle evaporation. The solid curves include broadening due to such evaporation. Note the prominent contribution of compound nuclei predicted in the first model.

Figure 3. Dependence of mean velocity on the charge of the primary fragment in the fission of uranium by high energy protons. Filled circles are based on results obtained at 2.2 BeV in experiments at BNL. For Pd^{103} and Ba^{131} , small corrections for contributions from spallation have been applied. Open circles are from an experiment performed elsewhere at an energy of 0.45 BeV. The curves are based on a simplified liquid-drop model calculation with $\text{U}^{234.4}$ and Bi^{203} as the fissioning species.

Figure 2. Charge distribution curves for products of mass numbers ≈ 131 , ≈ 146 , and ≈ 167 from the 28-BeV proton irradiation of uranium.

Figure 4. Yield as a function of mass number for products from the irradiation of silver with 3 and 29-BeV protons. The broken curve was obtained from Monte Carlo calculations of the intranuclear cascade and postcascade particle evaporation.

those observed in the fission of uranium by 2.2-BeV protons, provided that a reasonable range of fissioning species is assumed.

Spallation and Fission of Silver

A long-standing program of radiochemical investigations of the products formed in interactions between silver and 3 and 29-BeV protons was brought to completion. Comparison of the experimental results with Monte Carlo calculations, as shown in Figure 4, leads to the conclusion that products of $A > 50$ can be accounted for in terms of a cascade-evaporation mechanism, whereas lower-mass products must be formed mainly by fragmentation or a fissionlike process. Nuclear emulsion studies of the interactions of 1 to 3-BeV protons with silver and bromide nuclei were also carried out; from these it is concluded that processes leading to binary fissionlike events with product masses in the region of $A \approx 15$ to 33 have cross sections of 7 and 50 mb, respectively, at 1 and 3 BeV.

Light Fragment and Stable Isotope Production

Radiochemical investigations were concluded of cross sections for the production of light fragments (Be^7 , Na^{22} , Na^{24} , and Ne^{24}) from various targets (Cu , Ag , Ta , Au , Pb , and U) with protons of energies between 1 and 30 BeV. The inference from these results is that the amount of energy deposited in nuclei generally increases with increasing proton energy and increasing target mass number, but reaches a plateau even for the heaviest nuclei at about 10 BeV.

Theoretical Studies

An extensive investigation was completed of model dependence in the Monte Carlo calculations of cascades induced in complex nuclei by nucleons up to ≈ 380 MeV. The introduction of realistic diffuse-surface density distributions improves agreement with experimental data. When classical reflection and refraction are introduced by appropriate changes in the nuclear potentials, both excessive energy deposition and deficiency of outgoing nucleons result, especially in the interactions of high- Z targets with low-energy (< 200 MeV) nucleons. Study of the possible causes of this difficulty and of ways to remedy it, e.g., by the introduction of a velocity-dependent potential, has been undertaken.

Calculations performed on de-excitation processes for highly excited nuclei have been extended.

In collaboration with scientists at the State University of New York at Stony Brook, Texas A&M University, and Columbia University, various specific applications and extensions of these calculations have been made. In addition, an experimental effort was begun, together with the Columbia group, to observe the subbarrier α particle whose emission is predicted from excited nuclei of high angular momentum. In collaboration with the BNL Nuclear Engineering Department, a computer program was written for combinatorial calculations of nuclear level densities based on a nuclear shell model with pairing forces.

NUCLEAR SPECTROSCOPY

Decay Parameters of Co^{57} - Fe^{57}

Values of important decay parameters of the parent-daughter pair Co^{57} - Fe^{57} , important in Mössbauer studies, were obtained from measurements of the two coincidence rates: iron K x rays from Co^{57} K capture with, respectively, the 14.4-keV γ rays and the iron K x rays from internal conversion in Fe^{57} transitions. With the use of results from two electron spectrometers, the following accurate values were extracted.

Total and K conversion coefficients of the 14.4-keV γ ray:	$\alpha_T = 8.17 \pm 0.25$ $\alpha_K = 7.27 \pm 0.23$
Fraction of K capture in Co^{57}	
electron capture decay:	$f = 0.891 \pm 0.034$
K -shell fluorescence yield in iron:	$\omega_K = 0.342 \pm 0.012$

On the basis of consistency with other related accurate results, it is highly unlikely that the above values can be in error by much more than the stated standard deviations. The values of the conversion coefficients closely confirm the theoretical ones. They are about 10% lower than the currently accepted values obtained mainly by Mössbauer methods. This discrepancy may well be due to an inaccuracy in theoretical values for Mössbauer absorption fractions. The result for the K -shell fluorescence yield in iron fixes with some accuracy a value that, surprisingly enough, was poorly known, values between 0.291 and 0.375 having been reported.

Energies and Conversion Coefficients in Sn^{117m} and Sn^{119m} Transitions

Electron spectrometer measurements were made of the internal conversion electrons from the $M4$ and $M1(E2)$ transitions occurring in the decays of

17-day Sn^{117m} and 250-day Sn^{119m} . The results found were as follows.

Nuclide	Transition	Energy, keV	K conversion coefficient
Sn^{117m}	$M4$	156.0 $\pm$ 0.1	—
"	$M1(E2)$	158.6 $\pm$ 0.1	0.1373 ($\pm$ 0.0030)
Sn^{119m}	$M4$	65.66 $\pm$ 0.01	—
"	$M1(E2)$	23.875 $\pm$ 0.01	—

The Sn^{117m} results eliminate contradictions in the literature concerning these transition energies. Sn^{117m} is shown to be a convenient reference standard for measurement of internal conversion coefficients, and several working "coefficients" have been accurately established.

Measurements were also made of the relative intensities of electrons from conversion in different subshells. From these results it was possible to set very low upper limits on the amounts of $E2$ in the $M1(E2)$ transitions of both Sn^{117} and Sn^{119} . These low upper limits are consistent with theoretical predictions based on a pairing plus quadrupole force.

For the 23.875-keV Mössbauer transition in Sn^{119m} the total internal conversion coefficient was determined to be 5.12 ± 0.14 . This quantity is important for measurement of recoil-free fractions in Mössbauer absorption.

Characterization of Tb^{149} and Tb^{147}

In connection with measurements of cross sections for the production of rare-earth nuclides by 30-BeV protons, information was obtained about two neutron-deficient isotopes of terbium.

The α -decay branching of Tb^{149} , previously uncertain, was established as $23 \pm 2\%$ by measurement of the relative amounts of the two decay products, Eu^{145} (from α decay) and Gd^{149} (from electron capture-positron decay).

A new isomeric state having a 1.65-hr half-life was discovered in Tb^{147} . Radiations have been characterized and work is continuing to obtain additional information about this nuclide.

Measurement of Double- β Decay of Te^{130}

Many attempts at direct observation of double- β decay have been made in the past decade, but no conclusive evidence for either the neutrinoless or the two-neutrino mechanism has been found. An indirect observation of double- β decay can be made by detection of the decay product accumulated during geological time periods in a mineral rich in a suspected $\beta\text{-}\beta$ active isotope. A very suit-

Figure 5. Isotopic composition of xenon extracted from native tellurium ore (run No. 2). The horizontal lines indicate the maximum contribution of atmospheric xenon.

able case is the decay $\text{Te}^{130} \xrightarrow{\beta\beta} \text{Xe}^{130}$. Anomalous isotopic compositions of the xenon extracted from tellurium minerals have been reported several times, but in all cases the Xe^{130} excess was accompanied by excess concentrations of Xe^{129} and Xe^{131} which were not satisfactorily understood. Consequently the Xe^{130} anomaly has not been accepted as unambiguous proof of double- β decay.

The ideal mineral sample would be rich in tellurium, would be geologically very old, and would contain little or no uranium to perturb the isotopic composition of the extracted xenon. Such a mineral is a native tellurium ore (99.5% Te) from the Good Hope Mine in Colorado. Its geological age was measured as $1.31 \pm 0.14 \times 10^9$ yr by the K-Ar method. The mass spectrum of the extracted xenon is shown in Figure 5. The Xe^{130} excess amounts to 70% of the total xenon, and the ratio $\text{Xe}^{130}_{\text{excess}} / \text{Xe}^{130}_{\text{atmospheric}}$ is > 50 . The half-life for double- β decay of Te^{130} calculated from these data is $10^{21.34 \pm 0.12}$ yr, in agreement with the theoretically predicted half-life for the two-neutrino mode of decay ($10^{22.5 \pm 2.5}$ yr) rather than with the half-life predicted for neutrinoless decay ($10^{16.3 \pm 2}$ yr).

EMANATION SOURCES FOR SHORT-LIVED ACTIVITIES

In preliminary studies directed toward experiments with molecular beams of short-lived activi-

Figure 6. Fraction E of 0.032-sec At^{217} nuclei formed in lanthanum stearate powder that is in the gas phase when decay occurs. The At^{217} originates from the disintegration in the stearate of 10-day Ac^{225} , through the sequence $\text{Ac}^{225} \xrightarrow{\alpha} \text{Fr}^{221}(5 \text{ min}) \xrightarrow{\alpha} \text{At}^{217} \xrightarrow{\alpha} \text{Bi}^{213}(47 \text{ min}) \xrightarrow{\beta}$, etc. The decrease of E with increasing temperature above 390°K is irreversible.

ties, measurements were made of the efficiency of emanation of gaseous 0.035-sec Rn^{218} and 0.032-sec At^{217} from powdered stearates containing their longer-lived radioactive predecessors, 21-day U^{230} or 29-hr Ac^{226} (predecessors of Rn^{218}), and 10-day Ac^{225} (predecessor of At^{217}). These constitute the first observations made of the emanation of such short-lived nuclides. The emanation of longer-lived radons has been studied previously, but not that of astatine, which is a halogen.

At room temperature and pressures of 10^{-3} to 10^{-6} torr, 50% of the Rn^{218} and 23% of the At^{217} generated are observed to decay in the gas phase. Various experiments show that the gaseous At^{217} is probably in the form of HAt . The efficiency of astatine emanation is by far the largest ever reported for any halogen; this may be because previous halogen emanation studies were not carried out in vacuum.

The efficiency of At^{217} emanation as a function of the temperature of the emanating stearate is shown in Figure 6.

THE BROOKHAVEN SOLAR NEUTRINO EXPERIMENT

In the 1967 Annual Report a general description was given of the system constructed in the Homestake Gold Mine at Lead, South Dakota, to observe the neutrino radiation from the sun, and it was stated that initial measurements of the neutrino

flux would be made in the summer of 1967. The detection system is operating successfully at its designed sensitivity. The results obtained thus far have necessitated a re-examination of current theories of energy generation in the sun.

Neutrinos are produced in the sun by the thermal fusion reactions that are the source of the sun's energy. The current picture of these reactions is based upon laboratory measurements of nuclear reactions, the observed composition and estimated age of the sun, and a theoretical model of the internal structure of the sun. It is now generally believed that the sun produces energy primarily by the proton-proton chain of reactions, and that only a few percent of the energy is produced by the carbon-nitrogen cycle. As a consequence neutrinos should be produced in the sun by the $\text{H}(\text{H}, e^+ \nu)\text{D}$ reaction and in the β decays of Be^7 , B^8 , N^{13} , and O^{15} . The flux of neutrinos from each of these processes has been re-estimated in recent theoretical studies. It is of special interest to test this theory of solar energy generation. The most direct experimental test of these theoretical ideas is to measure the neutrinos emitted, since these particles have the ability to pass out of the sun without deflection or loss of energy. The Brookhaven solar neutrino detector (Figure 7) was designed to be sufficiently sensitive to observe a flux of neutrinos of roughly $1/10$ the theoretically estimated intensity.

Detection depends upon the capture of neutrinos by Cl^{37} to form the radioactive Ar^{37} by the reaction

The apparatus, located 4850 ft underground to shield it adequately from cosmic radiation, consists of a 100,000-gal tank of liquid tetrachloroethylene (C_2Cl_4) with provision for extraction of the radioactive argon by circulation of helium gas through the liquid. The argon is subsequently extracted from the helium stream by means of a charcoal filter and purified, and the Ar^{37} decay is observed in a small, low-level proportional counter.

The system, under construction for two years, was ready for operation in the spring of 1967 and two experimental runs were made during the summer. The neutrino capture rate in the tank was found to be $<0.5/\text{day}$, compared with the theoretical estimate of about 4/day, due primarily to neutrinos from B^8 decay in the sun. This experimental result places an upper limit of $2 \times 10^6 \text{ cm}^{-2}$

Figure 7. The Brookhaven solar neutrino detector located 4850 ft underground in the Homestake Gold Mine at Lead, South Dakota. The tank shown contains 100,000 gal tetrachloroethylene (C_2Cl_4). Neutrino detection is achieved by observing radioactive Ar^{37} produced in the tank by the capture reaction $\text{Cl}^{37}(\nu, e^-)\text{Ar}^{37}$. Initial results show that the solar neutrino flux is lower than anticipated from current theories.

Table 1

	β	ν	γ	η
Classical theory	0.5	0.5	1	0
Ising model	$0.312 \pm_{-0.006}^{+0.003}$	0.643 ± 0.0025	1.250 ± 0.003	0.056 ± 0.008
Experiment	0.26 ± 0.01	0.612 ± 0.015	1.150 ± 0.035	0.10 ± 0.04

sec^{-1} on the flux of B^8 neutrinos at the earth, a factor of 7 below the theoretical estimate. It can also be concluded from these experiments that $<9\%$ of the sun's energy is generated by the carbon-nitrogen cycle. This latter limit is consistent with current theory, according to which the central temperature of the sun is too low to allow hydrogen burning by the carbon-nitrogen cycle. A series of measurements extending over several years with counters having lower background rates than were used in these initial experiments would make it possible to increase the neutrino detection sensitivity by a factor of 5.

NEUTRON SCATTERING BY MAGNETIC MATERIALS

Critical-Point Scattering in Dysprosium Aluminum Garnet

At low temperatures a magnetic substance exists in a state of order in which atomic moments are fixed in a definite geometric pattern. As the temperature is raised the degree of long-range order diminishes, and it finally vanishes at a critical temperature above which only short-range correlations persist. From theoretical and experimental points of view, the critical-point behavior of magnetic materials in the vicinity of their Curie or Néel points is closely analogous to that of fluids, binary solutions, ordered alloys, and a number of other physical systems near their critical points. The qualitative similarity in the behavior of these diverse systems is thought to arise from the existence of cooperative interactions of large numbers of atoms. The object of current experimental research is to characterize behavior in the critical region and to relate this behavior to specific interaction models appropriate to the physical system.

In cooperation with the BNL Physics Department and Yale University, the magnetic properties of dysprosium aluminum garnet (DAG) were investigated by neutron scattering techniques in the

vicinity of the compound's antiferromagnetic ordering transition at 2.5°K . DAG was selected for study because it conforms closely to a three-dimensional Ising model in which individual spins are restricted to plus and minus magnetization states. It provides a means of partially testing the detailed theoretical calculations performed elsewhere for the Ising model.

The differential cross section for magnetic critical scattering above the Néel point, which is a measure of the spatial range of fluctuations in sublattice magnetization, is given by the expression

$$\frac{d\sigma}{d\Omega} \approx \left(\frac{A}{\kappa^2 + q^2} \right)^{1-\eta/2}$$

where q , the momentum transfer, is the magnitude of the displacement of the scattering vector from the antiferromagnetic reciprocal-lattice point, κ is the inverse range parameter, and A and η are constants. In terms of these quantities, the spin pair-correlation function at a given temperature falls off with distance as $e^{-\kappa r}/r^{1+\eta}$. The inverse range parameter, κ , is zero at the Néel point and increases with increasing temperature as $(T - T_N)^\nu$. The "staggered" susceptibility of the system measures the sublattice magnetization that would be induced by a hypothetical applied magnetic field which varied in space with a wave-vector equal to the antiferromagnetic reciprocal-lattice vector. It is given by the value of the cross section for zero momentum transfer ($q=0$); i.e., $\chi_S = (A/\kappa^2)^{1-\eta/2}$. The susceptibility is infinite at the Néel point and decreases with increasing temperature as $(T - T_N)^{-\gamma}$.

Shape analysis of the experimental curves of intensity vs momentum transfer, q , confirms the quasi-Lorentzian behavior indicated by the cross-section formula and gives values of κ and A as well as a preliminary estimate of η . In the temperature range $0.0007 < T/T_N < 0.017$, both the inverse range parameter and the susceptibility exhibit expected power law dependence on $T - T_N$. The indices ν and γ , associated with the temperature

compounds of the transition elements. Results from an investigation of the crystal structure of $(\phi_4\text{As})_2[\text{Fe}(\text{MNT})_3]$ (with ϕ = phenyl and MNT = 1,2-dicyano-1,2-ethylenedithiol) are shown in Figures 8 and 9. Unlike several tris-dithiolates studied elsewhere, this one is distorted only slightly towards the trigonal prismatic configuration. The distortion from the octahedral configuration is about 4.5° for each S atom. This distortion is very obvious in Figures 9 for S2 and S3.

The temperature dependence of the magnetic behavior of $(\text{bipH}_2)\text{MnCl}_5$ (with $\text{bipH}_2 = 2,2'$ -bipyridinium di-cation) is shown in Figure 10. (Recent, and independent, results obtained elsewhere are also shown.) The plot indicates that the MnCl_5^{2-} is not associated in the solid. This was verified by a structural study whose results are shown in Figures 11 and 12. Figure 11 shows the

MnCl_5^{2-} ion to be a square pyramidal species. This ion and $\text{Ni}(\text{CN})_5^{3-}$ (studied elsewhere) are the only two examples known of a $3d$ metal in a square pyramidal environment. It should be noted that, whereas in the $\text{Ni}(\text{CN})_5^{3-}$ derivatives only one half of the anions are square pyramidal, the other half being trigonal bipyramidal, in MnCl_5^{2-} all the anions are square pyramidal. This shows that the energy difference for the two configurations is very small for $\text{Ni}(\text{CN})_5^{3-}$ but not for MnCl_5^{2-} . Figure 12 shows the packing of the bipH_2^{2+} cations with the MnCl_5^{2-} anions in the crystalline lattice.

Isotope Effect on Structure of Hydrated Oxalic Acid

Deuterated oxalic acid crystallizes in two modifications, both containing two molecules of water per oxalic acid molecule. The fact that only one of

Figure 11. The square pyramidal MnCl_5^{2-} ion in $(\text{bipH}_2)\text{MnCl}_5$. (Stereo pairs may be viewed with a small, hand-held stereoscope, or by holding the page a few inches from the eyes and placing a card perpendicular to the paper between the two projections.)

Figure 12. Packing diagram for $(\text{bipH}_2)\text{MnCl}_5$. Stereo pair.

these exists for the protonated species indicates an isotope effect on crystal structure. Accurate neutron diffraction analyses have shown that the geometry of the water molecules is affected by the different hydrogen-bonding schemes in the two polymorphs. The arrangement of the water molecule and the hydrogen-bonding deuteron is almost planar in the β form and more nearly pyramidal in the α modification. The DOD angle in the β form is larger by $3.1 \pm 0.4^\circ$ (Figure 13) than in the α form. This difference can be explained theoretically. Comparison between x-ray and neutron

Figure 13. The configuration of the water molecules in α - and β -deuterooxalic acid dideuterate (DOX).

diffraction results on the α form has provided strong evidence that the spherical atom model is inadequate for the interpretation of accurate x-ray data; it introduces significant systematic errors in the atomic thermal motion parameters.

Structure of Ice II

A program of structural refinement of the proton positions in the polymorphs of ice by neutron diffraction has begun with a study of the structure of ice II. Ice II, in contrast to most of the ice phases, including ordinary ice I, has a structure in which the protons are ordered. The positions of the protons, which have been accurately determined, are in good agreement with those predicted from a simple model for the forces involved in the hydrogen bonds. A portion of the structure is shown in Figure 14.

The B—H Bond

The first accurate values for the B—H bond lengths in a boron hydride and good values for the structural parameters have been obtained in a

Figure 14. The molecular packing in the proton-ordered structure of ice II. Stereo pair.

Figure 15. Molecular structure of decaborane. A neutron diffraction study established accurate values for the B—H bond lengths in this classic compound. Stereo pair.

neutron diffraction study of decaborane. With this information and x-ray diffraction data, electron density maps have been derived for the bonding electrons in this compound, an extremely important one in the chemical theory of valence. The structural results confirm the asymmetry of the B—H—B bridge bond which was suggested by earlier x-ray studies. The bond lengths have been determined to an accuracy of 0.01 Å. The structure is shown in Figure 15.

Pentavalent Group V Compounds

Work on the structure of pentavalent group V compounds has continued. The structure of triphenyldimethoxyantimony has been determined. This compound has a trigonal bipyramidal configuration, in agreement with that found previously for tetraphenylmethoxyantimony and in contrast to the square pyramidal configuration that is found in pentaphenylantimony. The existence of these two types of structure supports the hypothesis of a small energy difference between the two configurations. Thus, postulated reaction pathways in which the activation involves a change from one of these configurations to the other in these pentacoordinated structures may reasonably be expected to have low activation energies.

MÖSSBAUER STUDIES

A Mössbauer study of $(\text{CH}_3)_2\text{SnF}_2$ with $\text{Sn}^{119\text{m}}$ incorporated has resolved a long-standing controversy over the origin of electric quadrupole field gradients in organo-tin halide crystals. The Mössbauer spectrum of a carefully powdered sample of this compound shows a large quadrupole splitting consisting of two lines of unequal intensity. The unequal line intensity observed with this carefully prepared sample indicates that the vibrational amplitudes of motion of the tin atoms at room temperature are highly anisotropic. This result was expected from a previous x-ray structure determination of this octahedral tin compound at Brookhaven, which had shown that the mean-square displacement of the tin atom along the fourfold methyl-tin-methyl bond axis was ≈ 40 times as great as in the plane of 4 fluorine ions. Knowledge of the nature of the vibrational anisotropy from the x-ray study, combined with the measured intensity ratio of the two Mössbauer lines, permitted a determination of the sign of the electric quadrupole field gradient at the tin atom. From

this it is deduced that there is a great deal of tin $5p$ character in the tin-methyl bonds and little, if any, $d\pi-p\pi$ bonding between the tin and fluorines. The existence of $d\pi-p\pi$ bonding in group IV compounds has been the subject of much discussion in the literature, with different experiments being cited for and against the existence of such bondings. On the basis of this Mössbauer study, if such bonding is present in $(\text{CH}_3)_2\text{SnF}_2$, it does not contribute significantly to the field gradient.

ISOTOPE EFFECTS

Statistical Mechanical Theory of Isotope Effects

Molecules that differ only in isotopic constitution show differences in chemical behavior that permit inferences to be drawn concerning intra- and intermolecular forces. With use of isotopic molecules it is possible to bypass the difficulties of exact chemical quantum statistics by considering ratios of partition functions instead of the partition functions themselves.

If the reduced partition function ratio of a pair of isotopic molecules is developed in an infinite power series with terms of the form $(\epsilon/kT)^{2n}$, it becomes possible to relate isotope effects directly to molecular and intermolecular forces and to motions of atoms taken n at a time. This expansion, however, converges only for values to $\epsilon/kT < 2\pi$. Recently, expansions that converge for all values of ϵ/kT , and converge much more rapidly, have been obtained by use of finite orthogonal polynomials. Considerable success has been achieved by the use of the Chebyshev polynomials. This has been further improved by the use of hypergeometric functions, in a collaborative effort with colleagues at Yeshiva University. One finds

$$\ln(s/s')f = \sum_i^{3n-6} \sum_{j=1}^n (-1)^{2j} \frac{B_{2j-1} \delta u_i^{2j}}{2^j (2j)!} C(n, j, u_{\max})$$

where $\delta u_i^{2j} = u_i'^{2j} - u_i^{2j}$ is the difference in eigenvalues for the molecular vibrations of the isotopic molecules, in units of kT/h ; B_{2j-1} is the $(2j-1)$ th Bernoulli number; and the $C(n, j, u_{\max})$ are modulating coefficients that depend on the molecular properties through the maximum frequency, $u_{\max}$. For each value of j the sum over i can be obtained by the method of moments.

The first term in the expansion,

$$\frac{1}{24} \left(\frac{\hbar}{kT} \right)^2 \left(\frac{1}{m_i'} - \frac{1}{m_i} \right) a_{ii} C(n, 1, u_{\max}),$$

gives the fundamental law of isotope effects in equilibrium systems. It depends on the atomic masses, m and m' , and the Cartesian force constant for the i th atom, a_{ii} . The form of the mass dependence of the isotope effect is independent of the molecular composition in this approximation; it is the same for all chemical species of the isotopes of a given element. In this approximation, isotope effects arise solely from force constant changes from one chemical species to another. From the u^2 law the rule of the geometric mean, the behavior of equivalent isotopic isomers, and additivity in double labeling are obtained directly. Higher terms in the expansion, powers of $(h/kT)^{2j}$, when combined with the n th moment of the eigenvalues, relate isotope effects to motions of groups of atoms taken j at a time. The successful development of an exact procedure for the calculation of the n, j coefficients in terms of exact mathematical functions and molecular properties opens new possibilities for the study of molecular and intermolecular forces in rate and equilibrium processes through isotope effects.

Vapor Pressures of Isotopic Molecules

Measurements of differences in the vapor pressures of isotopes, when interpreted in terms of the statistical mechanical theory of isotope effects in condensed phases, have given new information about intermolecular forces and the perturbation of intramolecular force fields by these forces. A new type of quantum mechanical phenomenon was discovered – the dynamic coupling of molecular motion in an intermolecular force field. It became apparent that further progress in this field would be possible with the development of cryostats capable of higher sensitivity, precision, and accuracy than had been heretofore attained. A new cryostat has been constructed and tested for differential measurement of vapor pressures of separated isotopes. In the range of test, 90° to 200° K, samples are maintained within 10^{-4} ° K of one another for long time periods. Pressure differences of 0.01% of the total pressure can be measured routinely.

With the new cryostat it has been possible to confirm and refine the difference between the equivalent isomers *cis*- and *trans*-dideuteroethylene discovered seven years ago at BNL and to extend the measurements to the solids. A large discontinuity in the vapor-pressure difference between

deuterium compound and ordinary ethylene is found at the melting point. The effect is much larger than can be accounted for by the volume change associated with phase transition. The "significant structure" theory of Eyring and co-workers, which approximates the liquid as a mixture of gaslike and solidlike domains, proves inadequate for dealing with isotope effects in polyatomic molecules. The discontinuity may be ascribable to greater hindrance of molecular rotation in the solid than in the liquid. Curvature in the plot of the vapor pressure ratio vs temperature in the liquid shows that the intermolecular force decreases as the liquid expands.

Kinetic Isotope Effects in Hydrogen Abstraction Reactions

The experimental determination of the isotope effects in the reaction of trifluoromethyl radicals with isotopic hydrogen molecules was reported last year. These reactions are

where the k 's designate the rate constants. The experimental rate constant ratios have been compared for simple models of the transition state, with theoretical values derived by two methods: the completely empirical bond energy–bond order (BEBO) approach developed by Johnston and co-workers and the semiempirical London-Eyring-Polanyi-Sato (LEPS) method. For each method two sets of calculations were made, one with and one without tunneling through the potential energy barrier. For both the BEBO and LEPS models, experimental results lie somewhere between the rate constant ratios calculated with and without the correction for tunneling (Figures 16 and 17). The implication is that tunneling does contribute to the isotope effect, but that its contribution is overestimated by the simple methods used here. The general success of these calculations also confirms the validity of a simplified three-atom model for the transition state in hydrogen abstraction reactions.

Figure 16. Comparison of experimental rate constant ratios (circles) for the reactions of CF_3 with hydrogen isotopes with those calculated from the BEBO model. Solid line, without tunneling correction; broken line, with tunneling correction.

Reactions of Excited Radicals and Molecules

A study was made of the photolysis of CF_3I by mercury 2537-Å radiation. By analogy with the photodissociation of CH_3I at this wavelength, CF_3 radicals should be produced with sufficient excess energy (about 20 kcal/mole) to permit abstraction of hydrogen atoms from H_2 or hydrocarbons. However, the experiments showed that such reactions do not occur. The inference is that in the case of photolysis of CF_3I , the excess energy of the product CF_3 radicals is all translational, whereas in the case of CH_3I the excess energy is largely in vibrational degrees of freedom. This accounts for the different reactivities of the two radicals, since the relaxation time of excess vibrational energy is greater than that for excess translational energy.

Isotope Effects in Azo Compounds

In a reaction proceeding by a unimolecular decomposition mechanism through an activated complex, such as $\text{R}_1\text{R}_2\text{CDX} \rightarrow [\text{R}_1\text{R}_2\text{CD} \cdots \text{X}]^* \rightarrow \text{R}_1\text{R}_2\text{CD} + \text{X}$, the decrease in the bending force constant of the $\text{D}-\text{C}-\text{X}$ group, induced by the

Figure 17. Experimental and calculated rate constant ratios based on the LEPS model. (See caption, Figure 16.)

stretching of the $\text{C}-\text{X}$ bond, has been shown previously to be a major source of secondary α -deuterium isotope effect. The greater the $\text{C}-\text{X}$ bond stretching, the greater the decrease in $\text{D}-\text{C}-\text{X}$ bending force constant, and the greater the secondary α -deuterium isotope effect. Primary nitrogen isotope effects have been determined in the thermal decomposition of three azo compounds ($\text{R}-\text{N}=\text{N}-\text{R}'$). The secondary α -deuterium effect and, in one case, a C^{13} isotope effect have been previously determined for these molecules. The wide variation of structure among these compounds provides cases of $\text{C}-\text{N}$ bond weakening and $\text{C}-\text{N}$ bond rupture and, in addition, a case of $\text{C}-\text{N}$ bond compression (N equals X in reaction equation above). Exact calculations were made to interpret these isotope effects in terms of changes in bending and stretching force constants between reactant and transition states. It appears from this study that for small secondary α -deuterium isotope effects, either normal or inverse, the relative change in the $\text{D}-\text{C}-\text{X}$ bending force constant in going from reactant to transition state is the same as the relative change in the $\text{C}-\text{X}$ stretching force constant.

Figure 18. The observed second-order rate constant of thiocyanate-catalyzed *cis-trans* isomerization of *cis-β*-acetylacrylic acid vs hydronium ion activity. The points shown represent experimental observations; the line is the theoretical curve.

Cis-Trans Isomerization Studies

Among the group of enzymes responsible for the stepwise oxidative metabolism of aromatic amino acids is one that together with the coenzyme glutathione catalyzes the *cis-trans* isomerization of malyacetoacetate to fumarylacetoacetate. To gain insight into the mechanism of this process, a model substrate, *cis-β*-acetylacrylic acid, possessing the necessary functional groups for *cis-trans* isomerization, has been synthesized and its chemistry investigated. As shown by nuclear magnetic resonance (NMR) and uv spectroscopy, the acid is

cyclic but the anion is open. At $pH = pKa \cong 4.5$, interconversion between the two forms is very rapid (lifetime, $\leq 10^{-3}$ sec). By analogy the natural substrate is expected to exist in open form at neutral pH . Thiocyanate ion, an excellent nucleophile, has been found to be an effective catalyst for the *cis-trans* isomerization of both the cyclic acid and open anion forms of the model substrate. At comparable pH values, thiocyanate is 10^7 times more effective than water in catalyzing the isomerization. The increase in the bimolecular rate constant with increased acid concentration is shown in Figure 18. A kinetic scheme involving thiocyanate and/or thiocyanic acid as catalysts, and open and/or cyclic forms of substrate, can

Figure 19. The chemical shift of isopropyl methyl groups in α -phenylethylazo-2-propane at different temperatures in chloroform (triangles), in 1,1,1,2-tetrachloroethane (open circles), in cyclohexane- d_{12} (squares), and in *m*-xylene (closed circles).

account for the pH -rate profile. This work suggests that glutathione probably functions as a good nucleophile in the enzyme-coenzyme catalyzed isomerization.

Magnetic Nonequivalence in Nuclear Magnetic Resonance

Geminal protons near an asymmetric center (as in I) are generally magnetically nonequivalent. Since the solvent exerts a strong influence on the

($R \neq H$; W = an atom or group of atoms)

corresponding chemical shift, a widely held notion is that the nonequivalence is primarily the result of the existence of rotational isomers that differ in energy (the dielectric of the medium determines the distribution of rotamers).

α -Phenylethylazo-2-propane (II) has been found to have magnetically nonequivalent methyls due

II

to the asymmetric center on the other side of the azo linkage. As shown in Figure 19, the magnitude of the nonequivalence (i.e., the chemical shift), measured in four solvents, decreases with increasing temperature. Between -20° and 60°C the dielectric constants of chloroform, *m*-xylene, and cyclohexane change by 27, 6, and 7% respectively. These dielectric changes do not correlate with the chemical shift data, and it therefore appears that change in the rotamer population due to dielectric constant change is unlikely as an explanation of the chemical shift changes. The temperature dependence of the chemical shifts appears to correlate more closely with that of the molar volumes of these solvents, which between -20° and 60°C change by 11, 8, and 10% respectively.

The solvent effect on the magnitude of magnetic nonequivalence can be understood in terms of the average orientation of the many collisions that take place, on the NMR time scale, between magnetically anisotropic solute and unsymmetrical, magnetically anisotropic solvent molecules. Such solvent molecules will exert a magnetic effect on neighboring solute molecules. As the temperature increases, the average distance between solvent and solute molecules increases and the magnetic effect of nearby solvent molecules falls off.

Kinetic Data Acquisition

An apparatus for automatic recording of kinetic data has been constructed with the cooperation of the Instrumentation Division. Digitized time and optical density data from a double-beam uv spectrophotometer are punched on IBM cards. Increments in time or density can be varied over a wide range. Reaction rate constants are obtained from the output by use of existing programs.

INORGANIC REACTIONS IN SOLUTION

This work includes both kinetic and equilibrium studies. In the kinetic studies, the emphasis is on substitution, oxidation-reduction, and isomerization reactions. The studies of equilibrium systems emphasize complex ion and solvent extraction equilibria.

Reaction Kinetics

Studies of oxidation-reduction reactions involving metal ions and their complexes have shown that many of these reactions proceed by inner-sphere mechanisms in which the two metal centers are connected by a common bridging group. The presence of such a binuclear intermediate is usually inferred from rate comparisons, from the rate law, or from the identities of the primary products of the electron transfer reaction. In only very few cases have the binuclear intermediates been observed directly. The chloro-bridged intermediate $[\text{RuClCr}]^{4+}$ has been observed in the reaction of chromium(II) with chloropenta-aquoruthenium(III).

This reaction is of particular interest because the bridged intermediate is relatively long-lived and consequently some of its properties could be studied by the flow technique. During the course of this work it was observed that the reaction of chromium(II) with perchlorate ions is strongly catalyzed by ruthenium(II).

Activation parameters for the reaction of vanadium(II) with the linkage isomers CrSCN^{2+} and CrNCS^{2+} have been determined. The sulfur-bonded complex reacts more than 10^4 times faster with vanadium(II) than does the nitrogen-bonded complex. The sulfur-bonded complex also undergoes chromium(II)-catalyzed isomerization,

and mercury(II)-catalyzed isomerization and aquation,

as well as spontaneous isomerization and aquation,

The kinetics and stoichiometry of these reactions have been studied and it appears that the aquation and isomerization reactions proceed via a common intermediate. The mercury(II)-catalyzed isomerization of CrSCN^{2+} provides the first example of a metal-catalyzed linkage-isomerization reaction that does not involve an electron transfer mechanism.

The hydrolysis of hydroxylamine disulfate ion, $\text{HON}(\text{SO}_3)_2^- + \text{H}_2\text{O} \rightarrow \text{HONHSO}_3^- + \text{H}^+ + \text{SO}_4^{2-}$,

has been thoroughly investigated in order to resolve discrepant reports in the literature. The main term in the rate law is known to be

$$k[\text{H}^+][\text{HON}(\text{SO}_3)_2^-].$$

It has been shown that terms not involving $[\text{H}^+]$ are negligible, and reasons for apparent evidence to the contrary have been found. Evaluation of the parameters of activation and ionic strength dependence has been made to a higher order of precision than in earlier work.

Equilibrium Studies

The equilibrium constant for the reaction

increases very rapidly with increasing perchloric acid concentration at acid concentrations above 3 *M*. Kinetic measurements have shown that the increase in equilibrium constant is due mainly to an enhanced rate of formation of FeCl^{2+} . These results have been interpreted in terms of the reduced water activity of concentrated perchloric acid solutions.

The extraction and solvating properties of methylisobutyl ketone have been studied in connection with the extractability of HCl , HClO_4 , HFeCl_4 , and HTiCl_4 . Evidence for anion solvation was obtained, and the hydration and solvation numbers of the extracted species were estimated. In the organic phase *pK* values were found to range from 4, for HCl , to 2.4, for HTiCl_4 .

HOT ATOM CHEMISTRY

Stereospecific Chlorine Replacement in Substituted Cyclopropanes

An investigation of chlorine hot-atom replacement at an asymmetric center was carried out in order to check the observation by other workers that front-side attack of the hot atom was the major mode of replacement. These studies involved a molecule with only *one* asymmetric center, 1-chloro-2,3-dimethylcyclopropane. The *syn*, *anti*, and *trans* forms of this molecule were prepared and irradiated. The results show that the displacement reaction is >95% stereospecific in the gas phase, with ease of substitution being greater in the *anti*

isomer. Experiments involving dilution of the isomer, so that the Cl^{38} atom must react with the substrate rather than another chlorodimethylcyclopropane molecule, show that lack of bond rupture cannot be a valid explanation for the observed stereospecificity. These experiments show further that displacement of chlorine by a hot Cl^{38} atom is from the front side (i.e., inversion does not occur), that the atom must be undergoing the reaction at energies near thermal since there is clear steric hindrance effect, and that lack of bond rupture is insignificant in the $\text{Cl}^{37}(n,\gamma)\text{Cl}^{38}$ reaction in an organic molecule. Other reactions of Cl^{38} in this system are still under investigation.

γ Radiation Dosimetry

An investigation related to hot-atom studies involves the use of CO_2/CO ratios as an internal dosimeter for radiation damage to hydrocarbon-oxygen mixtures undergoing accelerator bombardment for C^{11} production. Model systems with Co^{60} irradiation and with reactor irradiation were utilized. The absorbed dose range was from 0 to 250 Mrad. The results show that the CO_2/CO ratio can be used as a dosimeter in alkanes provided that a calibration is made for each alkane.

Photolytic Reactions Related to Hot-Atom Mechanisms

Two photolytic reactions of diazo compounds were intensively studied with regard to the mechanism of decomposition of carbene intermediates. These systems were chosen as models for the analogous species produced by hot carbon atom reactions.

The gas phase photolysis of diazoisobutane produces the same carbene as that obtained by insertion of a hot carbon atom into the methylene C—H bond of propane, i.e.,

It produces an insignificant yield of acetylene (1 to 3%) in contrast to a previous observation on cyclopropyldiazomethane, where the yield of acetylene was high (30 to 40%). The corresponding acetylene yields in the hot-atom cases are 24 to 28% and 50 to 60%. This work makes it clear that the acetylene yield-determining feature of the hot-atom reaction is the excess vibrational excitation in the intermediate occasioned by the hot carbon atom

insertion. The high yield of acetylene from cyclopropyldiazomethane appears to be due to the high strain energy in the resultant carbene. This work further points up the value of using model systems in which relatively good values of vibrational and electronic excitation can be ascertained; this allows estimates to be made of energy content in the analogous hot-atom systems. Another significant feature of the reaction of isobutylcarbene is the formation of *cis*- and *trans*-2-butene and 1-butene [Eq. (1)]. Mechanisms suggested by other workers involve the formation of excited methyl cyclo-

propane. By use of diazoisobutane-C¹⁴ it was possible to show that direct alkyl group migration is a major pathway for *cis*- and *trans*-2-butene formation.

A related photochemical study of the reactions of *trans*-1,2-dimethyl-cyclopropyldiazomethane was used as a model for the reaction between a hot carbon atom and *trans*-1,2-dimethylcyclopropane. Both reactions can give *trans*-1,2-dimethylcyclopropylcarbinylcarbene. The photolytic decomposition of the diazo compound gives the carbene, primarily in the singlet state, and this intermediate undergoes ring scission to give acetylene (41%) plus *trans*-2-butene (41%) [Eqs. (2) and (3)]. This means that the decomposition is stereospecific and thus probably one step. It further supports the view that the stereospecificity is controlled by the spin state of carbene.

A further result of theoretical significance in the light of the recent proposal by Woodward and Hoffmann relating to electrocyclic reactions is the discovery that good yields of *trans, trans*-2,4-hexadiene are produced from the photolysis of *trans*-1,2-dimethylcyclopropyldiazomethane at low pressure and that a mixture of the *trans, trans* and *cis, trans* compounds is produced at high pressure (inert gas added to 760 mm) [Eq. (3)]. Thus the

singlet carbene controls the stereospecificity of the reaction, possibly via an excited *trans*-3,4-dimethylcyclobutene to give the *trans, trans* product via conrotatory ring opening. At higher pressures where conversion to the ground-state triplet carbene can occur before rearrangement, the *cis, trans* compound can also be formed.

Hot-Atom Effects in Inorganic Crystals

In connection with previous work in this laboratory on the chemical effects of nuclear transformations in solids, a study was made in collaboration with the Brookhaven Solid State Physics Group on the changes produced by γ irradiation in the chemistry of $^{204}\text{Tl}^+$ ions substitutionally incorporated in KCl crystals. In these experiments optical measurements of the various color centers were correlated with chemical analyses of the oxidation

Figure 20. Percent ^{204}Tl extracted as $^{204}\text{Tl}^{3+}$ as a function of the γ dose received by the crystals (water-grown crystals); $[\text{Tl}^+]$ in the crystals $\approx 1.44 \times 10^{-5}$ moles/mole KCl. ●, Irradiated at 9.315 Mrad/hr; ○, irradiated at 0.969 Mrad/hr.

state of the thallium. It was found that a substantial fraction of the labeled thallous ion initially present (at mole ratios of 10^{-3} to 10^{-6}) in the crystal of KCl was converted into a form that follows thallic chemistry on dissolution (Figure 20). The disappearance of Tl^+ itself was followed by means of its characteristic absorption band at $247\text{ m}\mu$, and the increase in concentration of F -centers was also followed (Figure 21).

It was further found that thermal annealing, or bleaching with light absorbed in the F -band ($566\text{ m}\mu$), after γ irradiation, caused a reversion to the thallous form. The combined chemical and optical data permit these phenomena to be interpreted by the following equations, in which an asterisk represents a labeled thallium.

The Tl^{2+} -center may exist as a complex involving the nearest-neighbor chloride ions. On dissolution of the irradiated crystals in a solution containing thallous and thallic (Tl^{3+}) carriers the following reactions appear possible.

or

(the disproportionation reaction, with the label appearing equally in both stable oxidation states),

(exchange reactions with the inactive carriers).

It was assumed that Tl^0 would, by whatever reactions, eventually appear as Tl^+ .

Since optical bleaching (F -band) reduced the chemical yield of Tl^{3+} by a much larger percentage than the observed increase in Tl^+ (as measured by the absorption band at $247\text{ m}\mu$), the simultaneous reduction of Tl^+ to Tl^0 was postulated; i.e., both Tl^{2+} and Tl^+ act as traps for electrons released from F -centers by light.

RADIATION CHEMISTRY

Properties of H_2O_3 and HO_2

Work is continuing on the study, by pulse radiolysis methods, of the optical absorption properties and spontaneous decay rates of HO_2 and H_2O_3 formed by high-intensity irradiation of water containing dissolved oxygen. The two compounds, which both absorb at wavelengths around $2400\text{ \AA}$, can be distinguished by their decay kinetics: HO_2 decays by a second-order reaction, H_2O_3 by a first-order reaction. Both decay rates depend markedly on pH . Temperature dependences have been studied in detail.

The substance H_2O_3 is formed by combination of the radicals OH and HO_2 and decomposes by breakup into water and oxygen: $H_2O_3 = H_2O + O_2$. The decomposition occurs by an ionic mechanism and is catalyzed by acids and bases. A simple set of postulated reactions of H_2O_3 with H^+ and OH^- has been found to account quantitatively for the pH dependence of the rate. Maximum stability occurs near $pH\ 2$, where the half-life of the compound is around 1 sec at room temperature and 17 sec at 0°C ; the activation energy is 16.5 kcal. The half-life of the corresponding deuterium compound formed by irradiation of D_2O is about five times longer.

Figure 21. Effect of γ irradiation on the concentrations of Tl^+ and F -centers in KCl:Tl (melt-grown crystals); $[Tl^+]$ in the crystals $\approx 3.82 \times 10^{-5}$ moles/mole KCl; γ dose rate = 2.95 Mrad/hr .

In previous work, the decay of the radical HO_2 was studied by mixing a flowing irradiated solution with a solution of tetranitromethane (TNM) at various times after irradiation. TNM reacts with HO_2 to give highly colored nitroform, easily determined. The decay rate of HO_2 increases with increasing pH , and the TNM method was reported to show three plateaus in the curve of rate constant vs pH , occurring around pH values 0.5, 2.5, and 4.5, which were believed to indicate the existence of three forms of the radical, respectively: acidic, H_2O_2^+ ; neutral, HO_2 ; and basic, O_2^- . However, the new optical decay data do not show the middle plateau, so it seems that the radical may exist in only two forms after all. Further work is under way in the hope of resolving the discrepancy.

Accurate Yield Values for Water Radiolysis

A great part of the knowledge about free radicals and other transient intermediates is deduced from measurement of the yields of reactions undergone by various reactive solutes "(scavengers)" added to the medium being studied. In the case of water, a large quantity of data has been published from many laboratories on yields of reactions in various solutions under γ irradiation. There is still no agreement, however, on interpretation of the results; in two recent comprehensive critical reviews the interpretations of apparent discrepancies differ. At Brookhaven it is thought that some of the discrepancies may be due to errors in the reported yields of oxidation or reduction of various scavengers, the yields being low because account was not taken of competing reactions of free radicals with impurities or reaction products. Apparent yields in fact often decrease with increasing total radiation because of accumulation of reactive products of the main reaction, and the true yield value must be obtained by extrapolation to zero dose. To this end a program has been started to irradiate aqueous solutions with unusually small doses of γ rays by means of weak Co^{60} sources. This has necessitated the development of highly sensitive methods for determining the amount of reaction and of ways of obtaining and maintaining a high degree of purity in the materials irradiated. Initial yields have been obtained for TNM reduction in near-neutral solution, and study is now being made of the effect of pH on the oxidation of ferrous sulfate. For this work the source-intensity used is about 1.8 krad/hr, far below the minimum of 50 krad/hr used for most work in the literature.

Ionization of Liquids

A new method has been developed for determining the number of free ions produced by a given dose of radiation in a nonconducting liquid. An electric field is applied to the liquid after a pulse of radiation, and the charge collected from the liquid is determined by means of appropriate circuitry. The method is more convenient and probably more accurate than previous methods. The yield of ions has now been determined for a much greater number of liquids than had previously been studied. Some of the new results were quite unexpected.

The yield of free ions is smaller in a liquid than in a gas because in a liquid an emitted electron is usually slowed down to near-thermal energy while still within the electric field of its parent positive ion, and recombination immediately ensues. It had therefore been supposed that the relative yield of escaping ions in different liquids would depend mainly on the densities and dielectric constants of the liquids, and the scanty previous data seemed to bear out this supposition. New data obtained here show that this is far from true. For example, the three pentane isomers have almost the same dielectric constant and density, but the free ion yield in neopentane is *six times* that in normal pentane, while that for isopentane is intermediate. The ether 1,4-dioxane has a higher dielectric constant than its hydrocarbon analogue cyclohexane, yet the free ion yield in the ether is $< 1/3$ that in the hydrocarbon.

Data have also been obtained on the temperature coefficients of the yields for three pure liquids and on the yields found in two-component liquids. The observed effects of temperature and mixing have been rationalized by a stochastic model for the thermalization of electrons formed by ionization in a liquid. Such theories cannot explain the differences in yields found for different liquids.

Ionization and Positive Charge Transfer Studied by Optical Methods

Irradiation of dilute solutions of triphenylcarbinol, $(\text{C}_6\text{H}_5)_3\text{COH}$, in hydrocarbons gives rise to short-lived transient spectra that are identical with the known spectra of the triphenylmethyl radical, $(\text{C}_6\text{H}_5)_3\text{C}^\cdot$, and the carbonium ion, $(\text{C}_6\text{H}_5)_3\text{C}^+$. The yield of the radical increases linearly with the square root of the carbinol concentration, while

MASS SPECTROMETRIC STUDIES

Gaseous Ion Chemistry

Mass spectra generated by collision of positive ions with neutral molecules are potentially useful in the structural analysis of complex molecules and also provide basic information on the nature of energy transfer in isolated bimolecular collisions. Emphasis during the past year in the study of ion-molecule reactions has been primarily on energy transfer and reaction mechanisms.

Extensive studies have been made to determine the mechanism of energy transfer in neutralization of H^+ , H_2^+ , H_3^+ , and ArH^+ ions and their deuterium substituted analogues in collisions with certain hydrocarbons. These ionic species were selected to provide information on competitive charge transfer and proton transfer mechanisms. In the cases H_2^+ and H^+ , only charge transfer mechanisms are probable. With ArH^+ and H_3^+ , proton transfer, producing atomic argon and molecular H_2 , can compete with charge transfer in the ion-molecule collision process. In the formation of H_2 from H_3^+ , vibrationally excited H_2 may be formed. Evidence for all these processes was obtained in the study of ion impact spectra of cyclopropane and propylene. The observation of isotopic exchange demonstrates that proton transfer is a process of major importance in the formation of fragment ions by ion impact. Failure to observe isotope exchange in the formation of parent molecule ions provides good evidence that a charge transfer mechanism generates these species in collisions of H_3^+ and ArH^+ with cyclopropane and propylene.

The role of neutral molecule products in energy transfer in ion-molecule collision processes was investigated theoretically for reactions of H_2^+ ions. Calculations of the probabilities of transition of ionized H_2^+ to various excited states of neutral H_2 (Figure 22) were used to estimate a distribution of recombination energies for H_2^+ . This energy distribution, which ranged from 12.5 to 17.5 eV, was found to account well for the fragmentation pattern observed in the H_2^+ ion impact mass spectra of propylene and cyclopropene. This range of recombination energies is in sharp contrast to the single value of 15.5 eV estimated for neutralization of ground-state H_2^+ to ground-state H_2 molecules.

Absolute values of cross sections for charge transfer and proton transfer reactions as a function

the yield of the ion is independent of the carbinol concentration. It was found that the ion yield of the solute is limited by the total yield of free ions formed in the solvent; over a range of concentrations the yields of $(C_6H_5)_3C^+$ in cyclohexane, in *n*-hexane, and in isooctane were in the same ratio as the ion yields in the pure solvents determined by the clearing-field method discussed above. It is inferred from this that the carbonium ion arises by proton transfer from a solvent cation: $RH^+ + (C_6H_5)_3COH = H_2O + R\cdot + (C_6H_5)_3C^+$. Studies using the Febetron showed that the rate constant for this reaction is 1.0×10^{10} liters/mole-sec.

Similar experiments with triphenylmethyl chloride, $(C_6H_5)_3CCl$, give similar qualitative results. The ion yields in hexane and isooctane are twice as high with the carbinol, and in both solvents are equal to the total ion yields of the pure solvents as determined by the clearing-field method (provided it is assumed that the optical extinction of the transient ion in hydrocarbon is not changed when it is stabilized in concentrated sulfuric acid). Thus it seems that pulse radiolysis of solutions of the chloride provides an alternative method for determination of ion yields in pure liquids.

The solute tetramethyl-*p*-phenylenediamine (TMPD) is readily oxidized to the remarkably stable, colored, single-charged radical cation known as Wurster's Blue. Solutions of TMPD in cyclohexane give on pulse irradiation a transient blue color, the yield of which increases with concentration of TMPD, instead of reaching a constant level as a good ion yield should. Further study showed that a great part of the color was due to a triplet state of TMPD, which has almost the same absorption spectrum as the ion. Addition of naphthalene or *p*-terphenyl results in the appearance of triplet states of these additives, with a concomitant decrease in the absorption due to the TMPD triplet state; addition of N_2O also quenches the TMPD triplet absorption. The yield of the remaining absorption, due to the positive ion, is independent of TMPD concentration, and its absolute value ($G=0.15$) is equal to the yield of free ions in the pure solvent, cyclohexane. The kinetics of the decay of the blue color could be resolved into a first-order decay of the triplet with a half-time of 10.2×10^{-6} sec, and a second-order decay of the ion with a rate constant $k_2 = 1.0 \times 10^{12}$ liters/mole-sec. The latter value is of the order expected for diffusion-controlled ion recombination in hydrocarbon solution.

Figure 22. Estimated population of vibrational energy states in H₂ produced by charge transfer reactions of H₂⁺ with complex organic molecules having a wide range of closely spaced internal energy states. The calculation is based on the assumption that the probability of charge transfer is determined by the probability of Franck-Condon transitions between H₂⁺ and H₂.

of velocity were estimated from experimental data. The cross sections of the proton transfer reactions were found to be in good agreement with the $1/v$ law of Langevin. For both charge transfer and proton transfer reactions the observed cross sections were found to agree well with those calculated from simple classical theory.

Atmospheric CO₂ From Fuel Combustion

Techniques for precise measurement of the isotopic composition of carbon in CO₂ have been developed to investigate the effect of fossil fuel combustion on CO₂ in urban atmospheres. Isotopic carbon in fossil fuels has been shown to be depleted in C¹³ by $\approx 2\%$ compared with atmospheric CO₂. This makes possible estimates of fossil fuel CO₂ contributions to the atmosphere.

The sensitivity of the technique for estimating fossil fuel contributions to atmospheric CO₂ was established in studies on air samples from the Queens Midtown Tunnel, where the rate of fossil fuel emission can be accurately estimated and the characteristics of ventilation are well known. The C¹³ isotopic abundance was found to be 9 units above an arbitrary standard compared with ≈ 17 units for clean air, in good agreement with calculations. The precision of measurement was of the order of 0.3 units on the arbitrary index used.

A survey has been made of atmospheric CO₂ in samples taken from points over Long Island from the eastern tip at Montauk to the Borough of Queens in the City of New York. Samples were also taken at various points in Manhattan, including the observation tower near the top of the Empire State Building and street level in the same location.

The analysis of these samples showed that significant concentrations of fossil fuel CO₂ accumulate in areas of heavy automobile traffic between high-rise buildings. In the absence of such barriers mixing was found to be quite good, with rapid dissipation of relatively large amounts of fossil fuel CO₂.

These experiments established the usefulness of this technique for the study of the contamination of urban atmospheres by the burning of fossil fuels.

THEORETICAL CHEMISTRY

Kinetic Isotope Effects in Solvolysis

A program has been undertaken to calculate, by statistical mechanics, isotopic differences in the thermodynamic properties of simple molecules for which the requisite spectroscopic data are available. Results so obtained for the alkyl halides have been correlated with observed kinetic isotope effects in the solvolyses of organic chlorides and bromides. It has been found that differences in the α -deuterium isotope effects in limiting solvolysis reactions can be explained largely in terms of differences in reactants and that the transition states in such reactions are fairly independent of the particular halide.

Translation-Vibration Energy Transfer

Investigations have continued on the problem of translation-vibration energy transfer in the collision between an atom and a diatomic molecule. The method used for the study is the integration of the classical equations of motion. Such calculations, referred to as trajectory calculations, require a large digital computer. Of particular interest here has been a comparison of energy transfer in the case of collinear collisions with that in the noncollinear case. Previous to these calculations, approximation procedures had been developed for the estimation of steric factors in non-collinear collisions – the ratio of angle-averaged energy transfer to the energy transfer in the collinear case. The conditions under which such ap-

proximation procedures are valid have been determined.

Linear Free-Energy Relations

Many efforts have been made over the past several years to systematize various aspects of organic reactivity through the application of empirical linear free-energy equations. The parameters obtained in the Hammett and Taft equations for reactions and for selected physical properties of substituted aromatic molecules are of interest beyond their primary correlational role. They give promise of providing information about the driving forces in reactions of sets of related compounds.

Before successful theoretical interpretation of the internal electronic effects upon these parameters can be made, the contributions due to external effects that accompany the basic electronic effects for the isolated molecule must be separated. Considerable progress in this direction has recently been made for an important class of such external effects, i.e., those arising from variation of the solvent. In the process it has been shown that the use of simple electrostatic models to describe the propagation of internal effects is valid.

The dual substituent equation of Taft, $\log k/k_0 = \rho_I \sigma_I + \rho_R \sigma_R$, has been modified in an important way to collect in the rho values all effects not directly dependent on the nature of the substituent, a procedure that facilitates the separation of internal and external effects. (In this equation, k is the rate or equilibrium constant for the substituted molecule undergoing reaction and k_0 is that for the unsubstituted or reference molecule. The sigmas are parameters representative solely of the electron-donating or withdrawing power of the substituents relative to hydrogen and are independent of the reaction, of external conditions such as solvent and temperature, and also, importantly, of position of substitution.) Analysis of a select body of benzene reactivity data by means of this equation, with unbiased statistics, shows that the portion of the total effect called the "inductive (I) effect" (because of its resemblance to electrostatic behavior in saturated molecule systems) exhibits solvent dependence of a classical nature. For example, in reactions like carboxylic acid ionizations and amine protonations, the variation in the ratio $\rho_I(\text{meta})/\rho_I(\text{para})$, as the solvent composition is varied from pure nonhydroxylic composition to pure water, appears to depend upon the microscopic dielectric constant within

the cavity separating the substituent and reaction centers. Differential solvation of the reactant group, ionic in one reaction state but not the other, and ordered distribution of solvent from the aromatic framework outwards can produce dielectric conditions in the case of *meta* substitution that are quite different from those in the case of *para* substitution. In the mixed solvents, the water concentration appears to be enhanced in the solvent shell, a "solvent sorting" phenomenon. All these effects may be put into roughly quantitative form by use of the Kirkwood-Westheimer dipole-dipole field relation, $E \propto \cos\theta/D_E r^2$, with the microscopic effects contributing to the effective dielectric constant, D_E , while $\cos\theta/r^2$ is determined by the molecular geometry.

On the other hand, solvent effects upon the resonance (R) terms extend beyond modification of the dielectric of the cavity. Increased ion solvation ability of the medium appears to enhance the possible resonance polar interactions and direct conjugation interactions between the substituent and reaction center ends of the molecule through the aromatic framework. These effects are, however, not so important as the inductive effects already noted. The ratio $\rho_R(\text{para})/\rho_I(\text{para})$ is found to decrease uniformly with decrease in the bulk dielectric constant of the medium, despite the fact that $\rho_R(\text{para})$ itself increases. Extension of the analysis to systems with different solvation cavities is yielding consistent results for aromatics with long nonaromatic side-chains bearing the reaction group.

Molecular Orbital Theory

In complementary theoretical studies of the effects of substituents on reactivity, work on the important Lewis acid-base system $(\text{CH}_3)_3\text{B} + \text{N}(\text{CH}_3)_3$ has been completed. Application of the Lipscomb molecular orbital method has yielded insights into the problems of (a) electron flow in strong demand situations, (b) the validity of the concept of hyperconjugation, and (c) the way the latter is reflected in the observable phenomenon of β -secondary deuterium isotope effects. The system is considered an important one in connection with these problems; it is also important because reactivity effects are large and because both the reactants and the product are neutral molecules that are experimentally accessible. The theoretical results obtained account successfully for many experimentally observed properties of this reaction

Figure 23. North Devon sgraffito cup, deep dish, and jug restored from fragments excavated from fill under brick drain at May-Hartwell site, Jamestown, Virginia. The drain was laid between 1689 and 1695. Photo courtesy of Smithsonian Institution.

system (e.g., deuterium isotope effects in the borane and B^{11} quadrupole coupling constants).

The simpler reaction system, $C_2H_6 \rightarrow C_2H_5^+ + H^-$, is being studied also by *ab initio* Gaussian orbital SCF* calculations in connection with the problems of electron distribution stated above. The ethyl carbonium ion is the simplest species for which appreciable hyperconjugative stabilization is to be expected. Tests of this expectation and additional information relating to properties dependent on conformation of the ion (such as C—C bond rotation energies and distortion properties of methyl C—H bonds) are expected from population analyses based on the good wave functions for this ion recently obtained here.

INVESTIGATIONS OF ARCHAEOLOGICAL AND HISTORICAL MATERIALS

Nuclear investigations of archaeological materials now under way include the neutron activation analysis of Mayan pottery and of colonial North American and contemporary English Devonshire pottery. In addition, a number of precious metal objects, particularly the collection

of Sasanian silver objects in the Metropolitan Museum of Art, are being analyzed. The purposes of these investigations are to establish geographic origins and from them to develop criteria for authentication.

For example, fine orange ware, a particularly delicate, highly carved type of Mayan pottery, has the same composition whether found at Seibal, Altar de Sacrificios, Piedras Negras, or Kixpek. On the other hand, the utilitarian pottery from these sites shows a great variety of compositions; in only one isolated instance is a utilitarian piece of such composition that it might have been fabricated from the same clay as the fine orange ware. Fine orange ware seems to have been an item of commerce produced at a single site.

It has been possible to determine which of similar types of colonial American pottery were manufactured in England and which in the North American English colonies. (See Figure 23.)

Sasanian silver objects are found to be made of characteristically impure silver; and a gold-copper alloy, rather than pure gold, seems to have been used for their gilding.

Ages of some Coptic fabrics and some African wood sculptures are being determined by the C^{14} method. For this work the carbon in the samples is converted to methane, the radioactivity of which is measured in gas counters.

The possible application of α -recoil track counting to the dating of ancient glass is being investigated.

*Self-consistent field.

Figure 24. One of the crystal structures of pentavalent phosphorus compounds solved by the chemistry group, the unusual species 1,triphenylphosphino-1,diphenylphosphino-2,diphenylamino-2,phenylaminoethylene. The three-dimensional picture was produced on a color TV monitor by techniques developed by members of the Chemistry Department and the Instrumentation Division. By holding the viewing glasses in the pocket inside the back cover of this report at normal reading distance, a stereoscopic three-dimensional view of the object can be obtained.

Nuclear Engineering

The current program of the Nuclear Engineering Department falls into three categories. The first is basic research, which encompasses fundamental studies in reactor physics, chemistry, and metallurgy. Studies are also carried out in the fields of reactor materials at high temperatures, liquid-metal heat transfer and containment, fission product release, hydrogen storage media, and superconductivity in metals.

In the second category is the long-range work of developing components that may bring about significant advances in reactor technology and radiation application. Some of the more important phases of this work are effects of radiation on structural materials, utilization of fluidized beds for water desalination, radiation engineering methods, and ultimate waste disposal.

The engineering and evaluation studies in the third category are focused on practical application of the work in the preceding categories. A typical study that continued during the year concerned a pulsed fast reactor to be used as a source of neutrons for basic research in physics and chemistry. Assistance was given to the US AEC's Division of Reactor Development and Technology in the updating of *Civilian Nuclear Power: A Report to the President - 1962*, and in evaluating the 10-yr program plans for the Liquid-Metal-Cooled Fast Breeder Reactor (LMFBR).

In support of the mainline AEC program on the LMFBR concept, the emphasis in the Reactor Physics Division has shifted to work on fast reactor criticals, fast critical experiment analyses, and theoretical work on fast reactor safety and neutron cross-section data.

A conference on Industrial Needs and Academic Research in Reactor Kinetics, held at Brookhaven on April 8-9, 1968, was sponsored by the AEC's Division of Reactor Development and Technology. Its purpose was to improve working relationships between these groups and to accelerate progress in vital areas of power reactor kinetics, safety, and control.

The Nuclear Materials Division, a new division headed by Dr. H. J. C. Kouts, has been established

to assist the AEC in its programs related to the safeguarding of nuclear materials.

The Cross Section Evaluation Center and the Sigma Center were combined to form a new division, the National Neutron Cross Section Center.

The program of the Liquid Metal Center of the Metallurgy and Materials Science Division is also directed toward the AEC's fast breeder reactor program.

The program on superconductivity in cooperation with the Cryogenics Group of the Physics Department was continued.

The Engineering Division was expanded to include the pulsed research reactor project and the chemical engineering programs of the former Chemistry and Chemical Engineering Division.

With the transfer to private industry of the production and distribution of Sr^{87m} generators, Brookhaven has now withdrawn from the routine production of all special radioisotopes except Mg^{28} . Efforts are now being concentrated on the more important function of developing medical applications of isotopes.

EVALUATION AND TECHNICAL ASSISTANCE

Updating of the 1962 AEC Civilian Nuclear Power Report to the President

Participation is being continued in an AEC program to update *Civilian Nuclear Power: A Report to the President - 1962*. Seven task forces were formed to evaluate in detail the technical and economic capabilities of various reactor concepts in the nuclear power economy projected to the year 2020. BNL was represented on three task forces: Thorium Systems, Advanced Converters, and Systems Analysis.

A final report on the use of thorium in nuclear power reactors, prepared by the BNL task force working group, has been submitted to the AEC.

BNL participated in the study and evaluation of the economic potential of reactors capable of commercial power generation before the advent

of fast breeders, i.e., the heavy-water-moderated, organic-cooled and the high-temperature, gas-cooled advanced converter systems. A final report was prepared by the ORNL working group.

A linear programming technique is being used to optimize the cost of power in the U.S.; information prepared by all the other task forces serves as input. The task force and component working groups are carrying out data reduction and the writing of a final report with the help of BNL personnel.

Evaluation Studies

Four major areas of interest were evaluated for the AEC or its contractors. The first of these, a review of *Guide for Economic Evaluation of Nuclear Reactor Plant Designs*, by Nuclear Utilities Service, Inc., was completed for ORNL; the other three are continuing programs. At the request of the AEC's Division of Reactor Development and Technology, cognizant individuals at BNL are evaluating drafts of the 10-yr program plans leading to the introduction of an LMFBR as they are produced by the LMFBR Program Office at ANL.

BNL is supplying information on estimates of capital costs correlated with plant size for sodium-cooled fast breeders in the range of 150 to 1000 MW(e), and the release of evaluated technical and economic data on the Molten Salt Breeder Reactor (MSBR) to the joint India-USA Study Group. The MSBR data have been summarized, while work is continuing on the capital costs.

BNL is participating in the development of codes and standards applicable in the reactor field. This is part of an AEC-sponsored program at ORNL and Atomic International's Liquid Metal Engineering Center (LMEC). The ORNL work involves the consolidation of current power technology and engineering practices and the development of basic standards for AEC-owned water reactors. This work will also help to define the existing technological base upon which advanced development programs will be built. A similar effort at the LMEC involves standards applicable to the LMFBR program. Detailed comments on some 20 standards have been forwarded to ORNL thus far.

BNL is also represented on subcommittees of the USASI-NSB* Standards Committee N-101.

*USA Standards Institute, Nuclear Standards Board.

REACTOR PHYSICS

Experimental Reactor Physics

This year the activities of the Experimental Reactor Physics Group have been expanded to include some of the work performed by the Analytical Reactor Physics Group that is in direct support of BNL experiments. This amalgamation represents an even closer tie between the experimental and analytical activities of the two groups. Generally speaking, attention has been focused on experimental work on the physics of fast reactors in order to gain an improved understanding of the neutron physics of nuclear reactors.

A milestone was achieved with the start-up of FS-1, the first fast critical assembly at BNL. Prior to start-up, a comprehensive review was conducted by the Reactor and Critical Experiment Safety Committee, and approval was obtained from the AEC, since all prior critical assemblies at BNL had been characterized as thermal reactors. FS-1 is now being used for studies of heterogeneity effects in reaction rates of fuel cells and the development of techniques for measuring neutron spectra in fast reactors.

Measurements of reaction rates have progressed with the adaptation of the spark chamber reader to automatic scanning and counting of fission tracks in thin plastic films. Other developments in technique include a proton recoil counter for the measurement of neutron spectra in fast reactors. This counter has been tested with neutrons from the Van de Graaff generator and modified Pu-Be neutron sources, but is yet to be tried in a critical assembly.

Experiments have continued on the study of moderator blocks for a pulsed fast reactor. Measurements of thermal neutron pulse widths and energy spectra in various geometries and materials and at various temperatures were made by using the Medical Research Reactor and the Kaman pulsed neutron source. A fast critical assembly, designated CEPFR (critical experiment, pulsed fast reactor), was started up, and measurements of neutron lifetimes and reactivity worths of reflector materials have commenced.

In the course of certain pulsed neutron experiments for development of moderator regions for the pulsed reactor, a discovery was made that casts doubt on the correctness of many pulsed neutron experiments: when the thermal neutron detector

is located outside the moderator, the measured decay time depends on the distance to the detector.

Technical Assistance, Division of Reactor Licensing

Technical assistance is provided in the area of the reactor physics and safety of power reactors under review by the AEC's Division of Reactor Licensing. Part of the work is broad-based and includes the study of topics common to these reactors, such as methods of calculating temperature coefficients, control-rod worths, power distributions, fuel burnup, and transients during normal or abnormal operations. A second aspect of the work is to provide assistance and advice to the AEC on specific problems as they arise.

During the year studies were carried out on the external detection of power shapes in a pressurized water reactor (PWR), the stability of boiling water reactors against xenon oscillations, and the moderator temperature coefficient of a PWR controlled in part with soluble boron.

Theoretical Reactor Physics

The work in theoretical reactor physics has shifted to emphasis on fast reactor physics studies. These studies include the development of computer codes for fast reactor calculations, the theoretical interpretation of fast spectrum integral experiments, and the development of theoretical methods in reactor kinetics and of methods of determining resonance absorption in fast reactor systems.

In September a task force was formed to provide technical assistance to the AEC's Division of Reactor Licensing in the area of power reactor physics and safety. The task force carried out several assignments involving power reactors under review by this division of the AEC. On March 1, 1968, it was dissolved and the work was transferred to a new activity within the Theoretical Reactor Physics Division supported by the AEC's Division of Reactor Safety.

For fast reactor calculations, the chain of codes MC²-ETOE-ENDF/B-ANISIN was developed. For kinetics calculations, a 2-D version of the code NOMURK was programmed. Studies were carried out for the interpretation of experiments on deep penetration of neutrons through fast reactor materials such as iron and for the interpretation of pulsed fast reactor experiments. Investigations of reactor kinetics resulted in a useful improvement over the conventional prompt-jump ap-

proximation. Studies of two-phase flow included an investigation of stability conditions under which boiling or condensation occurs along a channel. An iterative method of calculating the resonance absorption of neutrons by discrete levels in fast reactors was developed which appears capable of yielding narrow upper and lower limits for resonance integrals.

Reactor Physics Analysis

The work in reactor physics analysis has emphasized the analysis of experiments that cast light on crucial fast reactor parameters. An example is the present uncertainty in α_{49} , the capture-to-fission ratio of Pu²³⁹ in the energy range of a few hundred to a few tens of thousands of electron volts. An analysis of α was started on data obtained from plutonium-fueled, heavy-water-moderated lattice experiments at BNL. More rigorous calculations, including Monte Carlo methods, were also initiated for this study. Additional experiments suggested for this purpose involve the irradiation of boron-shielded Pu²³⁹ foils in BNL's High Flux Beam Research Reactor (HFBR).

Other studies have included analyses of the Pu-D₂O exponential lattices, the U²³⁵-graphite critical experiment, and reflected exponential experiments. The principal reactor codes for these studies were HAMMER, MOCA, and ANISIN. The latter code is a one-dimensional multigroup DSN code with the capability of including anisotropic scattering. It is also being used for heterogeneity studies in the core of the FS-1. The cross-section libraries for these codes are being updated with ENDF/B data from the Neutron Cross Section Evaluation Center. Comparisons of British (BICEP) and U.S. critical experiments were completed; it was concluded that, based on current cross-section data and without any reduction in the resonance integral of U²³⁸, good agreement existed between theory and experiment.

NUCLEAR MATERIALS

A new division has been established in the Nuclear Engineering Department to assist the AEC in its programs related to the safeguarding of nuclear materials. The Division is a technical support organization that advises the Office of Safeguards and Materials Management of the AEC on tech-

nical aspects of these programs. The problems involved are connected with domestic control, exercised by the AEC, and international control through the International Atomic Energy Agency (IAEA). International control is at present effected through a number of bilateral and trilateral agreements to which the IAEA is a party, but in the near future it is expected to grow and be strengthened as a result of the pending nonproliferation treaty.

The Division is at present providing advice on a number of aspects of the safeguarding of nuclear materials, including pertinent research and development work and the over-all capabilities of specific methods of control.

NATIONAL NEUTRON CROSS SECTION CENTER

In May 1967 approval was obtained from the Research Division and the Reactor Development and Technology Division of the AEC to merge the cross-section compilation and evaluation activities of the Nuclear Engineering Department. This new entity, called the National Neutron Cross Section Center (NNCSC), combines the Neutron Cross Section Compilation Center (Sigma Center) and the Cross Section Evaluation Center, which formerly operated within the Department's Reactor Physics Division. On September 15, 1967, the merger was effected with the appointment of a Deputy Director who also functions as Acting Director. The functions of the NNCSC are to develop a highly computerized system for the storage and retrieval of cross-section information and to advance new methods of cross-section analysis.

Advisory Committee

An Advisory Committee was appointed by the Nuclear Engineering Department to review the activities of the NNCSC. The members of this committee are R. Ehrlich (Knolls Atomic Power Laboratory), H. Goldstein (Columbia University), P. Greebler (General Electric-Atomic Products Operation), G.C. Hanna (Atomic Energy of Canada Ltd., Chalk River), R. Lazarus (Los Alamos Scientific Laboratory), and A.B. Smith (Argonne National Laboratory). The first meeting of the newly formed committee with NNCSC personnel took place November 28-29, 1967.

SCISRS Information

Assessment of the energy-dependent data contained in *Neutron Cross Sections*, BNL 325, 2nd Ed., Suppl. 2, Vol. IIC, has been completed. These data should all be inserted into scisrs shortly. Culling of the older Sigma Center files for still-useful data has begun.

A tentative proposal for the new data storage system to replace scisrs has been completed and widely distributed to scisrs users. Comments and criticisms have been received, and a final proposal is in preparation now.

Studies of angular distribution data are being made for the purpose of seriously assessing the problems associated with computer-based production, including the fitting of curves through the data, of a publication similar to *Neutron Cross Sections*, *Angular Distributions*, BNL 400.

Evaluated Nuclear Data File

A major portion of the neutron cross-section data in the library of the Evaluated Nuclear Data File for Reactor Applications (ENDF/B) has cleared preliminary checking procedures and is available for distribution to laboratories in the United States and in countries that are members of the European Nuclear Energy Agency (ENEA). Domestic users receive data from the NNCSC at BNL, while ENEA members receive data from the Neutron Data Compilation Centre at Saclay, France.

The Cross Section Evaluation Working Group reconvened at BNL on January 16-17, 1968, to proceed with the testing and distribution of ENDF/B material. Prior to the meeting the major portion of the zeroth iterate of the ENDF/B library had been distributed for further testing. Included in the distribution were materials contained in the reference assemblies selected for study.

Multilevel Fitting of Cross Sections

A study of multilevel methods for the calculation of cross sections of fissile elements has been initiated. A program utilizing the Adler-Adler method for fitting cross sections is under study. It has an option for iterative fitting of calculated cross sections to experimental data. In its present form it does not appear to be capable of utilizing spin information. The Reich-Moore method has also been selected for study, and preliminary runs have been executed. This program, in its present

form, cannot accomplish fitting in an automated way, but does appear capable of utilizing spin information. Other multilevel schemes may be included in the study.

Cross-Section Statistics

The random matrix approach to the theory of nuclear reactions in the continuum region has been applied to the study of polarization effects in nuclear reactions. For simplicity, attention was first restricted to the polarization of spin- $\frac{1}{2}$ particles, whether in the incident beam or in the scattered beam. It was found that the average inelastic cross section is independent of the incident polarization, whereas the average elastic scattering cross section generally depends on it. In the latter case, the polarization of the elastically scattered beam is due to the shape-elastic rather than the compound-elastic component.

The polarization studies in the continuum region were then extended to include incident polarized nuclei of any spin, provided spin tensor moments of higher order vanish. The methods have also been applied to the calculation of the average polarization induced by the scattering of unpolarized nuclei.

Cross-Section Systematics

Earlier work concerned with estimation of thermal capture and fission cross sections and resonance integrals has been extended. The work is intended to review the various concepts and portray the "state of the art" techniques employed in analyzing neutron interactions by means of the optical model and associated reaction theories. The method of analysis has been improved and extended to include $\bar{\nu}_p$ (average number of prompt neutrons) and $\langle E_k \rangle$ (average kinetic energy of fission fragments).

METALLURGY AND MATERIALS SCIENCE

Liquid Metal Center

The program of the Liquid Metal Center consists of tests of the corrosion behavior of materials in liquid sodium, studies of the mechanisms of this corrosion, the physical chemistry of liquid sodium solutions, and the development of corrosion-resistant alloys suitable for use at 815°C.

Corrosion tests are conducted in natural and forced circulation loops, which have accumulated

Figure 1. Time dependence of corrosion rates of typical fuel-cladding alloys in sodium at 760°C. The sodium contained 4 to 8 ppm oxygen, and its velocity was 22 ft/sec.

a total of 24,554 and 1990 hr, respectively, of testing. Alloys under test* include types 321, 304, and 316 stainless steels; cobalt alloys S-1, Haynes-25, UMC0 51, and Multimet; refractory alloys V-20 Ti, V-15 Ti-7.5 Cr, V-15 Cr-5 Ti, Nb-1 Zr, Mo, and TZM; and a high-nickel stainless steel, Incoloy 800. Corrosion rates calculated from weight-change data from the first forced circulation loop test are shown in Figure 1. At shorter exposure times, the cobalt alloy Haynes-25 appeared more corrosion resistant than the stainless steels. However, after 1600 hr of test, both the cobalt- and iron-base alloys were corroding at about the same rate. X-ray fluorescence measurements of the corroded specimens showed that nickel and chromium were preferentially leached from the alloys by the sodium, which left the surface enriched in either iron or cobalt. Molybdenum alloys were found to be very resistant to sodium attack.

An attempt is under way to develop a cobalt-base alloy having the strength of Haynes-25 at 760°C, a minimum of high cross-section elements, and immunity to age embrittlement. Stress-rupture tests of the first series (15 alloys) showed that 2 to 3 wt % titanium is beneficial for meeting these re-

*Nominal compositions, in weight percent: type 316 SS, 17 Cr-12 Ni-3 Mo-balance Fe; type 304 SS, 19 Cr-10 Ni-balance Fe; type 321 SS, 18 Cr-10 Ni-(6×C)Ti-balance Fe; Haynes-25, 20 Cr-15 W-10 Ni-2 Fe-balance Co; S-1, 20 Cr-10 Ni-7 Mo; Multimet, 20 Cr-20 Co-20 Ni-31 Fe-3 Mo-2 W; UMC0 51, 28 Cr-18 Fe-1 Mn-2 Nb-balance Co; TZM, 0.5 Ti-0.1 Zr-balance Mo; Incoloy 800, 21 Cr-32 Ni-balance Fe.

quirements. Eight additional alloys were prepared and are being evaluated.

Corrosion of metals in sodium is related to their solubilities in sodium, kinetics of reaction at the metal-sodium interface, and often the oxygen concentration in the sodium.

Data have been taken on the solubilities of iron, nickel, and copper in sodium. These are all quite low and therefore difficult to measure and analyze accurately. Particulate matter of some form of these metals appears to exist in suspension at temperatures at which the apparent solubilities are <1 ppm. An apparatus was built for studying the dissolution kinetics of pure metals in sodium.

Studies were initiated on the interactions between oxygen and other impurities in sodium, with use of a solid electrolyte galvanic cell, the emf of which is determined by the chemical activity of oxygen in the sodium. The rate of change of emf indicates the reaction kinetics, while the equilibrium values indicate the oxygen activity. Soluble getters for oxygen (Mg, Li, or Ca) lower the oxygen activity more rapidly than insoluble getters (U, Zr, or Ti). Of these last, uranium controls oxygen most rapidly. Its oxidation in sodium is a linear function of both oxygen content and time at 500°C , and thus it can be used for oxygen analysis in sodium.

In an LMFBF, an electrochemical oxygen meter would operate in the presence of Na^{24} radioactivity. A meter operating in hot-trapped sodium was subjected to Ir^{192} activity of 1.50×10^3 R/hr* for 5 min. The potential decreased a negligible 0.3 mV from the original 1.233-V reading in the presence of the source, and returned to normal upon its removal.

Work was initiated on the absorption of controlled amounts of gaseous carbon compounds, at the ppm level, by excess liquid sodium, to distinguish the active forms of dissolved carbon from those that are particulate. Experiments with cyanogen are in progress.

Construction was completed on a sodium chemistry loop to be used as a controlled, well-characterized source of sodium samples for analytical development and the sodium chemistry program.

The blank, characteristic of the amalgamation method for determining oxygen in sodium, is contributed primarily by the glassware used, with stainless steel container material contributing a

lesser amount. Except for this blank, this method is comparable to the vacuum distillation method at the 10-ppm level.

Development continued on an isotope dilution method for oxygen in sodium in which the sodium is doped with O^{18} and reacted with graphite to yield a mixture of CO^{16} and CO^{18} .

Effects of Radiation on Structural Materials

Effects of microstructures on the high-temperature ductility of irradiated austenitic stainless steels are being studied to ascertain the optimum structure of these steels for fuel-cladding applications. Significant improvement in the 750°C ductility of type 304 stainless steel irradiated to 1.3×10^{20} nvt was obtained by deformation at liquid nitrogen temperatures ($\approx 77^{\circ}\text{K}$) to refine the grain size and redistribute the carbides. Effects of this treatment on superplastic, two-phase Fe-Cr-Ni alloys will also be studied. Cobalt-base alloys have been shown to be embrittled at 800°C after an exposure of 1.3×10^{20} nvt; however, they are not severely embrittled at 650° to 700°C and thus may be useful fuel-cladding materials. Their mechanical properties are superior to those of the austenitic stainless steels at 650° to 700°C .

A study of the effects of neutron irradiation on iron single crystals oriented for single slip indicates that crystals oriented for $\{112\}$ slip have a lower than average temperature dependence of their shear stress before irradiation, but are brittle below 150°K after irradiation. Crystals oriented for $\{123\}$ slip have a very high temperature dependence of shear stress after irradiation.

The yield stress of irradiated Ferrovac iron was fitted to a saturating formula based on a square-root dependence of the yield stress on the exposure. The defect size at saturation was calculated, and low exposure deviations were explained on the basis of radiation-induced changes in carbon atom sites in the lattice. No change in the deformation mechanism in Ferrovac iron tested at $<1\%$ strain was found after irradiation to 2×10^{18} nvt. However, prestraining samples to 9% elongation (to introduce uniform dislocation distribution, produce even deformation, and reduce "channeling") did affect their deformation mechanism after irradiation to 10^{20} nvt at 90°C . Measurements of the yield stress and activation volumes and energies for slip showed that the irradiation changed the rate-controlling slip process to one based on inter-

*10% of the estimated dose in LMFBF primary sodium.

actions between glissile dislocations and submicroscopic vacancy loops.

Measurements made on the defect structure and mechanical properties of irradiated tungsten showed that vacancy dislocation loops are present in tungsten after irradiation to about 5×10^{19} nvt. However, such loops are not observed in tungsten irradiated in a lower range of fluence, at which defects are introduced at a linear rate. The temperature dependence of the critical resolved shear stress of the neutron-irradiated tungsten is changed by irradiation, in contrast to predictions.

Electron transmission and optical microscopic observations disclosed that fracture at temperatures below the ductile-brittle transition in fast-neutron embrittled Ferrovac E iron is initiated by subsurface microcracks which form along grain boundaries at points of high stress concentration resulting from impingement of twins. The microcracks propagate transgranularly to produce fracture. The decrease in fracture stress accompanying this transition is apparently due to grain-boundary weakening which results from the tying up of the available carbon atoms by displacement-type radiation defects.

An embrittling irradiation of 2×10^{18} nvt ($E > 1.45$ MeV) has no detectable effect on the transmission microstructure of Fe_3C in iron. Fracture at temperatures below the ductile-brittle transition in fast-neutron embrittled iron containing Fe_3C is initiated by microcracks in the Fe_3C which propagate transgranularly through the ferrite matrix.

A new RCA EMU-4 electron microscope has been installed and calibrated, and modifications to adapt auxiliary equipment are being completed.

High-Temperature Properties of Materials

Electrical property measurements were completed on Th, ThB_4 , ThB_6 , and ThC-UC solid solutions. A significant contribution to the resistivity of the last-named group of compounds results from scattering by uranium atoms. The variation in thermoelectric power and Hall coefficients of these solid solutions with uranium content indicates that uranium is adding positive carriers to the electronic structure.

The thorium borides are metallic conductors. The Hall coefficient of both compounds is the same and temperature independent, and indicates about two electrons per thorium atom. These re-

sults agree with the predictions of boron valence structures proposed by Lipscomb and Britton [*J. Chem. Phys.* **33**, 275 (1960)] and extend their model to the tetra- and hexaborides of a tetravalent metal.

The magnetic susceptibilities of thorium carbides, nitrides, and carbonitrides have been measured at temperatures of -190° , -76° , and 22°C . All have a small, temperature-independent paramagnetism. The values for ThC and ThC_2 were an order of magnitude higher than those reported by other workers. A comparison of the susceptibility and electrical measurements on these compounds indicates that the electrical properties are controlled by the conduction electron concentration, but the susceptibility is determined primarily by the concentration of holes in a two-band model.

Thermodynamic properties of the potassium-graphite lamellar compounds have been determined in the temperature range 200° to 350°C by use of electrochemical cells of the type

in which the electrolyte is a glass reversible to potassium ions. The potassium-graphite system was found to be completely analogous to the cesium- and rubidium-graphite systems.

Superconductivity

Superconductivity in thin-film and small-particle samples has recently stimulated considerable interest. Superconducting properties have been measured of near-monolayer-thick films and of "sandwich" systems prepared by alternately evaporating ultrathin layers of different metals, or of metals and dielectrics. Surface layers and surface interaction play a crucial role in determining properties of such materials and produce unusual effects attributable to alteration of the interaction responsible for superconductivity. In "soft" superconductors such as Al, Sn, Zn, and In, "sandwich" structures and moderately thin films on dielectrics prepared on cryogenic substrates have critical temperatures (T_c) much higher than those previously observed for these materials. In the metallic "sandwich" structures, the thickness of the layers to optimize the enhancement of T_c is typically 15 Å. However, the T_c 's of the thinnest *single-layer* films (< 30 Å thick) decrease as the thickness is decreased. A model was proposed in which this depression is attributed to the destruction of long-

range phase coherence. An apparatus has been built in which ultrathin films can be prepared at cryogenic temperatures and their critical fields (up to 110,000 gauss) measured *in situ* for study of the way in which spin-orbit scattering affects the ultimate, paramagnetically limited critical field of superconductors. A low-temperature apparatus has been completed in which experiments can be cooled to 0.015°K and warmed up to 0.050°K in 24 hr. Preliminary measurements have been made on the superconducting properties of the lamellar compounds of graphite with Cs, Rb, and K, which have T_c 's in the range 0.1° to 0.5°K .

Hysteresis in superconductivity is treated as a form of thermodynamic equilibrium originating from surface energy changes by using free energy arguments, chemical potential concepts, and phase rule considerations. Previously unknown properties were predicted by the model and have now been confirmed experimentally from magnetization and transport current measurements. The findings include (1) supercurrents and persistent currents distribute themselves in a manner determined by the normal-state surface energies, the magnitude of the effect being dependent on the surface-to-volume ratio of the sample; (2) persistent current states in $H=0$ and $T\neq 0$ can have the same Gibbs free energy as the state without current; (3) only irreversible phase transitions can occur between states of the same free energy in zero field, but reversible phase transitions can occur when $H\neq 0$; and (4) surface current states with the same free energy in different applied fields can be connected by an isothermal, reversible path restricted by the conditions $B=0$ and $dB/dH=0$.

Liquid Metals

A model was developed in which electromigration in liquid alloys is attributed to the relative "drag" exerted on each type of atom by the electron current; electromigration is linked to electron scattering and thus to the difference in electrical resistivities of the pure components. This relationship holds quite well for many combinations of polyvalent metals, but apparently breaks down for combination of polyvalent and monovalent metals.

The motion of light atoms in dilute mixtures has been found experimentally to be approximately mass independent. However, theoretical arguments using dense-gas, hard-sphere models suggest

that diffusion should vary inversely as the square root of the mass. Molecular dynamic calculations of a mixture of atoms with a mass ratio of ten indicate that the light and heavy atoms diffuse at about the same speed.

An equation of state for hard spheres in a uniform negative potential has been derived and applied to the temperature-dependent properties of pure liquid metals. Reasonable agreement has been obtained for all metals in the case of self-diffusion coefficient, compressibility, and velocity of sound. The relaxation of the equilibrium atomic distribution with temperature has been successfully described by this model. A sensitive test of it is provided by the temperature dependence of the electrical resistivity. While theoretical and experimental resistivities of the alkali metals agree closely, a more detailed understanding of the attractive forces between screened ions is needed to explain the resistivities of polyvalent metals. The electrical resistivities of several binary alloys have been calculated. It has been demonstrated that the unusual behavior of mercury-based alloys can *not* be attributed to a minimum in the electron density of states near the Fermi level of mercury, as previously proposed.

CHEMISTRY

Metal Hydrides

The use of metal hydrides as media for the reversible storage and release of hydrogen continues to look promising. In a typical cycle, the evolved hydrogen would be used as fuel for a combustion engine or fuel-cell battery. The waste heat produced by either of these devices would suffice to provide the enthalpy of dissociation of the hydride, which would be of the order of 18 kcal/mole of H_2 . Design studies were made of integrated systems of this sort, and problem areas were defined. On the experimental side, apparatus was built in which pound quantities of hydride can be formed and decomposed. In this, a batch of Mg_2Ni was subjected to repeated hydriding-dehydriding cycles for the twofold purpose of making rate measurements and determining stability under cycling. The behavior of the system has so far been satisfactory in both respects. More basic research on pressure-temperature-composition relationships in alloy-hydrogen systems has also continued. Particularly interesting behavior was found for the

system $\text{Ti}_2\text{Fe-H}_2$. In it a hydride, or possibly a hydrogen solid solution, forms which has a dissociation pressure of about 1 atm at room temperature.

Some impetus has been given to this program by the current concern about air pollution. Hydrogen engines may not compete economically, but the fact that their exhaust is harmless might encourage the subsidizing of their use.

Fused-Salt Chemistry

Two new experimental methods have been applied to the study of the fundamental nature of fused salts: cold neutron scattering and alternating current capacitance measurements. In the first of these, a beam of cold neutrons from the Brookhaven Graphite Research Reactor impinges on a sample of fused salt or salt mixture in a silica container, and the inelastically scattered neutrons are analyzed by the slow-neutron chopper facility. From their observed energies, conclusions can be drawn about the structure and dynamical properties of the fused-salt state. Runs have been made on the binary system $\text{ZnCl}_2\text{-KCl}$. Results indicate strong scattering from acoustical phonon modes and also show the presence of diffusive modes.

The capacitance measurements are intended to shed light on the nature of the electrical double layer at a metal-salt interface. The research involves the use of a dropping bismuth electrode, previously developed here. In the first series of experiments, the salt used was highly purified LiCl-KCl eutectic; the absence of easily oxidizable or reducible ions allowed the system to act as an "ideally polarized electrode." Data were taken on capacitance as a function of potential, temperature, and frequency.

Fluorine Chemistry

A detailed kinetic study of the decomposition of perfluorobicyclohexyl was undertaken, since its thermal stability has been found to be orders of magnitude less than that of some other fluorocarbons. The reaction was found to be first order and homogeneous and not to involve a chain. The activation energy is 73 kcal. The main reaction products were identified, and from their relative abundance certain reaction paths involving postulated free-radical intermediates were deduced. The first step is very probably a homolytic split between the two rings to form cyclohexyl radicals.

The effect of pressure on both the pyrolysis and high-temperature radiolysis of this compound was

very marked. At 100 atm the pyrolysis rate was an order of magnitude lower than at 1 atm. On the other hand, radiolysis rates were extremely high at high pressure but contributed little to the overall decomposition rate at 1 atm.

Mechanism of Graphite Formation

The evaporation of graphite from heated filaments has been continued with emphasis on the results at temperatures above 3350°K . It is only at these high temperatures that the fraction of the total energy that goes into vaporization of carbon becomes significant enough, compared with that dissipated by radiation, to allow the heat of vaporization of graphite to be determined by an energy balance. Temperatures were determined in four ways: by photoelectric pyrometer measurements, from the filament resistance, from the cooling curve of the filament, and from the rate of carbon evaporation from the filament as measured via the rate of weight loss and resistance change. Pyrometer readings alone may be inaccurate as a result of the formation of carbon particles which absorb light from the filament. Direct experimental determinations of the heat of vaporization of graphite from a filament gave a value of 103 ± 10 kcal/mole C, which showed that C_2 was the primary carbon species evaporating.

Spectrographic second-law determination of the heat of vaporization of C_2 from inside a graphite cylinder gave values of 94.5 ± 8 kcal/mole C from emission data and 96.0 ± 7 kcal/mole C from absorption data. These values are in good agreement with the currently accepted value of 97.5 kcal/mole C. The oscillator strength of the 0,0 vibrational transition of the C_2 Swan electronic transition was measured and yielded a value of 0.0135 ± 0.0040 , which was intermediate in the range of literature values of 0.0040 to 0.0300. In this work, the presence of C_3 has been confirmed, but at $\approx 1/10$ of the pressure predicted.

ENGINEERING

Fission Product Release (Nuclear Safety) Studies

During the last year, research on this program was directed almost entirely toward fast reactor problems. The individual phases of the program encompassed both basic and applied studies to determine the behavior of fission products in sodium, their vaporization from sodium, and the genera-

Figure 2. Fission product partial pressures, P , per mole fraction, x , plotted vs reciprocal absolute temperature for dilute solutions in sodium. The broken lines show the predicted partial pressures with the assumption that the solutions are ideal, while the solid lines account for interactions in solution based on the appropriate excess free energies of mixing.

tion and dispersion of the radioactive aerosols of sodium and the plutonium compounds used in fast reactors.

In studies dealing with fission products in sodium, the partial molar excess free energies of mixing of Cs, Rb, Sr, and Ba with sodium were analytically evaluated for the entire region of concentration from zero to unit mole fraction. These values were combined with vapor pressure data to predict the partial pressures of these fission products under the conditions likely to exist in a reactor. The partial pressures of fission products Te, Ba, Sr, iodine (present as NaI), Rb, and Cs per mole fraction are plotted versus reciprocal absolute temperature in Figure 2.

In addition to the equilibrium studies, experiments were carried out to measure the rate of cesium transport from sodium as well as the rate of sodium vaporization into flowing helium and argon gas streams. Although the sodium release is

controlled by gas phase diffusion, the cesium release rate depends primarily on liquid phase diffusion, with only a small gas phase resistance.

The formation and agglomeration of PuO_2 and mixed $\text{PuO}_2\text{-UO}_2$ aerosols and their interactions with sodium aerosols were studied to provide data needed to assess the hazard associated with radioactive aerosol transport in the event of a reactor accident. Upon heating to temperatures above 2500°C in flowing gas streams, PuO_2 vaporizes to form chainlike particles ranging from 0.1 to $0.5\ \mu$ in size. Temperatures above 2950°C are required to vaporize equal quantities of UO_2 and produce particles with similar size distributions. The individual oxide aerosols were found to coagulate over long periods of time with rate constants of $(3\text{ to }9) \times 10^{-8}\ \text{cm}^3/\text{sec}$. Other experiments were done in which sodium was vaporized together with the fuel oxide. Aerosols were produced with mass concentrations ranging from a few milligrams to several grams per cubic meter and sodium-to-fuel ratios ranging from 1 to 100. In all cases, the fuel oxide coagulation rate is greatly enhanced in the presence of sodium.

Ultimate Waste Disposal

The Brookhaven phosphate glass process is now being tested at Pacific Northwest Laboratory (PNL Waste Solidification Prototype) with high-level radioactive wastes. In support of this operation the major emphasis during the past year has been on determining, through a number of extended runs in the Brookhaven pilot plant, the operability of the process with Purex-1 and Purex-2 flowsheets together with the effects of variations in the sodium and phosphate concentrations. These runs revealed a number of potential difficulties with respect to equipment performance, such as plugging of process lines. Practical solutions to these problems were obtained largely by means of mechanical modifications in the plant and changes in the nature of purge streams at specific points.

Since the sulfate component of Purex-2 waste is readily volatilized in the glass-forming step at $\approx 1100^\circ\text{C}$, along with small amounts of fission products, notably ruthenium, as well as the nitrate carried over from the evaporation step, the disposal of the contaminated sulfate-nitrate condensate presents a special problem. During the year it was demonstrated that these condensates could be separated into nitric and sulfuric acid fractions by

Figure 3. Heat transfer characteristics of rod C, showing the effect of moving rod B toward rod C, for mercury flowing in-line through an unbaffled rod bundle. Rod B was the central rod in a 13-rod bundle. The heat transfer coefficient drops more for rod C than for any of the other rods because it is the most confined. The horizontal portions of the three curves represent the heat transfer regime including molecular conduction only.

Figure 5. Heat transfer characteristics for rods in location B as they are moved along path $p \rightarrow r$, showing the effect of sheath thickness and conductivity. The symbol σ represents the ratio of the actual distance a rod was moved to the maximum distance it could have been moved.

Figure 4. Circumferential variation of surface temperature of rod B, showing the effect of moving it toward C. See Figure 3 or Figure 5 for spatial arrangement of rods. The variations for the nickel-sheathed rods were considerably greater than those for the copper-sheathed rods, and those for the stainless-steel-sheathed rods were greatest of all.

Figure 6. Experimental measurements of the superheat required to initiate boiling in potassium after deactivation of the heater at various operating pressures prior to boiling. The data are compared with a theoretical correlation developed here. Both experimental data and theory show superheats increasing with increasing deactivation pressure.

vacuum distillation, with essentially all the ruthenium remaining in the still-pot residue for recycling back to the glass. A procedure that shows considerable promise of increasing ruthenium decontamination is that of adding hypophosphorous acid to maintain the lower oxide state of ruthenium, without the need for operation under vacuum.

A process is being developed for removing radioactive noble gases, principally krypton and xenon, from bulk gas streams in which they are present in concentrations of ≤ 100 ppm. Such a process could be applied to the treatment of gases held in a containment shell following a nuclear reactor accident, as well as to the treatment of off-gases from reactor fuel reprocessing. The proposed process involves one or more of the following steps: reaction with hydrogen to remove oxygen, liquefaction and fractional distillation, and adsorption of the noble gases on solid absorbents.

During the past year the investigation has centered on studies of the adsorption of krypton in different N_2 -Kr mixtures on solid adsorbents at temperatures below $-200^\circ F$. The results show that good enrichment factors are obtainable with each pass through charcoal beds at $-250^\circ F$ and that the enrichment factors change only slightly over a wide range of N_2 -Kr concentrations.

Laboratory studies have been initiated to substantiate the usefulness of the phosphate glass process for disposing of future waste types with higher burnup of the order of 4.5×10^4 MWd/tonne of uranium and new fission product spectra.

Heat Transfer Research

This research activity is primarily concerned with heat transfer behavior in liquid metal media. The results (from both experimental and analytical studies) are applicable to the design of liquid-metal-cooled reactor plants and high-temperature liquid-metal Rankine power systems.

In a recently completed project, the effect of rod displacement on heat transfer behavior was determined for in-line turbulent flow of mercury through an unbaffled rod bundle. The bundle consisted of thirteen 0.500-in.-diam. rods arranged in an equilateral pattern with a pitch : diameter ratio of 1.75. The central rod was displaced by different amounts in two directions (see Figures 3 and 5), and circumferential variations of both wall temperature and the local heat transfer coefficient were determined for the displaced rod and its six

neighbors. In Figures 3 to 5 the Nusselt number can be considered as a measure of the ability of the rod to transfer heat and the Peclet number (Pe) as a measure of the flow rate. The quantity $(t_w - t_b)$ is the difference between the surface and bulk temperatures, y is the distance between rods, q is the average surface heat flux, and k is the thermal conductivity. The rods were special high-flux electrical heaters, having sheaths of either copper, nickel, or stainless steel. All rods in the bundle were uniformly heated. Typical results are shown in the figures. It was found that when two rods come closer together, there can be a considerable reduction in their average heat transfer coefficients, with concomitant increases in their circumferential temperature variations. It was further found that, although the average coefficients of some rods in the central seven-rod group increased when the central rod moved off center, the over-all average coefficient of the seven rods decreased.

In another project, the phenomenon of incipient boiling in alkali metals was studied. Measurements were obtained of the superheat required to initiate boiling in the liquid metal as it flowed through a heated tube. Operating conditions prior to boiling (deactivation conditions) and conditions at the moment of boiling incipience were carefully controlled and documented so that, for the first time, it was possible to determine the functional dependence of incipient-boiling superheats on each of the three independent variables: deactivation pressure, deactivation temperature, and boiling pressure. A theoretical model was also developed for correlation of the results and for possible extrapolations to other fluids and other test conditions. Figure 6 shows some of the results reflecting the effect of *deactivation* pressure on the incipient superheat. It can be seen that increasing operating pressures prior to boiling can greatly *increase* the amount of superheat subsequently required to initiate boiling.

Two equipment-oriented projects were also pursued this year. The objectives were to develop (a) reliable, inexpensive heater rods capable of operating in liquid metals at temperatures up to $1500^\circ F$ and heat fluxes of 10^6 Btu/hr-ft², and (b) miniature void probes for local measurements of vapor bubbles in high-temperature liquid metals. These instruments are very much needed for both heat transfer and safety experiments associated with the LMFBF. Early results obtained in both projects have been promising.

Pulsed Research Reactor Project

Activity on the pulsed research reactor project has been concentrated on the preparation of analytical techniques for application to the design of the reactor system and on supporting development work in the areas of fuel technology and experimental physics.

Analytical techniques were developed to evaluate the unique thermal, mechanical, and physics problems associated with repetitive power pulsing of the reactor core. A two-dimensional finite element code that provides an iterative solution of thermomechanical stresses in axisymmetric bodies was put into operation, and the adaptation of a shock code to calculate the inertial stresses resulting from the rapid temperature transient during a pulse is in progress. These analytical techniques, together with data on the mechanical properties of the fuel and cladding material, will provide a basis for the design of the reactor core. The fuel development work was directed toward fatigue testing of 60 vol % UO_2 -Mo cermet fuel. Mechanical fatigue tests have been conducted at frequencies as high as 800 cps and ultrasonic fatigue tests have been performed at 14,000 cps on this fuel. Specimens of alternative fuel materials, such as U-10% Mo and U-Nb-Zr alloys and a U-Th dispersion, have been fabricated.

The CEPFR-1 critical assembly was constructed and operated. The critical mass was determined and measurements were made of the neutron lifetime and of the reactivity as a function of position of a reflector block moved past a bare face of the otherwise fully reflected core. Calculations were made of the critical mass, lifetime, and reactivity change for the CEPFR-1 core. The calculated values will be compared with the measured values of these parameters to provide an evaluation of the analytical procedures.

Engineering Assistance Group

The Engineering Assistance Group contributed more than 50,000 hr to the support of departmental programs during the year. Most of this effort was expended in the design and construction of experimental facilities for radiation processing, liquid-metal heat transfer, experimental reactor physics, and advanced reactor concepts. The group continued to contribute to various national technical committees and the *High-Temperature Liquid-Metal Technology Review*. A more detailed ac-

count of the group's activities may be found in the section on Technical Operations and Services under the heading "Mechanical Engineering."

RADIATION RESEARCH AND DEVELOPMENT

Basic Research

Excitation of Nitrogen Gas by Fission Fragments.

Luminescence produced in nitrogen gas in small segments of fission fragment tracks was studied with a pulse technique. The amount of the $C^3\pi_u$ state formed per unit distance, L^* , was measured over the entire length of the low-mass fragment group as a function of track length. The energy loss per unit distance, $-dE/dr$, can be approximated by L^* over the entire track length. The observation of light produced from the second positive group ($C^3\pi_u \rightarrow B^3\pi_g$) near the end of the track, despite a major change in the primary mode of energy deposition by the fission fragments, indicates that a more detailed theory of chemical production from the deposition of energy by heavy charged particles must be formulated for the region of nuclear elastic collisions which predominates at the end of the particles' range.

Radiolytic Formation and Decomposition of Ozone.

The formation of ozone from gaseous oxygen under γ -ray irradiation was studied for various dose rates from 7×10^3 to 8×10^6 rad hr^{-1} . $G(\text{O}_3)$ was found to be independent of dose rate at low total dose, but the steady-state concentration of ozone was dose-rate dependent. The data showed that there are several competing reaction mechanisms leading to a net forward formation rate of ozone and an ozone decomposition process. These results lead to a steady-state concentration which is found to be dose-rate dependent and sensitive to impurities. The evidence favors a negative-ion chain decomposition mode in a glass-encapsulated pure oxygen system, where $[\text{O}_3]_{ss} \propto I^{0.45 \pm 0.06}$ at 10°C .

Radiolysis of Adsorbed Gases. The γ radiolysis of CO_2 adsorbed on silica gel and on 5A and 13X Linde molecular sieves has been investigated. Little decomposition occurred on the sieves. With silica gel, the major product was CO along with much smaller yields of O_2 and H_2 . To account for the high CO yields observed, energy transfer must occur from the sorbent to the sorbate, which may involve electrons, positive holes, or excitations.

Similar studies with adsorbed nitrous oxide, N_2O , showed very large N_2 yields. These have been tentatively explained on the basis of a rapid migration of radiolytically formed electrons in the solid to the surface, where either they react with N_2O to yield N_2 and O^- or they become trapped. Both O^- and trapped electrons then react with holes.

Solid State Reactions. Preirradiated crystals of propionamide, *n*-butyramide, and isobutyramide absorb large quantities of gases such as oxygen, NO , SO_2 , and ethylene. With oxygen, the chief products are hydroperoxides. In isobutyramide, the hydroperoxide accounts for 95% of the absorbed oxygen, formed in yields as high as 8 mole %, by reaction with a kinetic chain length >100 . X-ray diffraction studies show that the reaction with oxygen is accompanied by a marked expansion of the lattice in the $\langle 100 \rangle$ direction.

In the case of NO , initially about three molecules are absorbed per radical. Subsequent evacuation leads to the formation of a different radical, whose spectrum is similar to that of an irradiated oxime. Readmission of NO results in an increased rate of radical decay, indicative of an expansion of the crystal lattice caused by the previously absorbed NO .

Radiation Chemical Processing

Concrete-Polymer Materials. Because of the highly interesting results obtained in preliminary experiments on the plastic impregnation of concrete, an expanded cooperative program between Brookhaven, the AEC, and the Bureau of Reclamation and the Office of Saline Water of the Department of the Interior has been undertaken. The program includes screening of potential monomers, determination of optimum methods of impregnation, depth of penetration studies, initiation of polymerization by both Co^{60} γ radiation and thermocatalytic techniques, determination of methods of producing continuous surface coatings, and studies of the effects of using various types of concrete. Fundamental studies are being made to determine the nature of the bond between the polymer and the concrete. The microstructure is being studied by optical and electron microscopy. A series of sample concrete specimens impregnated with methyl methacrylate (MMA) and with styrene has been evaluated by the Bureau of Reclamation. For a sample containing 6 wt % MMA, the compressive strength increased to a maximum value of 20,250 psi, >4 times that of

the unimpregnated concrete control specimen. The tensile strength increased to 1627 psi, water absorption decreased by 95%, and water permeability decreased to zero. The coefficient of expansion remained about the same; a sample has gone through 1700 freeze-thaw cycles, whereas a control failed at 490 cycles. Initial applications to be evaluated for this new material of construction include concrete pressure pipe for underground drain and water lines, construction of multistage flash distillation units, bridge decking, and underwater concrete structures.

Ethylene Homopolymerization and Copolymerization. Because this work has been successful to the extent that industrial firms have begun to undertake pilot-plant work on the radiation polymerization of ethylene based on the Brookhaven studies, this program has been slowed down. The small-scale flow experiment is being maintained, and an information exchange agreement is in effect between BNL and the Takasaki Laboratory of the Japan Atomic Energy Research Institute.

A study on the radiation-induced copolymerization of ethylene and SO_2 was completed. High molecular material was obtained, with SO_2 compositions ranging from 9 to 50 mole %.

Radiation Effects on Electrode Reactions. Current work in this area is focused on increasing the rate of reaction in electrochemical systems by means of Co^{60} γ and Sr^{90} β radiation. The current density at a given anodic oxygen overvoltage in the perchloric acid-platinum electrode cell has been shown to increase by an order of magnitude in a Co^{60} γ radiation field of 7×10^6 rads/hr.

Heterogeneous Radiation Chemistry. A study has been completed on the decomposition of CO_2 over semiconductor oxides and silver oxides in a flow system in a Co^{60} γ field. The maximum *G*-value for CO formation obtained was 8.5 over silver oxide at 100°C, 3 atm, and 6.6 Mrad/hr.

Heterogeneous effects are being studied in the nitrogen-oxygen system for the fixation of nitrogen and in the oxygen system for the synthesis of ozone.

Radiation Treatment of Acid Mine Drainage. An intensive study of the radiation-induced oxidation and removal of ferrous iron from limestone-neutralized acid mine water has been carried out. It has been found that although Co^{60} γ radiation can yield high rates of Fe^{++} removal with high chain *G*-values, high rates of removal can also be obtained by using vigorous stirring with a high mass ratio of limestone to mine drainage in the

absence of a radiation field. As a result it is difficult for a radiation process to compete. Work on this program has been curtailed.

Chemonuclear In-Pile Research Loop. The fabrication, installation, and assembly of all the equipment for the chemonuclear loop, including the in-pile section, has been completed at the Brookhaven Graphite Research Reactor. An operating manual and a safety manual have been completed. Initial flow tests with the out-of-pile section were made by using the Rateau gas-bearing compressor. The aluminum oxide bearing pads became scored and it was not possible to continue the tests with this compressor. The gas-bearing compressor (see Figure 7) fabricated by Mechanical Technology, Inc., and provided with a canned stator at BNL was tested for installation in the loop. This compressor is a unique piece of hardware for gas service up to 1000 psi. It is corrosion resistant and completely sealed to provide a lubricant-free atmosphere.

Radiation Engineering

High Intensity Radiation Development Laboratory.

1. Operations and services. Activated Co^{60} sources of the Mark II bonded type (96 strips, 590,000 Ci) and ultrahigh specific activity Mark I Co^{60} sources (26 strips, 464,000 Ci at up to 500 Ci/g) were received from the AEC's Savannah River Plant. Special loadings of rectangular Cs^{137} sources were designed to optimize dose uniformity in the Brookhaven portable cesium development irradiators (BPCDI); the sources (200,000 Ci) were received

Figure 7. Compressor developed to circulate process gas in the chemonuclear in-pile research loop. It has gas-lubricated ceramic bearings, and both stator and rotor are completely encased in stainless steel.

from ORNL. Standard rectangular Cs^{137} sources (114,000 Ci) were installed in the University of Florida research irradiator to replace Co^{60} ETR sources.

A new γ irradiation facility under construction in the HIRDL Annex is expected to be in full operation in July 1968. Dose rates ranging up to 2×10^7 R/hr will be available in 20 4-in.-i.d. tubes, each well shielded to prevent tube-to-tube interaction.

Loading-dock, control, and conveyor modifications were completed to allow high throughput, low labor, continuous package treatment in the HIRDL irradiation cell.

2. Irradiator design. Modification, loading, trailer-mounting, and calibration of a portable cesium irradiator (PCI) were accomplished. The food irradiation capabilities of the unit have since been demonstrated extensively throughout the country.

Two units of the BPCDI (see Figure 8) are being fabricated by a private contractor. After loading, testing, and calibration at BNL, the units will be lent by the US AEC to the governments of Argentina and India in support of their food irradiation programs. A Mark IV research irradiator is being readied for loan by the AEC to Pakistan. A shipboard irradiator, originally located aboard a Bureau of Commercial Fisheries research vessel, is under modification at HIRDL prior to being lent to Iceland. Each of the foreign-loan irradiators will be installed under the direction of HIRDL personnel.

Recent changes in source shipment regulations required the extensive modification of existing casks and irradiators. Based on preliminary unit reviews by ORNL, BNL is preparing final designs and arranging for modification and licensing of three shipboard irradiators, a PCI, two BPCDI's, a mobile γ irradiator (University of California), and a bulk grain irradiator (Savannah, Ga.)

3. Source development, testing, and calibration. Cladding failure of 48 Mark I Co^{60} sources during on-deck shipment to Hawaii was shown to be due to sea water leakage into the ETR casks; source shipment preparation methods have been completely revised to prevent recurrence.

A pilot lot of Mark III Co^{60} sources was produced and evaluated; activation is planned.

A prototype niobium-clad Co^{60} source was prepared and evaluated. Bond quality of the electrodeposited cladding was good. The electrode weld

had good penetration but there was some porosity and cracking. Development of this and other plated prototypes will continue.

The first lot of a newly developed Sr^{90} β source is being fabricated at ORNL. These sources, expected to be of high integrity, consist of SrSiO_3 microspheres matrixed in aluminum and clad in 10-mil-thick stainless steel.

Stress cracking was recently discovered along the internal corners of the standard Cs^{137} source envelopes; these cracks could propagate under severe thermal stress. Pending further testing (now under way), these sources are not recommended for service involving frequent periodic pool immersion and removal.

4. Dosimetry. A program was started for the evaluation of dosimetry and irradiator calibration practices at all facilities of the AEC's Division of Isotopes Development involved in research in support of FDA petitions.

Exploratory studies of an "effects" dosimeter for use in grain irradiation were conducted. The

water extracts of irradiated wheat showed color changes bearing a linear relationship to absorbed dose when examined in the 235 to 300-m μ range of a spectrophotometer.

The development and evaluation of the Perspex-HX dosimeter was completed; the dosimeter is usable over the dose range from 0.1 to 6 Mrad, with a standard error of $\pm 2\%$.

Preliminary development and evaluation of a new cellulose acetate butylate film dosimeter indicates that the system develops a radiation-induced optical absorption peak at 320 m μ which is proportional to dose from 1 to 55 Mrad to within $\pm 5\%$; thermal bleaching is negligible below 30°C.

A thermoluminescent dosimeter readout designed to operate in the food-processing dose range was designed, built, tested, and calibrated. The unit is inexpensive (<\$1000) and portable (30 lb); it is currently in use with the AEC portable cesium irradiator.

Figure 8. Model of the Brookhaven portable cesium development irradiator.

5. Dose distribution measurement and prediction.

The modification of existing codes and the development of new codes significantly increased the versatility and scope of prediction methods this year. FUDGE-4 is a modification to allow internal integration within the four zones defined by the corners of a rectangular source. FUDGE-5, DOWEL, and GOLF are major FUDGE modifications allowing dose prediction in specific shuffle-dwell irradiators. GIRD is a new code handling generalized shuffle-dwell situations. The RAD-K series consists of very general codes, based on the Los Alamos QAD series, which allow dose prediction in complicated cases involving multiple, varying intensity sources with multiple-component, laminated absorbers and targets.

Co^{60} and Cs^{137} plaque-source dose distributions were compared in heterogeneous target configurations. Improvements in dose uniformity of 4 to 8% attributable to γ -ray streaming were noted when heterogeneous arrays were compared with homogeneous targets.

6. Irradco support. At the request of the Division of Isotopes Development of the AEC, HIRDL personnel provided experimental and theoretical aid and consultation to Irradco, Inc., in the design of the AEC-supported commercial meat irradiator. The BNL effort encompassed such items as experimental verification of predicted dose distributions in canned meats irradiated in a specially built, multiposition, shuffle-dwell conveyor system; experimental determination of the relative efficiencies of various Co^{60} source types; and environmental component testing.

Radiation Chemical Reaction Engineering. Theoretical analyses in which different radiation attenuation laws, residence time distributions, and mixing states were taken into account have been made of the performance of several types of radiation chemical reactors. Nonchain and chain reactions were considered. In a generalization of these analyses, the conditions were formally stated for the existence of an effect of mixing on a homogeneous s th order ($s \geq 0$) reaction, and the direction of mixing effects was established.

Several experiments based on these analyses were undertaken. In one, the performance of an annular flow reactor with an axial line source of Sr^{90} - Y^{90} was studied. The reaction was the oxidation of ferrous sulfate, with the standard Fricke dosimeter solution used as reactant. Conversion was measured as a function of net flow rate in (a)

laminar flow in a once-through system, and (b) turbulent flow in a recirculating system. Theoretical prediction of the laminar flow data was shown to require a detailed knowledge of the dose rate and velocity distributions and of the diffusion coefficients of ferric ion and dissolved oxygen. The turbulent flow data, however, could be accurately predicted if only average velocity and dose rates were known. No knowledge of diffusion coefficients was required.

A similar study of a stirred-tank continuous reactor is in progress. A line source of Co^{60} γ radiation, located on the axis of the stirred tank, is used, and the reaction is again the ferrous sulfate oxidation. Conversion has been measured as a function of flow rate and agitator speed when a 950-Ci source is used in a 5-liter reactor. The data for conversions up to 60% are accurately predicted by a model in which complete micromixing and a knowledge of mean dose are assumed.

Measurements have been made of the rate of direct photopolymerization of methyl methacrylate in a partially illuminated stirred-batch reactor. The variations of the rate with stirrer speed and with fraction of reactor volume illuminated were in qualitative agreement with theory. A compounding of the effects of stirrer speed and viscosity led to considerable scatter in the data. Future experiments will be conducted in such a way as to eliminate the viscosity effect.

A pulsed γ source for use in kinetics experiments was mocked up and the wave form measured.

A series of calculations of molecular weight distributions in nonuniformly initiated addition polymerizations has been started. Steps in the mechanism are direct photoinitiation, propagation, termination by combination and disproportionation, and transfer to monomer and solvent. Computer programs have been written for batch and stirred-tank reactors.

A theoretical analysis of the thermal stability of batch photochemical and radiation chemical reactors has been carried out. For chain reactions with biradical termination, the Frank-Kamenetskii conductive theory of thermal ignition was extended to include the explicit spatial dependence arising from nonuniform photoinitiation. The extended theory and a normal mode analysis indicated that the nonuniform initiation, if anything, confers additional stability. Neglect of thermal convection resulted in conservative design criteria.

A number of calculations have been made related to the scale-up of processes for the radiation inactivation of contaminants in liquids or particulate materials. The cumulative dose distribution in a liquid treated in a laminar-flow tubular reactor with outside radiation has been calculated as a function of absorption coefficient. Equations have been derived describing the steady-state performance of recirculating systems in which bacterial contamination, growth, and radiation inactivation are occurring.

A quartz dosimeter sensitized by a large radiation dose is being developed for the measurement of the low doses encountered in the radiation treatment of flowing materials.

Atmospheric Diagnostics Program. A study has been initiated on tracing the fate of sulfur compounds in municipal atmospheres by measuring the S^{32}/S^{34} ratio in the compound. The use of the method assumes that variations in the background value of the ratio will be small in municipal atmospheres and that fuels containing sulfur with a S^{32}/S^{34} ratio significantly different from background are available. Most of the effort in the past year has been devoted to studying the technical feasibility of the method.

Figure 9. Air scoop for collecting atmospheric SO_2 samples being installed in airplane.

A filter-pack sampling system has been developed that efficiently extracts a large quantity of SO_2 from the atmosphere in a short time. The pack consists of an initial glass fiber filter to remove particulates and a secondary filter impregnated with potassium hydroxide to remove the gaseous SO_2 . Suction is supplied by a standard high-volume air sampler. Flow rates >1 m^3/min are achieved, and the system operates with an over-all collection efficiency of $>90\%$. Without losing efficiency, the filter paper can extract >500 mg of SO_2 , ≈ 200 times the amount required for analysis in the mass spectrometer.

A quantitative measure of the SO_2 is made either gravimetrically for large amounts or colorimetrically for small ones. Miniaturized equipment has been built and utilized to process 1-mg samples of SO_2 for the isotopic ratio measurements. The procedure includes extraction of the SO_2 from the filter paper, conversion to barium sulfate, reduction to hydrogen sulfide, conversion to silver sulfide, reduction to SO_2 , removal of CO_2 , and collection of the sample. Off-site services have been used for isotopic ratio measurements. An isotopic ratio mass spectrometer has been installed and is in the process of being shaken down.

The sampling system has been adapted for use in a light aircraft by replacement of the left-hand window assembly with an air inlet system (Figure 9) and minor alterations of the electrical power and interior fittings. The aircraft instrument package also permits direct recording of ambient SO_2 levels and temperature lapse rate measurements.

Several series of 6-hr samples have been obtained in New Haven, Conn., and in New York City at selected ground-level locations. Airborne samples of the airborne plumes from major sources in the two municipalities have also been obtained.

In another phase of the sampling program, the aircraft is being used to study the changes in the amounts and isotopic ratios of sulfur associated with particulates and in gaseous form in the plume from the Keystone power plant near Indiana, Pa. This work is coordinated with a major study of the Keystone plume conducted by the Public Health Service, and the exchange of data between the two research projects enhances the value of each.

The study at Brookhaven is a combined effort of the Radiation Division, the Analytical Services Group, and the Meteorology Group.

HOT LABORATORY DIVISION

Analytical and Physical Chemistry Research

The Ni(II) chloride-bromide system in acetonitrile was found to be a rare case in which mixed ligand complexes are formed to a lesser extent than would be expected from purely statistical considerations. A thermodynamic steric effect may exist in the aqueous iodide replacement of chloride in PtCl_6^- . A systematic study of mixed β -diketone complexes with divalent copper in solvent extraction showed that, when two strong or two weak chelates are present, the formation of a mixed ligand complex is predicted from statistics; however, a strong ligand coupled to a weak one enhances the stability of the mixed complex. Trivalent systems, studied with indium, showed the same general trend, although, since more combinations of ligands were possible, the systems were more complex. Spectrophotometric and solvent extraction data proved the existence of a mixed-metal complex containing In(III), Cr(III), and a

Figure 10. Computer-generated family of curves showing the optical absorption of one of the products of an electrochemical reaction (viewed through a transparent electrode) plotted against a parameter involving time, the bulk concentration of one of the species, and the reaction rate constant. This is an example of the application of a digital simulation technique to one of the many diffusion-kinetic boundary problems in electrochemistry. The calculations were made with a CDC 6600 computer driving an auxiliary Calcomp CRT plotter.

Figure 11. The fraction of the $\text{Te}^{129m}(\text{IV})$ product that is easily oxidized by air. Open symbols represent results of isomeric transition decay from $\text{Te}^{129m}(\text{IV})$, and filled symbols represent similar decay from $\text{Te}^{129m}(\text{VI})$. These and similar experiments indicate that the decay of Te^{129m} produces at least three hot atom species, their formation and/or reaction with the medium depending on pH. The formation of two (?) of these species depends on environment, contrary to the explosion theory for isomeric transitions, but the formation of the species (or group of species) that is subject to air oxidation is independent of the environment; the latter may be the part of the product formed by explosion of the molecule.

Figure 12. Excitation function for production of Co^{56} from bombardment of a nickel target with α particles. The way in which a reaction cross section varies with energy, as shown in the figure, provides both practical information needed for the production of pure radio-nuclides and fundamental data that lead to an understanding of nuclei and nuclear reactions.

hydroxycarboxylic acid. The electrochemical reduction of technetium was found to be a two-electron process in the presence of gelatin but otherwise a one-electron process; the interpretation of this is being considered. Computer simulation of hydrodynamic phenomena involved at the dropping-mercury and rotating-disk electrodes permitted theoretical treatment of a wide variety of electrochemical mechanisms. Computer-generated time-lapse displays of concentration-vs-distance profiles during electrolysis are proving valuable as a means of understanding the physical significance of formidable mathematical problems. Computer simulation was used to predict the time-dependent absorbance of orthotolidine in an evaluation of the oxidation kinetics of this compound; preliminary measurements agreed well with theory. (See Figure 10 for an example of this computer output.)

Nuclear and Radiochemistry Research

A study of the chemical effects of tellurium isomer decay provided evidence for at least three hot atom species in the isomer transition decay of Te^{129m} (Figure 11). A study of Szilard-Chalmers reactions induced in metallophthalocyanines by 14-MeV neutrons provided additional evidence for our interpretation that differences in primary retention of activated atoms are due to differences in spin changes between the starting material and the product. A computer program is being written in which a single-particle model with realistic

pairing corrections is used to calculate nuclide level densities. In an effort to correlate target differences, Monte Carlo evaporation calculations were performed for all $(\alpha, \alpha n)$ reactions for which excitation functions are reported. Excitation functions measured for ≤ 80 -MeV α -particle reactions on aluminum indicated that much of the Na^{24} formed must be coming from other than the $\text{Al}^{27}(\alpha, \text{Be}^7)\text{Na}^{24}$ reaction. (See also Figure 12.) Ternary fission is being studied by triple-coincidence counting equipment and by radiochemical search for Si^{32} and P^{32} in an old fuel plate. The pink and blue species of reduced technetium can be formed reproducibly, but the oxidation state of each is unknown. Cross-section measurements under way will test correlations that indicate that epithermal neutrons should be much better than thermal neutrons for making transplutonic nuclides.

Development of Isotopes for Medical Use

The uses of Tc^{99m} have been extended by the development of procedures to incorporate the isotope successfully into human serum albumin and calcium diethylenetriamine pentaacetic acid. Newly developed methods of altering the particle size of Tc^{99m} -labeled colloids by a factor of 10 are permitting investigation of the effect of particle size on the colloid distribution within the reticuloendothelial system. Prior to turning the production of Sr^{87m} over to private industry, the generator systems originally developed at Brookhaven were further improved significantly.

Applied Mathematics

The Applied Mathematics Department performs a dual role: it engages in its own research activities and provides services to the various other research programs of the Laboratory. Efforts in mathematics research, programming research, and computer research and development are aimed not only at making general contributions in these fields, but also at advancing Brookhaven's over-all program in the physical and life sciences. Operation of the Central Scientific Computing Facility (CSCF) and provision of related ancillary services, such as computer programming, constitute the Department's service responsibilities to the research program of the Laboratory.

COMPUTER OPERATIONS

The CSCF is operated by the Computer Operations Division of the Department. The facility provides large-scale general and special-purpose computational support to Brookhaven's over-all research program.

Central Scientific Computing Facility Equipment

CSCF operations were supported by three large-scale and two small-scale digital computers – two CDC 6600's, one IBM 7094, one CDC 924, and one IBM 1401, respectively. The two CDC 6600 computers were operated essentially as one system and, as such, constituted the principal computing system at the Laboratory. They were utilized for general-purpose scientific computation. The first was acquired in fiscal 1966; the second, late in fiscal 1967. Both were in operation throughout fiscal 1968. The delivery of a one-million-word extended core storage unit to be coupled to and shared by both CDC 6600's was scheduled for August 1968. During the year, features were installed on all four of the disk files to improve disk file access time.

The second major computer system consisted of the IBM 7094 computer supported peripherally by the IBM 1401. This system was devoted almost entirely to special-purpose computing, such as bubble chamber data processing. The small-scale CDC 924 computer was used as a stand-alone system for processing small special problems and as peripheral support for the large-scale computers.

A Calcomp plotter supplying off-line graphic output from the CDC 6600 computers was upgraded to provide increased resolution and program-mable increment size. Varied punch card equipment was available to support data and program preparation for all the computers.

Computer Scheduling and Usage

Figures 1 and 2 show usage by quarters for the combined CDC 6600's and the IBM 7094, respectively, during the past two years. Only productive time was included in the figures; time used for such operations as tape mounting, hardware maintenance, and training was excluded.

The two CDC 6600 computers were in operation a total of 31 shifts or more per week. One was operated for 21 shifts, i.e., around-the-clock, seven day per week. The other followed a schedule of two shifts per day, Monday through Friday, except when demand necessitated additional shifts. The beginning of operation of the second CDC 6600 is clearly evident in Figure 1. Field installation of speed-up features on disk files, engineering changes, high unscheduled hardware maintenance, and a concentration of holidays accounted for a dip in usage during the second quarter of the fiscal year.

The IBM 7094/1401 computer system was in operation for 21 shifts per week during the fiscal year. Use of the 7094 for on-line processing of bubble chamber data film expanded and was accompanied by a decrease in the use of the system for other scientific computing.

COMPUTER PROGRAMMING

The Department's Programming Division maintains the software systems for CSCF computers, updates and expands the facility's service program library, supplies programming services to the various research activities of the Laboratory, and conducts Laboratory-wide training in computer programming.

Software System Maintenance

During fiscal 1968, operation of the two CDC 6600 computers was under the control of the SCOPE 2.0 operating system. Substantial improve-

ments were made in this system, including the addition of a job-scheduler and a permanent production library. Both were produced by Department personnel. The job-scheduler, which was completed, debugged, and placed in operation during the year, was instituted to maximize the use of machine resources, as well as provide quick turn-around for short time-limit jobs. The scheduler (1) assigns job priorities on the basis of time limits and memory requirements, (2) periodically upgrades priorities so that older jobs in equivalent priority groups are processed first, (3) inhibits the start of jobs whose input/output requirements cannot be met, (4) selects alternative jobs when highest priority jobs cannot be accommodated in available memory space, (5) orders the jobs in the output queue as a function of print file length and length of time the jobs have been in the system, (6) allows new classes of jobs to be handled easily, and (7) provides means for operator override.

The production library, called PROLIBE, was created to minimize the manual operations required for frequently used CDC 6600 computer user production programs, libraries, data sets, and

source programs. Disk file memory was utilized to store this information internally and make it available to the computer without repeated input operations. Use of PROLIBE resulted in reductions in the wear on user card decks, the work load on input equipment and operating staff, and the use of magnetic tapes.

Programmer Service

The programmer-of-the-day consultation service for users was continued at the CSCF throughout the year. The Computer Newsletters, which inform users of important changes in Computer Center procedures, software systems, hardware acquisition, and planning, continue to be published by the Division. Typical examples of work done under this service have been included below.

Irradiation Dosage for Food Preservation

A program was written for a study conducted by the Nuclear Engineering Department and Isotopes Incorporated on the long-term preservation of food through irradiation from various sources. The program was prepared for the CDC 6600 and

Figure 1. Histogram of CDC 6600 computer usage at Brookhaven National Laboratory.

Figure 2. Histogram of IBM 7094 computer usage at Brookhaven National Laboratory.

was designed to simulate the passage of food packages along a zigzag track passing over the front and rear faces of a rectangular array of radiation sources. Computation of the total radiation received by a given package after a partial traverse or after one or more complete traverses of the track was included. Facilities were provided to enable the track length and configuration, the incremental steps along the track, and the strength and composition of the radiation sources to be specified in various ways by input parameters. Provisions were incorporated in the program for the use of an off-line Calcomp plotter to prepare output graphs of cumulative dosage as a function of package position along the track.

Plant Chamber Data Processing

Computer programs were prepared to aid the Ecology Division of the Biology Department in processing data emanating from plant chamber stations that monitor the effects of radiation on the metabolism of a forest community. Each station was constructed to measure solar radiation, carbon dioxide produced by plant metabolic processes, and other related factors for a small adjacent region and transmit the data to a central station for recording on paper tape. CDC 924 and CDC 6600 computer programs were written to read the data from paper tape, apply various correction equations to the measurements, and tabulate maxima, minima, and averages for such items as corrected absolute temperature, radiation intensity, and absolute carbon dioxide for specific periods. Means were provided in the CDC 6600 program for recording selected quantities on a magnetic tape in a form suitable for plotting on a Calcomp incremental plotter.

Particle Track Scanning

A program to detect and summarize spark chamber track information photographed on 35-mm film was written for the CDC 924 computer. The photographs were produced during experiments at the Alternating Gradient Synchrotron (AGS) pertaining to the measurement of momentum change in μ mesons accelerated through magnetic fields. The program utilized the CRT film scanner attached to the CDC 924 computer. Each frame combined 2 views of each of 4 adjacent spark chambers. Mirrors were used to combine these 8 views and 2 views of matrices of lights. One of these light matrices provided a frame number that

uniquely identified the associated photographic frame. The other gave coded information on conditions existing at the time of a spark passage. The scanning rate in terms of frames per hour was estimated to be about 100 times faster than a scan of comparable accuracy done by a trained operator using manually operated special scanning equipment.

COMPUTER RESEARCH AND DEVELOPMENT

The Systems Engineering Group of the Department continued to work on design and development projects to provide extensive on-line facilities for the CDC 6600 computer system. The principal project was the development and construction of prototype hardware for BROOKNET, the Brookhaven Digital Data Communications Network (see Figure 3). Furthermore, research into the use of computers as adjuncts to research facilities resulted in the invention of a promising new system for digitizing tracks on bubble chamber photographs.

BROOKNET

BROOKNET was conceived as a means of coping with the diverse and often conflicting computing requirements of the many different research activities at the Laboratory. It was created to accommodate demands for quick real-time, on-line, large-scale processing from remote locations, as well as enormous local and remote batch processing. Specialized requirements, such as collecting data at slow rates during the course of experiments, were left to the smaller remote computers which, when necessary, could communicate through BROOKNET with the large-scale central computers. Hence, BROOKNET provides communication between the computers at the CSCF and any other computer at the Laboratory for which on-line support from the CSCF is required. The design of BROOKNET was based on the requirements that (a) no modification to the network be necessary in order to add additional computers of widely varying types, (b) no additional software or software modifications be needed for the connection of additional computers, (c) the network be sufficiently modular to allow relocation and reconfiguration of equipment without redesign or disruption of service, and (d) the data transmission rates be near computer memory speeds.

Implementation of BROOKNET continued during the year. Cables for the network were laid underground between the CSCF and five on-site loca-

tions: the AGS control room, the AGS Experimental Area, the Chemistry Building, the High Flux Beam Research Reactor Building, and the Cyclotron Building. All these multiconductor coaxial cables were tested and made ready for connection to terminal equipment.

The design and construction of equipment for the first medium-distance branch of BROOKNET were completed. This "local" branch, which can accommodate distances up to 500 ft, will connect

Figure 3. Diagram showing major components of typical local and remote branches of BROOKNET.

a Sigma-7 computer installed in the Physics Building with the CDC 6600 computers of the contiguous CSCF. The Sigma-7 computer is connected on line to bubble-chamber photograph scanning tables and a number of keyboard consoles equipped with displays. Scanning data will be collected by the Sigma-7 and transmitted along with programs to the CSCF for processing. Results of CDC 6600 computation will be returned to the Sigma-7 for output operations.

Construction of the equipment for the first long-distance branch of BROOKNET, which will service the computers in a building remote from the CSCF, was less than a month from completion by year end. The equipment consists of

- (1) a local control unit to control the branch from the CDC 6600 computer data channel,
- (2) data transmission equipment and an inter-building, multiconductor coaxial cable up to 5000 ft in length,
- (3) a remote multiplexer to provide access to the data transmission equipment for as many as eight computers, and
- (4) a remote computer adapter which will be located adjacent to the remote computer and within 1000 ft of the remote multiplexer.

Remote Input-Output Station

Construction of the hardware for interconnecting the purchased units of a prototype remote input-output station and for connecting the station to BROOKNET is expected to be completed by August. The breakstate multiplexer and the magnetic tape controller were built from designs developed for the Input-Output Supervisory System (IOSS). The controllers for the line printer and the remote adapter were based on new designs.

Figure 4. Testing hardware and software operations of the Input/Output Supervisory System. The computer engineer on the left is examining signal levels of control circuitry. The programmer seated at the console of the PDP-8 computer is checking out the operation of software.

Input-Output Supervisory System

Existing large-scale computer systems require many operators and a great deal of machine-to-operator, operator-to-operator, and operator-to-machine communication. The IOSS was developed to minimize these communications and the attendant errors. Additional capabilities were incorporated to enable the IOSS to perform computer usage accounting functions and supply computer operations management information. The equipment consists of a PDP-8 computer connected to a CDC 6600 computer input-output channel via BROOKNET, and the following units connected to the PDP-8:

- (a) a breakstate multiplexer to enable the necessary equipment to be attached to the PDP-8,
- (b) a teletype multiplexer and seven Model 33 teletype units to provide hard-copy computer-to-operator and operator-to-computer communications,
- (c) a magnetic-tape label reader to permit automatic tape assignment and verification of correct mounting, and
- (d) a magnetic tape unit for data logging and program storage.

Construction of the basic IOSS was completed and the individual units were checked out before being connected to the CDC 6600 computer. The system was installed in the CSCF and connected to the CDC 6600. On-line testing began shortly after installation (see Figure 4). As soon as dual 6600 monitoring and tape assignment on all magnetic tape units have been accomplished and the CDC 6600 operating system has been modified to take advantage of IOSS hardware with minimum system degradation, the IOSS will become highly useful in the complex of computer activities.

Direct Access to Extended Core Storage

Development was started on a buffer to enable BROOKNET users to have direct access to the extended core storage to be shared by the two CDC 6600 computers. High-speed current mode logic and monolithic memory elements were selected rather than thin film memories because the monolithic memory elements proved to be less expensive and more reliable for data-burst buffering and multiplexing.

Flying Image Digitizer

Research into the use of computers as adjuncts to research facilities resulted in the invention, by a member of the Department, of a flying image system for digitizing the tracks on bubble chamber photographs. Called FID (flying image digitizer), it is simple in structure, yet accurate and very fast. Devices have been in use for some time to scan and measure the tracks on bubble-chamber photographs and convert the information into a digital form that can be accepted by computers for analysis. However, the rate at which current

digitizing equipment can measure photographs is still substantially behind the exposure rate at the bubble chambers.

FID represents an advance in speed and definition over existing equipment. This was evident from a comparison of FID with the Mark II Hough-Powell digitizer (HPD) now in use at Brookhaven. The total time to digitize three views on FID, including both normal and orthogonal scans for each 80-in. bubble chamber photograph, will be 2 sec compared with 35 sec on the Mark II HPD. The elementary film area read by a single FID photodetector is a $10\text{-}\mu$ square compared with a $15\text{-}\mu$ -diam flying spot on the Mark II.

The device will consist of a linear array of a large number of photosensitive detectors on which several optical systems project illuminated images of each view (Figure 5). The three segments, designated views 1, 2, and 3, are identical. In each segment there are two separate units of optics, one for normal scan (scan lines orthogonal to the film edge) and the other for orthogonal scan (scan lines parallel to the film edge). The configurations of projection lenses (L, L') and rotating mirrors (RM, RM'), combined with a set of plane mirrors fixed in space (M, M', M'', M'''), are made in such a way that each of the six rotating mirrors moves the projected sharp image of one of the corresponding pictures in an identical manner across the detector array. The actual direction of scanning on the film differs, however, by 90° between normal and orthogonal scans. Digitizing of a frame by 1000 scan lines can be executed in a single sweep of the image if 1000 detectors are arranged on the detector array. Coordinates of bubble centers are digitized by measuring the distance that the image moves across the array; the superposed image of a precision grating which moves in exactly the same manner as the picture image is used as a reference.

Figure 5. Schematic of flying image digitizer.

The mirrors, which rotate with a constant angular velocity of $\frac{1}{4}$ revolution/sec, have four rectangular faces. The phase relations of rotation among the six units are chosen in such a way that after one frame is finished, the image of the next frame on one of the other units begins to fall upon the detector array. Six different frames (or a triad in two modes) are thus digitized successively in one cycle, that is, in 1 sec.

PROGRAMMING RESEARCH

Programming research activities of the Department continued to be related to and coordinated with the work in mathematics research and computer research and development. Major efforts were devoted to the development of software for BROOKNET and the CDC 6600 computer system. Other efforts were concerned with algebraic manipulation, interactive computing, and computer graphics.

BROOKNET Control Software

Development of software for BROOKNET continued throughout the year. The design of a general-purpose software system was completed and implementation began. This system was designed to accept up to 64 remote terminals of various types by using areas in CDC 6600 central memory, with one peripheral processor for control and another for data transmission. The ability to handle computers as different as the Sigma-7 and the PDP-8 under the same logical communications structure was included in the design. An intermediate version of the general-purpose BROOKNET software for the CDC 6600 was prepared. This version does not include those functions of the general-purpose system that interact with the CDC 6600 operating system, but does possess all the features required for communication between the CDC 6600 and remote computers. This course was taken to permit debugging to proceed at the time of the first remote connection to BROOKNET, regardless of the CDC 6600 operating system in use at that time. Partial debugging of the interim system was performed prior to the availability of hardware, through the use of techniques to simulate the connection between two computers. PDP-8 computer control programs, which permit the use of this type of computer on BROOKNET, were completed and partially debugged by using simulation techniques, as mentioned above. The branch of

BROOKNET serving the Chemistry Building, which utilizes a PDP-8 computer, will make use of these programs.

Dual 6600 Operating System

Research continued on the design of an efficient operating system for a central computing facility equipment configuration based on two CDC 6600 computers sharing the use of a one-million-word extended core storage unit. An initial version of the system was designed to permit completion by the delivery date for the extended core storage hardware and, at the same time, perform most of the desired operations. The system consists of central computer programs that monitor and control the over-all flow of computational programs and data. The control programs also handle the automatic scheduling of computational programs and the allocation of computer time, memory, and input-output equipment. Specifications were completed for the modification of existing software and the design of new software for integration of the extended core storage into the system. The system was designed to transfer programs and data to and from the extended core storage and central memory of either CDC 6600 computer (at the rate of 10 million words/sec). This specific approach was necessary because, although the extended core storage can hold any information a CDC 6600's central memory can, instructions or commands stored in the extended core storage cannot be executed until brought into central memory. The optimal manner of performing these functions was analyzed by using, among other data, statistical measurements of current CDC 6600 operations, and a comparison was made with the results of simulation studies conducted for the same purpose. Initial debugging of the system began late in the year.

Algebraic Manipulation by Computers

A list-processing language, designated FOREST, was developed and implemented for the CDC 6600 computer. FOREST was written to aid in the development of algebraic manipulation routines. It was designed to optimize processing of tree-structured lists of symbols as well as numbers, and to be accessible from the FORTRAN language. A package of programs for performing polynomial algebra was written, with use of FOREST, to test new concepts. The results were highly satisfactory, and these routines provided the basis on which to build more complex routines for algebraic manipulation.

Interactive Computing

An equipment configuration for a remote station with graphic facilities was determined in cooperation with the Systems Engineering Group. The configuration included a small computer, a keyboard, a card reader, a CRT display unit, a light pen, and a printer. Equipment has been ordered for a prototype station to support further studies in both interactive computing and computer graphics.

MATHEMATICS RESEARCH

The general aim of the mathematics research activity is to make broad general contributions to the field of mathematics, in addition to supporting and advancing the scientific program at Brookhaven. Some of the work done in 1968 had direct bearing on other research activities at the Laboratory and hence provided fruitful interaction between the mathematics research staff and other scientists at Brookhaven. Work done in this area also complemented the service functions of the Applied Mathematics Department.

Partial Differential Equations

Solution of general partial differential equations involving time and a finite region of space, which include the mathematical problems of nuclear research, is a major goal of applied mathematics. Techniques that use high-speed digital computers to obtain valid numerical approximations to these solutions are of great importance; in fact, the numbers obtained in this way are generally used as the solution to these problems. A method was developed, with the help of the abstract Wiener-Hopf technique, for solving those problems for which the region in space is symmetric, so that only one variable need be considered. Sufficient conditions for the solution of difference equations in several space variables were also found. In addition, the Wiener-Hopf technique itself was improved. As a result of these achievements, efficient computer techniques can now be applied to a wide class of complicated physical problems with substantial reductions in computer processing time.

Neutron Transport Theory

The mathematical theory of a pulse of neutrons passing through a medium was reinvestigated. Contrary to anticipation, it was found that the

qualitative nature of the behavior of the time delay of this pulse does not depend on certain details of the rate of collision of the neutrons with the substance of the medium through which they are passing. This result provides additional insight into neutron transport theory and may turn out to be useful in improving the accuracy of formulas used in reactor design theory.

Plane Wave Propagation in Kinetic Theory

New mathematical results were obtained bearing upon the extent of validity of the Chapman-Enskog method for approximating solutions to the Boltzmann equation in rarified gas dynamics. A specific criterion was found which is dependent upon the nature of the force law between the gas molecules and on whether the motion of the molecules is due to some initial configuration or to steady disturbance at some fixed location in space. This criterion is an extension of some previously obtained results for so-called model equations which are useful mathematical approximations to the full Boltzmann equations (different Boltzmann equations are obtained depending on the nature of the intermolecular force law). The equations of neutron transport theory are a specific category of Boltzmann equations, and any additional insight into the equations of the kinetic theory of gases can, in general, be carried over into neutron transport theory. These results can also be of use in reactor design.

Combinatorial Analysis

Problems falling under the heading of combinatorial analysis occur in all branches of science, from biology to physics, as well as in the social sciences. Loosely speaking, these problems involve counting of some type, such as determining the number of elements in a collection that share each of a given set of attributes. These elements may be enzymes, molecules, or people. Research in this field at Brookhaven yielded some new methods for handling these problems. The methods are concerned with certain types of counting, in particular, the systematic use of the structure of a set to solve counting problems on that set. Methods of this type have already found application to statistical mechanics in cluster star expansion problems. The results obtained at Brookhaven, in addition to being used to solve problems in physics and other branches of science, are expected to be an aid in putting difficult problems into a format that will

enable other existing methods to be used for their solution.

Theory of Integral Equations

Integral equations of the so-called Wiener-Hopf type occur in a great many different contexts of applied physics and engineering, ranging from the behavior of neutrons in reactors to the design of electronic equipment. These equations have received extensive study, but until recently many basic questions remained unanswered. For example, how can the number of independent solutions to such an equation be determined in an effective manner? A method for constructing complete normalized sets of solutions to such equations was found at Brookhaven as a side result of an investigation of a more abstract mathematical problem. It was found that Wiener-Hopf equations, as well as several other widely occurring integral equations, can be analyzed by a method that springs from the study of certain pairs of non-commutative operators.

A Quantum Mechanical Model of Reactive Scattering

A quantum mechanical model of reactive scattering was formulated and studied. This research was helpful in increasing theoretical understanding of basic chemical reactions. Early results of these studies challenged conclusions of 25 years' standing. Initial experiments with reacting particles of equal mass were carried out. By means of a two-dimensional Helmholtz equation, associated with certain boundary conditions and asymptotic forms, and the use of Bessel functions, the problem was reduced to a set of linear equations which can be solved numerically with the aid of a high-speed computer. The solution required accurate and rapid calculation of certain special functions that often arise in problems of mathematical physics. A computer program satisfactory for the initial investigation was written.

Approximation Methods of Known Accuracy

In the AEC's basic physical research program, problems often arise that, although too difficult to solve by direct calculation, can be related mathematically to simple, solvable problems. The procedure of calculating successive corrections to the solution of a simple problem in order to reduce the difference between its answer and that of the

real problem is called perturbation theory. However, perturbation theory suffers from the deficiency that the accuracy obtained after a number of corrections have been computed is not readily ascertainable and, indeed, in some cases the higher corrections may be farther from the correct answer than the earlier ones were. Methods were developed at Brookhaven which allow upper and lower limits to be placed on the correct answer based on the perturbation theory corrections and a careful analysis of the problem under consideration. These limits were shown to quickly approach the correct answer as more perturbation corrections are included in the calculation. This procedure, which is applicable to many problems, was successfully applied to several problems involving the properties of magnets and of liquids and gases.

A Method for Reducing Products of γ -Matrices

The well-known Dirac equation is the means of formally describing the principal constituent particles of atomic nuclei, that is, protons and neutrons (or, for that matter, any spin- $\frac{1}{2}$ particle). The Dirac equation introduces algebraic elements called γ -matrices whose properties have been well studied. All calculations for high energy processes involving such particles require extensive manipulation of these matrices, which usually is the main complication in these calculations. Work during fiscal 1968 showed how certain classes of expression made up of these γ -matrices, whose reduction in the past required pages of algebra, can be reduced in one line. This was the initial result of a more ambitious program aimed at formally simplifying the procedure of writing down a reduced expression corresponding to any Feynman diagram.

Graph Theory

Theoretical work in the use of digital computers in graph theory was initiated during the year, and emphasis was placed on the study of certain local coloration properties of maximal planar graphs. An improved version was prepared of a computer program, originally written (for the CDC 1604 computer) at Technische Hochschule, Hanover, West Germany. The program has made possible the accumulation of important information, otherwise unobtainable, which has great bearing on the four-color problem.

LIFE
SCIENCES

Biology

The present report provides brief summaries of projects conducted by members of the scientific staff of the Biology Department. Research is in progress at all levels of biological study, from ecology to biophysics, and is related to the development of basic information that will lead to improved understanding of the manner in which ionizing radiations affect living things and in which these effects may be used constructively for specific biological purposes. Insofar as the problems examined permit, emphasis is given to the molecular approach and mechanistic rather than descriptive studies are stressed. Thus, a common theme throughout is the correlation of macromolecular structure with biological organization and function.

A number of the projects derive immediate benefit from the availability of research reactors and particle accelerators at Brookhaven, while more specialized irradiation sources are utilized directly within the Biology complex. A noteworthy feature of the program is the number of projects that relate to studies with plants. In addition to extensive field and greenhouse facilities, specialized growth-chamber space is available for precise manipulation of the environments in which plants are maintained.

The Biology Department maintains a number of collaborative programs with visiting scientists from other institutions, both in this country and abroad, and sponsors the Brookhaven Symposia in Biology, a series of annual conferences at the Laboratory on topics of current interest in biological research. The topic of this year's symposium is *Structure, Function, and Evolution in Proteins*. The proceedings will appear as the 21st volume in the series.

PLANT SCIENCES

Ecology

Ecosystems are living units of environment with boundaries definable in various ways but often set by obvious physiognomic, geographical, or biological criteria. Thus a watershed, island, community of plants, city, or even the world may be considered an ecosystem. The concept of an

ecosystem includes not only the organisms in an area but also the physical, chemical, and historical factors affecting the organisms. Natural ecosystems, some of which include man, are products of biological evolution, i.e., they contain plant and animal communities adapted for survival under the special conditions prevalent within a given system. Considerable evidence indicates that natural ecosystems in maturity, or "climax," contain arrays of plants and animals that allow most efficient long-term use of resources necessary for life.

Modern concepts of ecosystems are based on a detailed knowledge of structure. To obtain such knowledge for a system as complex as the forest now under study is difficult. A significant contribution of the work being done here is the perfection of "dimension analysis," a system for measuring complex attributes of vegetation such as total weight, areas of leaves, branches, and stems, and annual increments of growth. The analysis has been generalized for any vegetation and includes computer programming of data. It has provided details about the Brookhaven forest that allow an evaluation of production within this ecosystem. "Production" reflects energy fixed by the plant community during photosynthesis and is conventionally expressed as weight of dry organic material. The difference between the energy fixed, "gross production," and that used in autotrophic (i.e., plant) respiration is the "net primary production" represented by new organic material. The difference between gross production and the energy used in plant respiration plus that of heterotrophs ranging from herbivores to decay organisms is the "net ecosystem production." As yet, only the net primary and net ecosystem production and total respiration are directly determinable. The values obtained for these parameters (expressed as grams of dry organic matter per square meter per year) and for those obtained by difference are as follows:

Net primary production (1124) = gross production (2546) – autotrophic respiration (1422).

Net ecosystem production (442) = gross production (2546) – autotrophic plus heterotrophic respiration (2104).

The ratio *total respiration/gross production* reflects the progression of succession toward climax. At climax the ratio would be unity. The ratio for the forest, 0.83, in agreement with other evidence, indicates a late successional stage. This is the first quantitative estimate for a terrestrial ecosystem.

Modification of Damage Caused by Ethyl Methanesulfonate in Maize

The use of chemical agents for the production of mutations in plants is complicated because a given agent may bring about damage not necessarily related to mutagenic activity. Therefore a search is being made for ways to reduce such damage without affecting mutagenic activity. Since damage by ethyl methanesulfonate (EMS) is thought to be caused mainly by water-soluble decomposition products, water-extraction of seeds treated with the mutagen was tested as a way to reduce such damage. The treatment is feasible in maize, since the seed tolerates soaking in water and drying. When seeds were soaked in water for 4 to 6 days after treatment with EMS, dried, and then planted, development was normal. When the drying was omitted, development was abnormal. Apparently, water extraction and subsequent drying are required for reduction of damage caused by EMS.

Photoperiodism and Photomorphogenesis

Photoperiodism and leaf and stem growth can be controlled by red and far-red light, probably through the chromoprotein photoreceptor phytochrome. Yet most studies fail to find an intelligible relationship between spectrophotometric assays of Pfr (the far-red-absorbing and presumably active form of phytochrome) and physiological response. Most recently, pea seedlings were pretreated in two ways that resulted in the same tissue morphology and a fourfold difference in total phytochrome content. Nevertheless, exposure to light with conversion of, say, 20% of the total phytochrome to Pfr caused the same growth response in each lot of tissue, even though any given conversion actually represents four times as much Pfr in the one tissue as in the other. Either the response depends directly on the ratio Pfr/total phytochrome – a conclusion unacceptable on certain other grounds – or spectrophotometry and physiology have again failed to agree.

Phytochrome effects on growth and development may take hours or days, but phytochrome

action is rapid in the nyctinasty ("sleep-movement," or leaflet-closing in darkness) of many plants. Nyctinasty is fast if darkness immediately follows red light, and slow if it follows far-red; the difference is detectable within minutes. Recent experiments on the location of light sensitivity in this response show that it is confined to the pulvini (swollen leaflet bases) and is seemingly independent of any hormonal or other translocatable effect. The system has great promise for the study of phytochrome action.

Figure 1. Localized phytochrome response in a portion (pinna) of the compound leaf of *Albizzia julibrissin*, the silk tree. Just before being darkened, the entire pinna was given red light, and then alternate pairs of leaflets received 2 min of far-red light, which caused them to close more slowly in darkness. This and similar experiments indicate that even adjacent pairs of leaflets respond independently to light or darkness. Each leaflet is about $\frac{1}{2}$ in. long.

Figure 2. Structure of phycoerythrobilin. The pigment was isolated from red algae, in which it functions as a photoreceptor in photosynthesis. The structure of phycoerythrobilin (b) and that of phycocyanobilin (a), a pigment from blue algae, differ only in the side-chain at position 8. Both substances are related to pigments found in bile.

Bile Pigments of Plants and Animals

Bile pigments are widely distributed in plants and animals. In plants they function as photoreceptors. The red bile pigment, phycoerythrobilin, was prepared from algae. Its structure was determined by nuclear magnetic resonance and mass spectroscopy. The structure of phycoerythrobilin is the same as that of biliviolin except for substitution of an ethylidene for a vinyl group and is isomeric with that of the blue bile pigment of algae, phycocyanobilin. Phylogenetic studies of phycoerythrobilin revealed that the structure was invariant in blue-green, red, and cryptomonad algae. The defensive pigment of the sea hare, *Aplysia*, was compared with phycoerythrobilin and found to be primarily a specific monomethyl ester of phycoerythrobilin. The sea hare obviously derives its defensive pigment from the red algae, the principal diet of the animal.

Protochlorophyll Holochrome

The terminal reaction in chlorophyll biosynthesis is photoreduction of protochlorophyll. A phototransformable protochlorophyll holochrome can be extracted from dark-grown bean leaves.

Improved procedures for isolation and purification have provided a highly purified preparation of the holochrome. The holochrome exists as aggregates with molecular weights of about 550,000 and 300,000 and protochlorophyll-to-protein ratios of 2:1 and 1:1, respectively. Amino acid analysis and subunit structure indicate that the holochrome is not, as thought earlier, identical with ribulose diphosphate carboxylase.

The Mechanisms of Electron Transport and Energy Conversion in Isolated Chloroplasts

Illuminated spinach chloroplasts accomplish the oxidation of water and reduction of pyridine nucleotides by a series of electron transfers involving two photochemical and several thermal steps. Energy conversion resulting in adenosine triphosphate synthesis (photophosphorylation) accompanies electron flow. The objective of the present work is to determine how chloroplast components interact during electron transfer and the location of the phosphorylation sites. Cytochrome *b*-559 was identified as a component of the photochemical system II and was found to be as abundant as cytochrome *b*₆ and twice as abundant as cytochrome *f*, on a heme basis. Two classes of uncouplers of phosphorylation were distinguished on the basis of ability to promote rapid oxidation of cytochrome *b*-559 and inhibit the P 518 absorbance shift induced by light. The findings are explicable in terms of two different uncoupling mechanisms and close linkage of P 518 and cytochrome *b*-559 with the phosphorylation site. Chloride ion is necessary for electron flow from photosystem II. The ion was found to function somewhere between the oxidation of water and photosystem II. Absence of the ion leads to diminished chlorophyll fluorescence. Kinetic evidence indicates that electrons can flow around photosystem II in a cycle and that chloride deficiency, presumably by causing accumulation of photochemically generated oxidant, enhances the rate of this cyclic process.

Cell Proliferation and Metabolism in Tissue

The ability to establish experimentally a proliferative and a stationary state in excised root tips makes possible the study of cellular recovery after exposure to ionizing irradiation. The stationary state is characterized by the absence of cell division and nuclear deoxyribonucleic acid (DNA) synthesis and a low level of metabolism; the pro-

liferative state by cell division, nuclear DNA synthesis, and a high level of metabolism. In the stationary state, cells are in G_1 , the phase of the mitotic cycle that precedes DNA synthesis (S), or in the G_2 state that follows it; in the proliferative state they are in all phases of the cycle – G_1 , S , G_2 , and mitosis.

When cells in the stationary state are irradiated and kept in this state for 24 hr, recovery occurs, i.e., G_1 cells initiate DNA synthesis and G_2 cells enter mitosis without delay, in the same manner as unirradiated controls. Although G_1 and G_2 cells both require 24 hr for full recovery, the rates differ. G_1 cells recover at a constant rate while G_2 cells recover at a variable rate during the postirradiation stationary state. These and other experiments suggest that recovery of G_1 and G_2 cells involves the same site of damage and similar but not equivalent recovery systems.

Experimental control of DNA synthesis and cell division also makes it possible to regulate the number of cells going from G_1 to S . This was achieved by providing G_1 cells with just enough carbohydrate for initiation of DNA synthesis and entrance into S . The degree to which DNA synthesis was completed by former G_1 cells was controlled by the length of time carbohydrate was made available. The data obtained support the hypothesis that the mitotic cycle is characterized by phasic metabolic demands and that a higher metabolic rate obtains during S than during either G_1 or G_2 .

Fine Structure of Endodermal Cells During Development of the Casparian Strip

The Casparian strip of the root is formed by the deposition of impervious materials in the radial walls of endodermal cells. The strip provides a barrier to free passage of salts from soil water to the transpiration stream of the xylem and thus subjects the entrance of these salts to selective control of the endodermal protoplasts. The radial walls of the endodermal cells of *Limonium sinuatum* (a sea lavender) are at first undifferentiated. The earliest cytological change noted in the development of the Casparian strip is an inpocketing of the plasma membrane adjacent to the presumptive site of the strip. This kind of activity of the plasma membrane is common in cells with rapidly growing walls, and in this case is accompanied by an increase in density of the wall material adjacent to the modified membrane. The membrane then adheres to the developing strip. In the fully devel-

oped Casparian strip the outer dense proteinaceous layer of the plasma membrane is tightly fused to the strip. The attachment of adjacent endodermal cells to this strip forms a zone that is functionally similar to the "tight junction" found between certain animal cells. In the true "tight junction" the outer layers of the plasma membranes of adjacent cells fuse, while in these plant cells the impervious Casparian strip intervenes between the membranes.

Figure 3. Development of Casparian strip along radial wall of endodermis. (a) Inpocketing of plasma membrane (arrows) as deposition of lignin and suberin begins. $\times 19,000$. (b) Adhesion of plasma membrane of one cell to strip (arrows). Deposition has not begun in adjacent cell. $\times 60,000$. (c) Portion of fully developed strip with outer dense layer of membrane (arrow) fused to strip. $\times 107,000$.

Relationship Between the Responses of Maize to X-Rays and Neutrons Applied Over a Wide Range of Doses

A problem of continuing interest in radiobiology is to determine why radiations that differ in pattern of energy distribution in exposed tissue elicit different degrees of response for equal energy absorption. One measure of this difference in response, designated relative biological effectiveness (RBE), is the ratio of the doses of two radiations of different quality required to produce the same effect. Usually no single RBE value holds throughout a range of absorbed doses. Maize plants grown from Yg_2/Yg_2 seeds that received various absorbed doses of fission neutrons (N) or of 250-kVp x rays (X) were scored for radiation damage on the basis of nine criteria. The kinds of damage and corresponding responses considered were sublethal genetic effects (Yg_2 leaf sectors), gamete lethality (pollen sterility and reduced seed set), growth retardation due to somatic cell death (reduction in plant height, survival, and emergence), and complete cessation of cell division ("reversal" of emergence and plant height). With increasing dose and consequent progression in damage, the RBE, i.e., X/N for the same response, decreased steadily from 76 to 3.5. However, a logarithmic plot of X vs N for each criterion gave points that fitted a straight line for which the equation is $\log N = -2.6 + 1.95 \log X$. This simple power function, which spans four orders of magnitude of neutron dose, is amenable to the following straightforward explanation: (1) the responses measured have a common cause, chromosome breakage and genetic loss; (2) increases in somatic growth inhibition and gamete lethality are attributable and directly proportional to increase in genetic damage; (3) neutron-induced damage increases linearly with dose, x-ray-induced damage with the approximate square (slope = 1.95) of the dose; and (4) the relationship between the responses to the radiations is maintained throughout development from seed embryo to mature plant.

Radiosensitivity of Woody Plants

Because trees, as indicated earlier, are generally more radiosensitive than other plants, special attention was given to woody species in a recent study. Survival curves were established for 12 species of woody angiosperms (deciduous trees or

Figure 4. Radiosensitivity of woody plants. Based on relationships observed in many plants, the radiosensitivity of others can be predicted from the interphase chromosome volume (ICV). The figure indicates the distribution of observed ICV's and predicted sensitivities (LD_{50} 's) for a series of gymnosperms (evergreens) and angiosperms (deciduous trees and shrubs). The former species tend to have large ICV's and low LD_{50} 's (high sensitivity); the latter tend to have small ICV's and high LD_{50} 's. The LD_{50} 's for most gymnosperms do not exceed 2000 kR. For comparable conditions of irradiation, the sensitivity of the gymnosperms is about the same as that for mammals.

shrubs) and 16 gymnosperms (evergreens) exposed to γ radiation. The LD_{50} 's ranged from 460 to 1203 R (average, 826 ± 54 R) for the gymnosperms and from 477 to 17,500 R for the angiosperms (the range was 3000 to 8000 R for 8 of the 12 species). As found previously for other end points, the LD_{50} 's were inversely related to the interphase chromosome volumes (ICV). This relationship allows prediction of an LD_{50} for species of known ICV. For such prediction, the ICV's for about 200 additional woody species were determined. The range of ICV's was wide, the gymnosperms tending to have large and the angiosperms relatively small ICV's, with little overlap between the groups. For about half the 120 gymnosperms studied the predicted LD_{50} was ≤ 1 kR. The LD_{50} 's for only five exceeded 2 kR, and these are of minor economic value. The predicted LD_{50} 's for the 95 angiosperms examined were relatively high, between 2 and 8 kR for 80%. The observed and predicted LD_{50} 's indicated are for a 16-hr period of exposure. Shorter exposure (as common in mammalian radiation studies) would lower the LD_{50} 's appreciably. Thus the radiosensitivity of many species of gymnosperms is in the same range as that of mammals.

Radiation Mutation Program

The facilities at Brookhaven National Laboratory are used to irradiate biological material for scientists in this and other countries. About half the irradiations are made for plant breeders who employ the irradiated material in the search for improved varieties; the remainder are for individuals concerned with various aspects of radiation biology. Use of this service is illustrated by the following. Biological control of some species of insects has been achieved through sexual sterilization effected by appropriate x- or γ -irradiation. Attempts to produce sexually sterile boll weevils have met with little success because of the high mortality associated with exposure to even partially sterilizing doses of x or γ rays. The mortality reflects arrest of cell regeneration in the midgut. Testing of the suitability of thermal neutron irradiation for production of sexually sterile weevils is being carried out by J.F. Nordland and W. Klassen (USDA Metabolism and Radiation Research Laboratory, Fargo, North Dakota) and R.W. Briggs (Brookhaven National Laboratory). Neutrons seem to cause less damage to the gut than any other form of radiation.

Chlorophyll-Proteins From Green Photosynthetic Bacteria and Blue-Green Algae

In shape the chlorophyll-protein from *Chloropseudomonas ethylicum* is thought to approximate a prolate ellipsoid, 88 Å long and 65 Å in diameter, on the basis of the molecular volume (1.93×10^5 Å³), and crystalline packing considerations described previously. Chlorophyll-protein crystals show a dichroic ratio of 1:1.2 at 603 nm (orange band of bacteriochlorophyll) and a dichroic ratio of 1.3 at 809 nm (far-red band). A radial distribution of chromophore sites within each macromolecule is consistent with these values. A chlorophyll *a*-protein (m.w. $\approx 1.5 \times 10^5$) was extracted from the blue-green alga, *Phormidium luridum*, with the help of anionic detergent. The amino acid composition of this new complex indicates that it is related to the bacterial chlorophyll-protein and the chlorophyll *a*-protein from Swiss chard (*Beta vulgaris*). All three complexes appear to consist of 4 subunits, each with 5 chlorophylls, 15 proline residues, and 20 isoleucine residues. The isoleucine residues may play a key role in binding the phytyl chain of the chlorophyll molecule to the protein.

Figure 5. Model of bacteriochlorophyll-protein. The complex is thought to have an ≈ 6 -Å outer layer consisting of polar amino acid residues. Eight of the 20 chlorophylls are shown as discs (Mg-porphyrin rings) with tails (phytyl chains.)

GENERAL PHYSIOLOGY

Oral Glucose Tolerance Test

During a glucose tolerance test, insulin secretion increases promptly. The additional secretion increases uptake of blood glucose by muscle and fat tissue, one factor that limits the rise in blood glucose concentration. The extra insulin also decreases the rate at which liver releases new glucose to blood and increases uptake of blood glucose by liver. Two forms of glucose tolerance test are in use; glucose is administered intravenously in one and orally in the other. Equal amounts of glucose cause greater insulin secretion in the oral than in the intravenous test. In the oral test, incoming glucose passes first through the liver. In present work glucose metabolism during the oral test was evaluated quantitatively in the normal dog. The oral glucose load (1 g/kg body weight) was labeled with glucose- U -C¹⁴ for measurement of the influx. Glucose-6-C¹⁴ was continuously infused in trace amount for measurement of the release of new glucose by liver. During the 3-hr test period about $\frac{3}{4}$ of the orally administered material appeared in the circulating blood despite the initial pass through gut and liver. The release of new glucose by liver

decreased from the control value of 0.63 g/kg to 0.34 g/kg, while the uptake of blood glucose by tissue increased from 0.63 g/kg to 1.03 g/kg. Thus the oral test, as shown earlier for the intravenous test, measures not just the "disposition of the administered glucose load" but a combination of this and a decrease in glucose release by liver.

Heterogeneity of Normal Hemoglobin

In animals generally, blood probably contains more than one normal hemoglobin. The significance of this is not clear. In present work, which may lead to an assessment of significance, duck hemoglobin was found to be separable into two forms. The relative amounts of each were about the same in all animals tested; thus the hemo-

globins presumably are normal constituents of blood. The rates of formation of the hemoglobins by erythrocytes *in vitro* differ and are not simple functions of the relative amounts of the pigments. The difference in rates applies to both heme and globin. The relative amounts of the two hemoglobins were not affected notably by changes in the erythrocyte population brought about by x-irradiation of the animal or manipulation of blood *in vitro*. However, the rates of formation were affected somewhat.

Material Transfer Across Biological Barriers

The large pressure differences between the internal fluids of higher plants and their environment is associated in an unknown way with respiratory and photosynthetic activity. If the premises of a general theory of material transfer through biological barriers are correct, it should be possible to construct model systems in which the mechanical pressure difference between two liquid phases is proportional to the rate of an enzyme-catalyzed chemical reaction occurring in one phase. Such a model system has been constructed. Urea is hydrolyzed by the enzyme urease in one phase of the system, while in the other it is added at a constant rate. A pressure difference across the cellophane membrane separating the phases equivalent to a column of water 15 ft high results from ammonia production at a rate of the order of 10 μ mole/min. The quantitative data obtained for the model system experimentally verify some consequences of the general theory of material transfer and supply evidence for a physical-chemical explanation of the observed pressure differences in plants.

Radiation-Induced Aging

Long after irradiation, effects appear in animals that closely resemble the natural aging process. Study of somatic mutations has indicated a close parallel between chromosome stability and both natural and radiation-induced aging. Based on this parallel, a somatic mutation theory of aging was proposed. Although evidence for the theory accumulated steadily, some findings were not consistent with the simple theory. A composite theory was thus developed which proposes that aging is due not to a single chance event such as a mutation, but to a series of such improbable events.

Figure 6. Glucose metabolism during the oral glucose tolerance test. The data in the figure illustrate change in metabolism induced by oral ingestion of 1 g glucose/kg body weight in the fasted dog. Most of the ingested material appears in blood (3). The influx of glucose leads to an increase in blood glucose (4), which induces additional insulin secretion (7). This leads to an increase in the uptake of blood glucose by tissues (2) and a decrease in output of new glucose by liver (1). The estimations of glucose influx (3), uptake (2), and release (1) are based on the determinations of plasma glucose specific activity (5 and 6).

This theory correlates much of the information on aging and predicts an average of about five events as necessary for induction of a degenerative disease.

It has been generally thought that nondividing mammalian cells accumulate faults with increase in age, whereas dividing cells, e.g., those in bone marrow, eliminate faults through cell selection. To test this supposition a method was developed for scoring chromosome aberrations in the rapidly dividing cells of bone marrow. By use of the method, the frequency of aberration was found to increase steadily with age and to be as high as 25% in old mice. Irradiation increases the accumulation of aberrations. Although final interpretation of the findings is not obvious, the necessity for revision of earlier notions about chromosome stability is apparent.

Comparison of different inbred strains of mice has indicated a direct relation between chromosome stability and longevity. Conceivably, the same holds for individual mice. To test this possibility, a technique was developed that allows estimation of chromosome aberrations in liver cells and of life-span in the same animal. The findings obtained by use of this procedure indicate that within a strain of animals chromosome stability and longevity are not related. This reinforces the concept that the variability of life-span within a population reflects a series of chance events (composite theory) and that individual differences associated with any one event, e.g., chromosome stability, are not large enough to determine mortality.

Environmental Stress and Radiation Injury

Earlier work suggests that an increase in the mortality of rats exposed to whole-body x-irradiation occurs when the animals are kept in the cold after being irradiated. This increase in mortality is thought to reflect an increase in metabolic rate induced by the exposure to cold. However, there is little information indicating how exposure to cold modifies the sequelae of radiation injury. In the present work rats exposed to fission neutrons (300 rads) or x rays (600 rads) were examined for effects of maintenance at a low environmental temperature (2°C). According to the findings, the life expectancy for irradiated rats kept in the cold is shorter than that for those kept at a usual temperature (25°C). Curiously, the incidence of neo-

plasms in irradiated rats kept at 2°C is less than that in those kept at 25°C. The exposure to cold did not increase resistance to the growth of transplanted tumors. Maintenance in the cold for 40 days before irradiation and subsequent return to a usual environment increased the life expectancy in animals exposed to x rays but did not increase it in those exposed to neutrons. While the stress represented by exposure to cold clearly affects responses to irradiation, the physiological mechanisms involved remain obscure.

MOLECULAR BIOLOGY

Protein Structure

Interactions between amino acid side-chains largely determine the folding of the polypeptide backbone in enzymes and define patterns of specificity and mechanism of action. Understanding of the manner in which stable conformations of side-chains develop in particular regions of an enzyme is of considerable theoretical and practical interest and requires a variety of approaches: chemical modification of side-chains, physical or chemical perturbation of side-chain interactions at the enzyme surface, and examination of variation in structure among enzymes of the same specificity but different biological sources. Interpretation provided by the modification approach is illustrated by work designed to determine stereochemical effects produced by reaction of aryl fluorides with amino groups in bovine pancreatic ribonuclease A, particularly the groups in positions 7 and 41, which are located close to the anion-binding site in the active center of the enzyme. Introduction of a bulky substituent at the surface of the molecule perturbs the structure locally. The effect of such perturbation and its dependence on the structure of the reagent employed yields insight into forces responsible for stabilizing the surface conformation. Earlier modification studies indicated that introduction of a dinitrophenyl (DNP) group at position 41 is accompanied by structural rearrangement. This view was substantiated by recent x-ray crystallographic analysis of 41-DNP ribonuclease S (conducted by Wyckoff and his colleagues at Yale), which shows that the DNP group is in fact folded into the surface in a direction away from the active center. The properties of 41-DNP ribonuclease A were found consistent

with this structure: binding of 3'-cytidylate was about 100 times weaker in the modified protein than in ribonuclease A; lack of free rotation of the DNP group manifested itself in a Cotton effect at 350 m μ ; and the DNP group was not fully accessible to ethylene glycol molecules in the solvent environment. The inactivation of ribonuclease that accompanies substitution at lysine-41 is postulated from these observations to be due primarily to removal of the positive charge contributed by that residue. Kinetic and product distribution studies with the reagents 4-sulfonyloxy-2-nitrofluorobenzene and 4-fluoro-3-nitrophenyltrimethyl ammonium chloride reveal that the charge on the reagent markedly influences the velocity of reaction at lysine-41, but not its selective destruction of activity.

Regulation of Gene Function

Cells of the bacterial species *Diplococcus pneumoniae* utilize maltose or related sugars as the sole source of energy. They contain distinct transport mechanisms, or permeases, for maltose, maltotriose, and maltotetraose and two enzymes, amylomaltase and phosphorylase, used in catabolism of all three sugars. Mutant cells deficient in one or more of the functions mediated by the permeases and enzymes were analyzed genetically by means of DNA-mediated transformation. According to the analysis, the genes for the permeases are not linked to each other. One, however, is loosely linked to the closely linked genes for amylomaltase and phosphorylase. This complex of genes is loosely linked to a regulatory gene that controls synthesis of all components of the system of permeases and enzymes. Normally, the levels of these components increase when maltose is present. Certain mutations in the regulatory gene prevent this induction; others render the cells constitutive, i.e., allow synthesis of high levels of all components without induction. Cells carrying both types of mutation are constitutive, as are cells in which the regulatory gene has been deleted. These results are consistent with a scheme of negative control in which the normal regulatory gene produces a repressor that, in the absence of inducer, impedes synthesis of all the components of the system. Novel features of the present work are the demonstration of negative control in coordinate induction of unlinked genes and the extension of findings for enteric bacteria to an unrelated species.

Structure and Function of Enzymes

Enzymes have two important characteristics, specificity and the ability to promote chemical change. The structural features of trypsin responsible for these properties, i.e., the identity and interrelationship of the amino acid residues at the active center, are being sought. Residues related to catalysis, namely histidine-46 and serine-183, were identified earlier. Some suggestion of the special relationship between these residues comes from the observation that substratelike alkylating agents hit one or the other site in the catalytic region. The site attacked depends upon the chain length of the reagent. Thus, chloromethyl ketones derived from lysine or arginine alkylate the histidine, whereas shorter agents, e.g., *p*-guanidinophenacyl bromide and *p*-amidinophenacyl bromide, inactivate trypsin by ether formation at the serine. Therefore the serine is closer than the histidine to the fixed point in the specificity site responsible for binding the positive charge characteristic of substrates. This unidentified feature of the specificity site is believed to be a particular carboxyl group the description of which has become the goal of chemical modification studies. Isoxazolium salts, which react with carboxyl groups, were selected for study in the hope that the positive charge of the reagent might lead to substratelike attachment to trypsin and subsequent modification of the specificity-site carboxylic acid. Conditions were found which resulted in limited reaction associated with considerable reduction of enzymic activity. Thus the approach may prove successful.

The Intracellular Development of Small Bacteriophages

When bacteriophage ϕ X174 infects its host, *Escherichia coli*, its single-stranded DNA is first converted to a double-stranded replicative form (RF). This conversion is followed by intracellular development which includes synthesis of several physically distinguishable forms of RF and then formation of single-stranded DNA and phage maturation. Another small phage, ϕ R, follows the same replicative pattern in *E. coli*, but in *Salmonella typhimurium* its development is markedly restricted. In the present study, host-induced changes in one double-stranded replicative intermediate were found which can account for modification of the replicative process in *Salmo-*

nella. The replicative intermediate observed, RF-II, is circular in form. One of the two strands of the DNA is a closed ring; the other bears a single break. During ϕ R development in *Salmonella*, a major fraction of the RF becomes fragmented, i.e., has more than the single break characteristic of RF-II DNA. That restricted synthesis of mature ϕ R phage occurs in *S. typhimurium* is consistent with recent indications that normal RF-II is a precursor of progeny, single-stranded DNA. ϕ R and ϕ X174 are similar in physical properties such as size, buoyant density, and DNA content, but exhibit differences in protein subunit structure, antigenic behavior, and plaque morphology which are of potential usefulness in studies of recombination. For use in such studies, a number of mutants of ϕ R were isolated. Mutants of ϕ X174 had been obtained earlier.

Histidinol Dehydrogenase of *Salmonella*

Analysis of multiple amino acid replacements in bacterial enzymes resulting from compensating double frame-shift mutations offers a unique opportunity to study both the nature of the genetic code and structure-function relationships in proteins. In work bearing on such analysis, 60 revertants, or double frame-shift mutants, were isolated from one mutant in the *hisD* gene of *S. typhimurium*. In the revertants, the *hisD*-encoded enzyme, histidinol dehydrogenase, displays activities ranging from undetectable to near that of the wild type. Most of the enzymes are so labile that isolation by conventional methods is precluded. However, purification of the two most active revertant enzyme types was achieved at 25°C, where the revertant enzymes, in contrast to the wild type, are considerably more stable than at 4°. This reversal in temperature stability suggests generation or exposure of a hydrophobic region in the double mutant enzymes. Maps of tryptic peptides from each double mutant enzyme show an extra peptide, i.e., one not apparent on the map for wild-type enzyme. The extra peptides are identical in amino acid composition except for an additional residue in one. Maps of trypsin plus chymotrypsin digests reveal the extra revertant peptides but again no corresponding wild-type peptide. However, the wild-type peptide, as well as the extra revertant peptide, is evident on maps of chymotryptic digests. Isolation of the pertinent peptides is in progress on a large scale. Sequence analyses

of these peptides will establish the frame-shift amino acid substitutions in the revertant enzymes.

Conformational Studies of Macromolecules by X-Ray and Neutron Diffraction

When myoglobin binds xenon, an anesthetic agent, the rates of carbon monoxide and hydroxide binding are altered. To determine how such alterations in rate come about, an x-ray crystallographic analysis of the xenon-hydroxide myoglobin complex was undertaken. The analysis, now nearing completion, indicates a number of structural changes. These mainly involve breakage of hydrogen bonds and resultant relocation of side-chains and small shifts in whole helical segments. There is some indication of a shift in location of two functional histidines. Further assessment of these small structural perturbations will require application of a real-space Fourier refinement technique. Preliminary test of the applicability of neutron diffraction to the study of protein structure indicates that myoglobin crystals do not deteriorate under neutron bombardment and produce small diffraction peaks. However, considerable improvement of the neutron collimator and monochromator system will be required before it can be determined whether the anomalous dispersion associated with neutron diffraction will facilitate the phase determination required for structural description of proteins and whether the hydrogen atoms in proteins can be located by use of this technique.

Genetic and Physical Characterization of T7 Bacteriophage

One component of T7, a small, virulent bacteriophage which infects *E. coli*, is a single molecule of double-stranded DNA (m.w., 26×10^6). The system represented by the phage and its host is one of the simplest available for study of macromolecular interactions necessary to biological function. Particular aspects of the present study of this system are a genetic characterization of the phage directed toward elucidation of the infection and phage assembly and a physical characterization of the purified phage. For the genetic characterization, some 250 "amber" mutants were isolated and placed in 35 complementation groups. A DNA molecule the size of T7 would be expected to code for about 50 proteins of average size; i.e., about 50 complementation groups of mutants are anticipated. Representative mutants from about

half of the 35 groups were placed on a linear genetic map. Further mapping is in progress. At least three mutants are defective in DNA synthesis, seven in assembly of phage particles, and a number in control of protein synthesis. Physical description of the phage by use of gel electrophoresis reveals the presence of 6 to 8 protein components. Treatment of intact phage with alkali or solutions of low ionic strength gives rise to partially degraded particles. Isolation and characterization of such particles, as well as the partially assembled phage found in mutants, are under way. From a knowledge of the structure of these materials it may be possible to define the assembly of intact phage.

Pancreatic Enzymes

The acinar cells of pancreas elaborate two polypeptides that inhibit the proteolytic enzyme, trypsin, and many of the "trypsinlike" enzymes that participate in blood clotting and release of the hypotensive peptides, bradykinin and kallidin. The biological role of the inhibitors is obscure. Conceivably they protect the pancreas against autodigestion. To obtain information bearing on the role, inhibitors of the cow and pig are being compared with respect to intracellular distribution, chemical structure, and mechanism of interaction with proteolytic enzymes. Considerable progress has been made in the last two phases of the study. Forty-five of the 56 amino acid residues comprising the bovine inhibitor found in pancreatic juice were assigned to unique positions in the peptide chain. Treatment of the inhibitor with small amounts of trypsin at pH 2.7 results in hydrolysis of one peptide bond, that between arginine-18 and isoleucine-19. The modified material inhibits trypsin. Treatment of the modified material with carboxypeptidase B splits off arginine-18. The resultant polypeptide is inactive. The porcine inhibitor, when compared with that from the cow, exhibits a minimum of nine amino acid substitutions concentrated in a limited region of the polypeptide chain. In the porcine inhibitor, position 18 is not occupied by arginine. The corresponding amino acid probably is lysine. This difference at position 18 may be responsible for the difference

between the activities of these inhibitors toward the enzymes plasmin and thrombin.

Determination of Biological Structure by X-Ray Diffraction

A rather general method for covalent attachment of a series of heavy atom compounds to a given protein, to yield an isomorphous set of labeled protein crystals, was developed in association with D.E. Koshland, Jr. (University of California, Berkeley). The method is being applied to chymotrypsin and subtilisin, the structures of which are under investigation here. To facilitate collection of data, a diffractometer was interfaced to a computer which performs closed-loop control of data collection and on-line analysis. The system permits unattended collection of some 4000 protein reflections per 24-hr day.

Pneumococcal C-Polysaccharide

The C-polysaccharide of pneumococcus is of particular interest since it reacts with and precipitates the C-reactive protein found in some pathological but not in normal human sera. Earlier work showed that the C-polysaccharide consists of two main covalently cross-linked polymeric substances, one a mucopeptide, the other a polymer of N-acetylgalactosamine phosphate. The latter is the major serological determinant of C-polysaccharide and reacts with human C-reactive protein. Current work is concerned with a nitrogen-containing component of C-polysaccharide other than the polymers indicated and a fragment of the polysaccharide that contains muramic acid linked to part of the N-acetylgalactosamine phosphate polymer by a phosphodiester bond. The structure of the nitrogen-containing component is unknown. Preliminary evidence suggests that the two known components of the polysaccharide are cross-linked through a phosphodiester bond of muramic acid 6-phosphate. C-polysaccharide reisolated from its complex with the C-reactive protein in human sera lacks the amino acids originally present in the polysaccharide. Definition of the enzyme, an amidase, responsible for this loss of amino acids is under way.

Medical Research

In developing its research program, the Medical Department has several responsibilities. It has the broad responsibility to advance medical knowledge and the more specific responsibility to advance understanding of the effects of ionizing radiations in man. Some of the investigations are directed toward beneficial applications of these radiations and toward improvement of measures to prevent or counteract their detrimental effects. Other investigations are centered on elucidation of disease states and development of improved methods of diagnosis and therapy. Investigations in these two areas complement each other, since the study of radiation effects contributes to the understanding of diseases, and vice versa, yet the pace of progress in both is controlled by the advances in knowledge of the normal biological processes of man.

A great influence on these advances is the rapid development of new techniques for the examination of structures and mechanisms at the molecular as well as the subcellular and biochemical levels of organization. Information revealed through these techniques and with the aid of such instruments as the electron microscope dictates re-examination of such medical and biological phenomena at even finer levels of organization. Findings from such investigations present the Department with the additional responsibility to exploit them for clinical applications.

The diversified talents and extensive facilities uniquely concentrated at Brookhaven provide the Department with unusual advantages for pursuing its objectives. Its broadly based program incorporates the experience and skill not only of those devoted to research in the field of medicine but of many from the various disciplines in other Departments and from collaborating institutions. The interchange of ideas, information, facilities, and services is essential for the staff to keep abreast of the new developments that have medical implications, and within the framework of the program opportunities are limited only by the scope of the vision and interest of the individual investigator.

Thus, in its role of service to Associated Universities, Inc., to the Atomic Energy Commission, and to the medical community, the Department's pri-

mary responsibility is the assemblage of talented scientists capable of elucidating biological phenomena at the finest level of organization and experienced physicians capable of relating these researches to clinical studies.

Specific examples of research under way are given in the following pages. The report is not comprehensive, and the reader may obtain additional information from publications of the Department.

EFFECTS OF RADIATION

Cellular Basis for Strain Differences in Radioresistance of Mice

Different strains of mice, tested in groups of the same age and sex, may require quite different doses of x rays to cause death of half the animals within 30 days. It is of interest to attempt to account quantitatively for such strain differences in terms of the kinetics of cellular repopulation of the blood-forming system.

A 50%-lethal irradiation reduces immediately, by several orders of magnitude, the number of primitive hemopoietic cells (stem cells) capable of reinitiating blood formation. The few surviving stem cells begin to divide and differentiate soon after irradiation, but it is some time before functional mature cells are again supplied to the blood at a significant rate. During the interim, the numbers of the various types of functional blood cells decrease, the shortest-lived granulocytes falling rapidly to a very low level, and the longest-lived red cells decreasing only gradually. The principal cause of death in the 30-day period after irradiation is infection contracted during the time of profound granulocyte depression. The infecting bacteria are of types carried normally by the mice, and normally nonpathogenic. Thus survival depends on the balance struck between the radioresistance of the hemopoietic system and susceptibility of the tissues after irradiation to invasion by the bacteria carried.

A mathematical model has been formulated in which the 50%-lethal dose of radiation is expressed in terms of parameters that measure (1) the original number of stem cells per animal, (2)

the radioresistance of the stem cells (two parameters), (3) the capacity per stem cell to proliferate and supply mature granulocytes, and (4) the requirement of mature granulocytes for survival. This last is related to the susceptibility of the animal to bacterial invasion and the relative virulence of the bacteria.

Experiments are in progress to ascertain the relative importance of differences in these various parameters in accounting for the observed difference in lethal dose between two selected strains, one quite radiosensitive, designated BALB/c, and the other relatively resistant, a hybrid of the strains C57BL and C3H. Mice of the two types will be housed together to equalize their flora, and then various determinations will be made on them which will lead to estimates of the above-named parameters.

Californium-252 as an Interstitial Neutron Source

Californium-252 undergoes spontaneous fission with the emission of fast neutrons as well as associated γ rays and α particles. Because of their low oxygen enhancement ratio, fast neutrons have been considered for use in clinical radiotherapy. Californium needles have been designed which are suitable for interstitial implantation in a manner similar to that for radium needles. Ten needles of 4.0 μg each have been obtained for dosimetry and radiobiological experiments.

The dose distribution due to the γ rays and fast neutrons has been determined. At the ranges of interest in tissue the falloff in dose is primarily due to the inverse square law. About 1 μg Cf^{252} is equivalent to 1 mg radium.

Cultures of HeLa cells are being irradiated to determine the relative biological effect (RBE) and oxygen enhancement ratio of Cf^{252} in comparison with those for radium. Following this, studies of skin response and clinical trials will be made.

Influence of Radiation Quality and Dose Rate on Early and Late Effects in Cell Renewal Systems

A high RBE has been demonstrated to cause visual lens opacification in small mammals exposed to fission neutrons. Further sequential studies are being carried out at this Laboratory with use of (1) radiation exposures of mice to "fast" neutrons at selected discrete energy levels, (2) highly refined serial examination and minute opacity "scoring" techniques, and (3) a data analysis method developed by H.H. Rossi (Columbia

University) which circumvents the limitations inherent in the use of an arbitrary (although reproducible) scale of opacity size.

The results of three experiments have been compiled and analyzed. These studies included exposures over broad ranges of dose for 250-kVp x rays and 0.43-MeV neutrons, and doses covering somewhat shorter spans for neutrons of 1.8 and 14 MeV. The RBE of 0.43-MeV neutrons compared with that of 250-kVp x rays has been found to be dose dependent; it is about 10 when the dose is 500 rads of x rays, but rises with increasing steepness to 60 as the dose falls to 35 rads of x rays. Neutrons of 1.8 MeV were found to be about one-half as effective as those of 0.43 MeV. Neutrons of 14 MeV, however, yielded an almost constant RBE of 6 when compared with 250-kVp x rays. Preliminary results of a current experiment in which doses as low as 0.02 rad are used indicate continuity with the RBE relations described above.

Figure 1. A dwarfed boy in the exposed group of Marshallese, shown (left) before thyroid hormone therapy and (right) after 6 months of thyroid hormone therapy and spurt in growth.

Medical Studies of the People of the Marshall Islands Accidentally Exposed to Fallout

Annual medical surveys of the Marshall Islanders who were accidentally exposed to radioactive fallout in 1954 are conducted by the Medical Department of Brookhaven National Laboratory in conjunction with the Trust Territory of the Pacific Islands. The development of thyroid abnormalities has been the most important of the later effects resulting from the exposure of the Marshallese. A total of 21 of the original 82 people exposed (67 now living) have developed abnormalities of the thyroid gland, including two cases of marked hypothyroidism. Of the 19 children receiving the larger exposures at <10 years of age, 17, or 90%, have developed thyroid abnormalities. Thyroid surgery in 11 cases has revealed benign adenomatous goiters in all but one case, an adult who had a thyroid cancer with localized metastases. During the 1968 survey, examination of the exposed people revealed four additional cases that had not responded satisfactorily to treatment. These people will be brought to the Laboratory for further evaluation and possible surgery. Growth impairment in exposed children, believed to be related to thyroid damage, has been favorably influenced by thyroid hormone therapy.

CLINICAL AND METABOLIC STUDIES

L-Dopa and Parkinsonism

Large doses (4 to 8 g/day) of L-dopa have now been administered to 25 patients with Parkinsonism, including postencephalitic, idiopathic, and possibly arteriosclerotic cases of widely varying severity, for periods of 4 to 20 months. Each case showed amelioration, ranging from modest (but sometimes lifesaving) to dramatic. In exceedingly severe cases, particularly those with prior neurosurgery, beneficial effects were less striking. The symptoms responded in a fixed sequence: inability to move, difficulty in urination, slow motion, rigidity, and tremor, when present, were diminished or abolished in that order. The mechanism of alleviation is under study.

These therapeutic effects appear to be linked to at least one of the discrete neurochemical changes, namely the diminution of dopamine in the corpus striatum of the Parkinsonian brain. The evidence supporting this hypothesis is as follows. (1) Dose-

dependent increases in excretion of dopamine and homovanillic acid were induced by L-dopa. (2) L-Dopa has induced vomiting, as has the activator of dopaminergic receptors, apomorphine. (3) L-Dopa has induced involuntary gnawing, as have injections of dopamine into the caudate nucleus of the rat. This raises the question of whether the characteristic immobility, rigidity, and tremor of Parkinsonism might not signal that dopamine was diminished in the neostriatum of the brain rather than indicate what kind of injury the brain had suffered to begin with. If so, it may become possible to detect and correct, at the bedside, low brain dopamine levels in diseases other than Parkinsonism, without waiting until sufficient numbers of brains have been analyzed for dopamine.

Figure 2. A Parkinsonian patient (left) before treatment with L-dopa and (right) during treatment.

Studies on Hypertension

In man, the evidence that implicates dietary salt as an etiological factor is circumstantial, but in the rat it is direct and unequivocal. In both species, however, genetic factors probably play the decisive role in determining whether or not an individual will develop hypertension after exposure to salt.

For some years the interaction of genetic and environmental factors (primarily salt) that lead to the development of hypertension has been studied at BNL. In the course of these studies, by the process of selective inbreeding, two strains of rats have been developed, one of which rapidly and predictably develops fatal hypertension from the same salt intake to which the other does not re-

Figure 3. Effect of transient high salt diet on blood pressure of rats of the sensitive strain 12 months (max) after salt feeding was started, compared with the effects of constant low and high salt diets.

spond. In this experimental situation, it is very clear that the genetic background is decisive. It appears, for instance, that the addition of a nongenetic factor (e.g., dietary salt) is required for significant hypertension to develop even in the predisposed strain. Similarly, in the other strain the marked resistance to hypertension can be overcome if the nongenetic insult is severe enough. In the hypertension-prone strain, if dietary salt is restricted at the time of weaning, animals remain normotensive or develop only mild, benign elevations. When dietary salt is increased, the blood pressure rises and, in general, a higher average salt intake will be reflected in a corresponding increase in average blood pressure. The age of the animal and the duration of salt feeding also modify the response. Thus, depending on the genetic background, the amount and duration of salt feeding, and the age at which it is begun, animals can predictably have normal pressures, benign elevations, or fulminating hypertension.

Although originally selected on the basis of their opposite responses to salt ingestion, these two strains were found to respond in the same divergent manner when other techniques, including some in which dietary NaCl is not critical, were used to induce experimental hypertension.

If these experimental models have relevance to hypertension in man, they suggest that hypertension may result from one or more nongenetic factors interacting with the appropriate genetic substrate. If this thesis is valid, at one extreme there should be individuals with such a strong genetic predisposition to hypertension that they require only minimal appropriate stimuli to develop hypertension; at the other extreme should be individuals who do not develop hypertension even after exposure to apparently appropriate stimuli of great intensity and duration. There is clinical evidence that is compatible with this hypothesis. It would help to explain, for example, the rapid development of a malignant phase in some young individuals with hypertension and, on the other hand, the failure of many persons with severe kidney disease to become hypertensive. Given the usual genetic heterogeneity of man, however, the more common individual presumably would be one with some genetic predilection who, after variable exposure to one or more of the effective nongenetic influences, manifests hypertension.

A long genetic study of the mode of inheritance of hypertension in the two strains of rats is in its

final year. The data are still incomplete, but the evidence now at hand suggests that inheritance is multifactorial.

Studies With Radioisotopic Carbon and Hydrogen of Disorders of Intermediary Metabolism of Carbohydrates and Fats

Further studies have established more definitely that the large majority of obese patients show pronounced increase in formation of glucose and decreased formation of CO_2 from C^{14} -labeled pyruvate and lactate and glycerol. This alteration in intermediary metabolism is also characteristic of diabetic patients (obese or nonobese); therefore most obese subjects are "diabetic" by this criterion, which, in the case of gluconeogenesis, is referable mainly to metabolism in the liver.

A special type of diabetes, that occurring in some patients with acromegaly (excess growth hormone), has been studied also with pyruvate-2- C^{14} . Acromegals who show low intravenous glucose tolerance (about one-third of them) also show decrease (to two-thirds of normal) in oxidation of labeled pyruvate to C^{14}O_2 , but no increase in formation of glucose- C^{14} . Those with normal glucose tolerance (and typically superelevated blood insulin levels) show normal conversion to C^{14}O_2 and low formation of glucose- C^{14} . These findings suggest resistance to insulin effect on oxidation of carbohydrate but no interference with insulin control of gluconeogenesis in the liver in acromegalic patients.

In studies of the effect of hydrocortisone on gluconeogenesis in rats *in vivo* it was shown that within 2 to 4 hr after intraperitoneal injection of the steroid the conversion to blood glucose of i.p.-injected C^{14} - or H^3 -labeled lactate or malate (but not labeled glycerol or succinate) was increased. This study has recently been extended to include the isolated perfused rat liver. Direct addition of hydrocortisone to the perfusate did not significantly increase conversion of DL-malate-3- C^{14} or DL-malate-2- H^3 to glucose, but the positive effect of prior administration of cortisone to the liver donor rat for 4 days was further enhanced by the presence of hydrocortisone in the perfusate. Injection of hydrocortisone 1 hr prior to isolation of the liver plus addition to perfusate also had a positive effect. As with *in vivo* studies, no effect on conversion of labeled glycerol to glucose was evident. These findings further suggest a directness of re-

Figure 4. Comparative disposition of C^{14} between CO_2 and glucose at 1 hr after intravenous injection.

lationship between the physical presence of the steroid in the liver and its effect on gluconeogenesis.

Lipogenesis in obese human subjects has been further investigated by analysis of C^{14} and H^3 in serum lipid fractions after intravenous administration of glycerol-1,3- C^{14} ,2- H^3 . Incorporation of radioactivity into triglycerides and free fatty acids was lower in obese subjects than in nonobese controls, but incorporation into di- and monoglycerides was higher in the obese. The ratio of C^{14}/H^3 incorporation into various serum lipid fractions was generally higher in the control subjects. Preliminary interpretation of these data suggests that in these obese subjects the lipid metabolism is in a state that is more static (and diabetic-like) than dynamic.

A study including glucose-1- C^{14} ,1- H^3 in the oral glucose load of a cortisone-glucose tolerance test has been extended to include additional obese (some diabetic) subjects. On the average, appearance of C^{14}O_2 in obese subjects (13) is 50% lower than in control nonobese subjects (8). The intravenous glucose tolerance shows a similar but slightly less significant difference between the two groups. The blood glucose values show much more scatter, with an average difference between groups of only 15 to 20%. Conversion of glucose-1- H^3 to H^3OH of total body water is also much less different between groups than conversion to C^{14}O_2 , in agreement with earlier findings after intravenous administration of labeled glucose. The differences between C^{14} and H^3 suggest that after initial glucose utilization there is in obese subjects a diversion of in-

termediary compounds to fat, carbohydrate, or other products prior to formation of $C^{14}O_2$.

Methods of Extending and Improving Radiographic and Isotopic Diagnostic Techniques

Methods for providing optimal techniques to utilize Tc^{99m} as a scanning agent are under investigation. With the high count rates available from Tc^{99m} distributed in the body, it is possible to obtain greater resolution than heretofore. An analysis has been made of the count density per unit area required to provide adequate statistical data in order to resolve lesions of various sizes with the collimators available for technetium scanning. The calculated values are close to those obtained experimentally with phantoms. It has been concluded that, under clinical conditions, it is feasible to visualize 4-mm-diam lesions without too much difficulty. Three-mm lesions are at the borderline of feasibility, and 2-mm lesions require count densities too high to be obtained in reasonable time under clinical conditions.

Rectangular light spots of various sizes have been used for photorecording of scan data. The use of light spots larger than those routinely used, along with very fine increments of line spacing which cause multiple overlaps, results in scans with almost no line structure and smoother appearance, much like that obtained in data blending. Measurements on phantoms reveal no resolution loss if the light spot is approximately the same as the field of view of the collimator.

The method of multiple overlapping of lines has been useful in reducing respiratory motion artifact. This type of artifact can seriously degrade scans performed at high speeds. The overlapping technique averages out the fluctuations and enhances resolution, as shown by studies on phantoms.

Transmission scanning is under investigation, primarily as a means of quantifying bone density and for future use in absorption edge spectroscopy. An ultrastable generator and x-ray tube have been mounted under the table of the 5-in. scanner. A secondary target has been set in the beam, and characteristic fluorescent radiation is taken off at right angles. By using a fine beam of 1.5-mm diameter, high count rates have been obtained. Future improvements will include use of mixed targets, a solid state detector, and computer read-out. It should be possible to image the thyroid because of the stable iodine within it with a very low dose to the patient.

Clinical Research in Leukemia With Extracorporeal Irradiation of the Blood and Cell-Labeling Techniques

The use of extracorporeal irradiation of the blood (ECIB) as a method of treatment and as a research tool has been continued in adult patients with leukemia. Those treated include 16 patients with acute myelocytic leukemia, 6 with chronic myelocytic leukemia, and 13 with chronic lymphocytic leukemia. ECIB-treated patients with acute myelocytic leukemia had a slightly longer survival time than those treated with chemotherapy; those receiving the highest transit dose survived longest. Patients with chronic lymphocytic leukemia have responded with reductions in peripheral blood lymphocyte concentration and spleen and lymph node volume and in some instances with increased platelet counts and reticulocytosis. Early treatment of chronic lymphocytic leukemia by ECIB will be undertaken in an attempt to prevent late effects due to extensive organ infiltration by leukemic cells.

Physiologic measurement of the readily accessible compartment of lymphocytes in patients with chronic lymphocytic leukemia has been made by isotope-labeled cell dilution studies and compared with independent estimates of pool sizes from extracorporeal irradiation data. There is a readily accessible compartment that is ≈ 0.67 to 7 times that of the peripheral blood compartment.

Low-Level Counting Facility

A 54-crystal whole-body counter constructed by the Harshaw Chemical Company has been installed in the low-level counting facility. The whole-body counter consists of two banks, an upper and a lower, of twenty-seven 6-in.-diam NaI(Tl) crystals each, arranged in 9×3 rectangular grids. Utilization of this counter awaited the installation of the Sigma-2 computer for on-line data processing, and the complete system became operational only in the final quarter of the year. Initial studies have concentrated on calibration procedures and development of corrections for geometry and attenuation as functions of body build and γ -ray energy. The whole-body count has become part of the routine annual physical examination for laboratory employees, and some metabolic research studies now include use of the new counting system. The old single 11½-in. crystal whole-body counting equipment has been

moved to a room of the low-level counting facility and continues to be used for some clinical research studies.

Computers

An SDS Sigma-2 digital computer has been installed in the Medical Department primarily for use in on-line data acquisition in connection with the whole-body counter and the electron paramagnetic resonance (EPR) system. The initial installation includes a central processing unit with 16,000 words of magnetic core memory, a 750,000-word rapid access drum, and punched paper tape input-output equipment, as well as direct interfaces for the whole-body counter and EPR systems. It is planned to add magnetic tape handling equipment and another 8,000 words of core memory. A basic program has been developed for accepting data from the whole-body counter system and for processing and displaying the data, and a start has been made on a similar program for the EPR system. With the additional core memory it is expected that the computer can handle the two systems simultaneously. Long-range plans include linking the Sigma-2 with the Laboratory's CDC 6600 at the central facility.

The Medical Department continues to use the central facility for most of its computing requirements. Established programs still in use include the ones for analysis of tracer data in terms of multicompartiment models, radiation dose in extracorporeal irradiation of blood, separation of carbon and tritium counts in double tracer experiments, γ -ray spectrum analysis, electrolyte patterns, and synthesis of EPR spectra. New programs include one for processing data associated with the areas of labeled cells and one for processing data on the effects of radiation in suppressing the hatching of *Drosophila* eggs. A program developed for computation of continuous ascent schedules for deep sea dives is being published in collaboration with the U.S. Naval Submarine Medical Center.

NUCLEIC ACID STRUCTURE AND FUNCTION

Compensatory Enlargement of the Kidney

The mechanisms that regulate the sizes of organs of the body are not understood. The mouse kidney provides a useful system for the investigation of this problem because removal of a single kidney

can be accomplished with minimal injury to the animal and provides a growth stimulus to the remaining kidney which is quite uniform from one animal to the next.

For many years it was thought that the compensatory growth of the kidney was the result of an increase in the mean cytoplasmic mass of the functional cells, or hypertrophy, as occurs in heart muscle, for example, when its work load is increased. More recently the regulatory mechanism, whatever it may be, has been thought to operate through control of synthesis of the genetic material, deoxyribonucleic acid (DNA).

In order to compare these two hypotheses, the increase in kidney mass has been measured by the increase in dry weight and by the rates of incorporation of amino acids into protein and of cytidine into ribonucleic acid (RNA). The cell proliferative activity has been measured by the fraction of functional cells synthesizing DNA at a given time, the index of synthesis. The absolute increase in the size of the cell population is determined by integrating the index of synthesis over the elapsed time. Cellular hypertrophy is gauged by the increase in organ mass in excess of that required by cell proliferation.

These indices show that hypertrophy begins within the first 2 hr following nephrectomy, whereas acceleration of DNA synthesis is delayed for >18 hr. At 72 hr after operation, hypertrophy accounts for $>75\%$ of the increase in organ mass. It appears that the initial response to the growth stimulus is an increase in mean cell mass and that DNA synthesis and cell division are secondary phenomena which do not directly mediate the control of compensatory growth of the kidney.

The immediate increase in mass appears to be largely the result of mitochondrial proliferation. Functionally this represents an increased capacity to do work. The implication is that the stimulus for compensatory growth is not a regulator of mitosis or DNA synthesis but an increased work load.

Interaction of Daunomycin and Actinomycin With DNA

Daunomycin is a typical representative of an extensive class of carcinostatic antibiotics now being evaluated in human therapy. Like all such antibiotics, it binds strongly to DNA. The nature of this binding is largely unknown.

Further studies on the interaction of daunomycin and DNA have resulted in improved

Figure 5. By counting the mitochondria in a section of proximal tubule, shown in (a), it is possible to measure the increase in mitochondria in the left kidney at various times after right nephrectomy (b). Mitochondrial proliferation is much more prominent than cell proliferation in compensatory growth of the kidney.

models of the interaction. The pitch of the DNA-daunomycin complex increases with the amount of drug bound to DNA. Experimental evidence from diffraction patterns from DNA-daunomycin complexes and molecular model-building on the change in pitch with drug concentration suggests that if this change in pitch is due to intercalation of the daunomycin between successive base pairs, the sugar-phosphate helix is untwisted $\approx 10^\circ$. If the change in pitch were due to external binding of the daunomycin to DNA rather than to intercalation, an untwisting of the DNA helix of $\approx 41^\circ$ would be required.

For the intercalated model, it has been possible to build two families of models that differ in the pucker of their sugar rings. In one model, the pucker of the sugar is like that in *B* DNA; in the other, like that in *A* DNA. These are the only two types of deoxyribose sugar pucker that have been observed. If the sugar pucker is like that in *B* DNA, an intercalated model with untwisting of the phosphate-sugar chain of 10° to 20° can be built. If the sugar pucker is in the *A* conformation, the untwisting must range from $\approx 20^\circ$ to 45° . This means that if the drug is intercalated, the pucker of the sugar is like that of *B* DNA rather than that of *A* DNA. In general, untwisting of the DNA helix by about 41° , which is required for an external binding model without any separation of the base pairs (i.e., with no intercalation), is stereochemically impossible, since the sugar-phosphate chain cannot be compressed in this way to the extent necessary to achieve such a degree of untwisting. These considerations favor the intercalation interaction for the DNA-daunomycin complex and essentially exclude external binding of the drug.

In contrast, further studies of the interaction of actinomycin and DNA exclude the possibility that this drug intercalates between the base pairs and confirm earlier observations that the antibiotic binds in the small groove of the DNA helix. Studies are in progress on the cyclic peptide moieties of actinomycin to delineate more precisely the geometry of their interaction with the phosphate-sugar base as well as those of the chromophore of actinomycin with the DNA helix.

These contrasting interactions may serve to distinguish between the various types of carcinostatic antibiotics working by direct action on DNA. These antibiotics appear to require a minimum of metabolic activation and so allow direct correlation between carcinostatic action and interference with DNA function.

Messenger RNA Synthesis

Cell differentiation requires selective inhibition of genes unnecessary to the function of the differentiated cell. This inhibition apparently takes place at the stage of messenger RNA synthesis in which an RNA molecule is formed with a nucleotide sequence complementary to one of the DNA strands of the gene. The details of this process are not known, but the complementary nucleotide sequence of the RNA suggests that it originates as a hybrid with DNA in which each nucleotide base

in RNA is hydrogen-bonded to its complement in DNA. Mouse liver nucleohistone has been examined for such hybrids. The procedure used to detect these hybrids is based on their resistance to digestion by pancreatic ribonuclease. This property can also be used to determine the effect of physical and chemical agents on the stability of the hybrids, since the RNA component becomes sensitive to ribonuclease digestion when the hybrid structure breaks down.

Recent experiments suggest that DNA-RNA hybrids account for 0.8% of the total nucleic acid in mouse liver deoxyribonucleohistone. The hybrids are unstable in solution and are not detectable in preparations >2 days old. They are destroyed by heating, freezing, and high ionic strength, but not by very low ionic strength. These properties suggest that the hybrids are stabilized by protein.

Structure and Function of RNA

The ribosome is central in protein synthesis. Knowledge of the structure of the ribosome's RNA components is important for understanding protein synthesis, and studies are in progress to provide information on the primary and secondary structure of ribosomal RNA from animal sources.

High molecular weight ribosomal RNA's are several thousand nucleotides in chain length. To facilitate nucleotide sequence and secondary structural analyses, segments of the RNA with a chain length of several hundred nucleotides are studied individually. Controlled nuclease digestion is used to produce fragments of various sizes, and gel filtration is used to isolate them. Structural studies are made on these isolated segments of the RNA.

Data on rabbit liver ribosomal RNA have yielded the following information. Ten to 15% of the RNA (≈ 500 to 700 nucleotides) contains primarily 2 of the 4 major nucleotides, guanylic and cytidylic acids. These segments of the RNA contain >80% guanine and cytosine, the guanine content being nearly equal to that of cytosine. These fragments represent regions of the RNA that most resist nuclease attack; they are the last to be degraded by ribonucleases and probably are from one or two regions of the RNA. These segments also have a stable ordered structure. Extensive guanine-cytosine hydrogen-bonding has been detected by optical methods, and from hydrodynamic studies a rigid, three-dimensional structure can be pos-

tulated. These high guanine-cytosine regions may serve the function of defining the tertiary structure of the ribosome.

Satellite DNA

Evidence has accumulated that chloroplast DNA is responsible for much information required for synthesis and replication of chloroplast and proplastid. Preliminary experiments indicate that a photomorphogenetic system (a "phytochrome" type) is operative in chloroplast synthesis.

Polyacrylamide gel electrophoresis of the structural proteins of the mutant (yellow) chloroplasts of strains unable to form chlorophyll indicates that several are missing from the mutant. Electron micrographs of the mutant strains show absence of normal chloroplast lamellae.

A very rapid loss of photoreactivation capacity occurs in cells exposed to red light after uv irradiation; this loss may be inhibited by sulfanilamide, cyclohexamide, and fluorouracil. Cytoplasmic (nonchloroplast) ribosomes may be the site of this effect. A preliminary action spectrum indicates chromophore action in green as well as red light.

The way nalidixic acid (NA) inhibits chloroplast replication is directly linked to the cells' ability to synthesize a "normal" chloroplast. Drugs that specifically inhibit chloroplast synthesis induce resistance to NA. The action of NA on chloroplasts requires photosynthesis; mutants unable to carry out photosynthesis are resistant to the drug. Treatment of wild-type cells with 3,3,4-dichlorophenyl-1,1-dimethyl urea, which blocks system II of the photosynthetic electron transport pathway, induces resistance to the drug.

The possibility that the loss of photoreactivability and the high sensitivity of chloroplasts to NA may be due to chloroplast nucleases synthesized during chloroplast formation is being studied.

ANTIGENS AND ANTIBODIES

Studies on Lymphocyte Kinetics by Cell Labeling and Extracorporeal Irradiation of Blood and Lymph

Lymphocytes occupy a central role in immunological processes involving production of antibodies and rejection of foreign tissues. Extracorporeal irradiation of blood (ECIB) and of lymph (ECIL) depletes the body of lymphocyte stores. This depletion suppresses immunological

competence to some extent. Thymectomy prior to ECIB or ECIL results in a marked increase in the time required for animals to replete lymphocyte stores.

Thirty-four calves have been studied by thymic artery or lymph node artery perfusion of tritiated thymidine. A substantial migration of thymic lymphocytes has been observed to enter the blood by way of the thymic lymphatics and the thymic veins. Lymphocytes labeled in the thymus have been found in the spleen and lymph nodes, and some may have migrated back to the medullary region of the thymus. Lymphocytes labeled in lymph nodes leave the lymph node almost exclusively by way of the efferent lymphatics.

Neonatal Migration of Lymphoid Cells From the Thymus

The thymus has long been recognized as a site of lymphopoietic activity. As early as 1900, it was noted that more lymphoid cells were produced in the thymus than seemed necessary for its normal rate of growth. Attempts to demonstrate significant numbers of thymus-derived cells in other lymphoid tissues have failed; until recently, the hypothesis has been favored that most of the newly produced cells do not leave the organ but die *in situ*.

The growth in wet weight of the thymus from 260 mice and proliferative activity of thymic lymphoid cells of 40 mice were evaluated on days 3, 2, and 1 before birth, immediately at birth, and on days 1, 2, 3, 4, 5, and 6 after birth. A statistically significant decrease in the rate of weight gain was observed ≈ 1 day before birth. The sharp change in the growth rate of the thymus was tentatively viewed as a consequence of (1) a change in the rate of cellular migration out of the organ, (2) a diminished influx of cells, (3) a change in the mean generation time of proliferating thymic cells, (4) an increase in the rate of intrathymic cell death, and (5) a combination of several of these possibilities.

The over-all proliferative activity of thymic lymphoid cells during the same interval of perinatal life was estimated autoradiographically by studying the initial incorporation of tritiated thymidine by proliferating thymic lymphoid cells. The relative number of cells incorporating the tritiated DNA precursor within 30 min after its administration remained stable at around 10% up to 2 days after birth. An increased proliferative activity was noted during days 3 and 4, as revealed by an

increase of (1) the relative number of cells in mitosis and (2) the over-all initial labeling index after the administration of thymidine. Based on these data, obtained in mice during a time interval in which the relative number of all thymic lymphoid cells in proliferation increased from 12 to 19%, it may be estimated that at least one-third of the total number of lymphoid cells in the thymus are newly produced in this 24-hr period. Since the increment in thymic weight gain during the same time interval was only 14%, massive migration of cells out of the thymus and/or equally massive cell death would be required to account for the observed difference. Since extremely few pyknotic cells were found, there is little evidence for massive cell death in the thymus of 2-day-old mice. It therefore seems most likely that the newly produced cells leave the organ.

The present evidence for lymphoid cell migration out of the thymus has recently been corroborated by studies in which a substantial number of locally labeled thymic cells were demonstrated in various organs of the lymphoreticular system and in peripheral blood. A direct quantitative estimate of the actual number of cells peripheralizing from the thymus is impossible until more is known about the efferent pathways of the organ and until the number of lymphoid cells immigrating into the medulla can be more accurately determined. Thus, the thymus may function as a highly efficient production site of lymphoid cells which are distributed to other organs of the lymphoreticular system. The reasons for a higher proliferative activity of lymphoid cells in the thymus than in other locations are unknown.

Transfer of Delayed Hypersensitivity by Lymph Node Cells

The failure to detect antibody early after transfer in animals receiving cells from sensitized skin-tested donors initiated investigations on possible differences in the ability of cells that had been sensitized only once and those that had been repeatedly sensitized to initiate antibody production in recipients, since the cells may be sufficiently primed to transfer delayed hypersensitivity but not to produce antibody. Guinea pigs were sensitized with *Trichinella spiralis* antigen in combination with complete adjuvant either once or 4 times and were skin-tested with the homologous antigen, after which lymph nodes were re-

moved and transferred to normal recipients. The repeated sensitizations were done at 1-, 2-, or 3-week intervals. The donors and recipients were bled to determine the presence of antibody by passive cutaneous anaphylaxis (PCA) and microimmunoelectrophoresis. Recipients were bled daily for 10 days after transfer and at weekly intervals thereafter for 3 weeks or more. The results thus far with animals repeatedly sensitized (4 times at 3-week intervals) show that the reaction to a skin test is of the Arthus type and antibody can be detected by both PCA and microimmunoelectrophoresis; antibody is in the γ -globulin region consisting of both γ_1 - and γ_2 -globulins. More interestingly, in the recipients receiving cells from these repeatedly sensitized donors, the skin reactions are negligible or negative, but antibody can be detected by PCA 1 day after transfer in almost half of the animals. Therefore, when the

cells are primed by repeated antigenic stimulation, there is interference in the transfer of delayed response but antibody can be detected early (1 day after transfer) in the recipients. Since at least 95% of the cells transferred are small lymphocytes and since PCA antibody can be detected in recipients within 1 day after transfer, this means that the small lymphocyte is the cellular precursor of the antibody-forming cell, if not the antibody-forming cell itself.

Fine Structure of Lymphocytes Sensitized to *Trichinella spiralis* Antigen

Guinea pigs were sensitized with *Trichinella spiralis* antigen combined with complete adjuvant and skin-tested 7 days later. Cells from lymph nodes were processed for electron microscopy before or after *in vitro* cultivation with homologous antigen. Lymphocytes from sensitized animals were usually larger and had a greater nucleocytoplasmic ratio than unstimulated lymphocytes. The nucleus was eccentric, with patches of compact chromatin around the periphery; the cytoplasm had many ribosomes and a few scattered channels of endoplasmic reticulum, mitochondria, Golgi bodies, and some dark granules. After incubation for 5 days with homologous antigen, about 15% of the cells were greatly enlarged. The most striking cytoplasmic change was in the ribosomes; these were more numerous and dispersed, either singly or in rosettes. Other changes included increase in lamellae of the ergastoplasm and mitochondria. The nucleus was mainly round, with lighter nucleoplasm and diffused chromatin. In contrast, unstimulated lymphocytes had a nucleus with compact chromatin and a thin rim of cytoplasm containing ribosomes, few mitochondria, Golgi bodies, and few cisternae of endoplasmic reticulum. Unstimulated lymphocytes incubated with antigen for 5 days did not differ in ultrastructure from those cultured without antigen or from freshly isolated lymphocytes from unsensitized donors.

Figure 6. Lymphocytes from sensitized guinea pig transformed after incubation for 5 days with *Trichinella spiralis* antigen. Note decrease in density of chromatin in nucleus (N); increase in polyribosomes in cytoplasm; few small, round mitochondria (M); and channels of endoplasmic reticulum (E). Note the size of nontransformed lymphocyte (L) at top left corner. 10,400 $\times$.

PROTEIN STRUCTURE AND FUNCTION

Synthetic Insulin

The protein-hormone insulin, produced in the pancreas, controls the metabolism of carbohydrates. Lack of insulin causes diabetes mellitus, a disease of increasing importance as the population ages.

Synthetic insulin is required because the supply from animal sources is limited and diabetics become sensitized to animal insulins after long years of treatment. The immediate need is for a synthetic insulin for diabetics who have become resistant to insulin and may develop other complications that could be prevented in all probability by use of a synthetic human insulin or its analogues.

Studies in the Medical Department have resulted in the total synthesis of human and sheep insulins and in the development of highly efficient methods for the isolation of these hormones in purified form. Application of these methods of synthesis and isolation has resulted in the production of several other naturally occurring animal insulins and one nonnaturally occurring hormone. All these synthetic components are endowed with the full biological activity of the natural hormone. As a result of these accomplishments, the road is now open for the synthesis, in an unlimited way, of analogues of the parent molecule and for study of the relationship between the chemical structure and biological activity of insulin. Successful outcome of this work may lead to the synthesis of custom-made insulin analogues which might possess more desirable biological and immunological properties than the naturally occurring hormone.

Protein Biosynthesis

Elucidation of the mechanisms whereby proteins are manufactured in living systems is one of the most important problems of present-day biochemistry. The problem has great intrinsic interest because of the fundamental role of proteins in the normal life processes of living systems. It is of practical importance also, since an understanding of this mechanism may illuminate certain little-understood aspects of genetic disorders and tumor and immune phenomena.

The information for the proper arrangement of the amino acid residues during the biosynthesis of a protein resides in the DNA molecule. DNA directs the formation of messenger RNA, which possesses all the necessary information for the sequential arrangement of the amino acids in a protein. The messenger RNA attaches to ribosomes to form a multiple ribosomal structure, the polyribosome. Amino acids in an activated state are brought by transfer RNA molecules to the polyribosome, where the genetic message is decoded and the protein formed. At Brookhaven

National Laboratory, various antibiotics are being used that are specific inhibitors for certain steps of the protein biosynthetic process. At present the mechanism of action of sparsomycin, a potent inhibitor of protein synthesis, is being investigated. It has been found that sparsomycin inhibits the protein synthesis by affecting the ribosomes. Through use of sparsomycin labeled with tritium, it has been found that the antibiotic binds to a critical site of the ribosomes and as a consequence inhibits peptide bond formation.

Collagen

Hydroxylysine occurs only in collagen, an important structural protein in all animals. It is formed by oxidation of lysine during collagen formation and after the lysine is incorporated into a polypeptide chain. During the past year additional understanding has been gained of the biochemical mechanism of hydroxylysine formation and of the function of hydroxylysine in the collagen structure. An enzyme that carries out the hydroxylation has been purified about 70-fold from chick embryo tissues by ammonium sulfate precipitation and hydroxylapatite and DEAE-cellulose chromatography, followed by gel filtration. At this stage it is not yet pure. Its molecular weight, determined by gel filtration, is about 380,000. It is inactivated by sulfhydryl reagents, but α -ketoglutaric acid provides partial protection against this inactivation. Dithiothreitol also inactivates the enzyme, possibly by disrupting its native conformation.

Studies of oxidation of collagen hydroxylysine by sodium periodate have shown that not all hydroxylysine side-chains have free ϵ -amino and/or δ -hydroxyl groups. It has been shown previously that the fraction of unreactive hydroxylysine is different in collagen from different tissues or species. Perhaps a covalent linkage of the reactive groups may be involved in interchain bonds. To test this hypothesis, soluble collagen from rabbit skin was separated into the two monomers and the two dimers (composed of these monomers) derived from the three-stranded native structure. In both monomers (α_1 and α_2), unreactive hydroxylysine was found to be one-third of the total, even though the α_2 chain contains twice the amount of hydroxylysine found in the α_1 chain. The dimers (β_{11} or β_{12}) showed no increase in the unreactive hydroxylysine. This indicates that hydroxylysine is not involved in the simpler states of aggregation. If

the unreactive hydroxylysine has its hydroxyl group bound in glycosidic linkage to carbohydrates, then it is still possible for the attached carbohydrate to participate in cross-links. Although hydroxylysine does not appear to participate in simple states of aggregation, it might take part in linking between collagen molecules to form higher states of aggregation. Higher aggregation

states of the protein are being isolated in order to resolve this question.

Collagen formed in vitamin-C deficient guinea pigs contains only about 50% of the usual amount of hydroxylysine. Yet this collagen is found in both the soluble and the more highly aggregated, insoluble fractions. These results indicate that hydroxylysine may not be required for aggregation.

SUPPORTING ACTIVITIES

Technical Operations and Services

The technical services and facilities essential to the Laboratory's research programs are provided by a number of organizational units whose operations are described below under appropriate headings.

REACTOR OPERATIONS

High Flux Beam Research Reactor

The High Flux Beam Research Reactor (HFBR) operated successfully at design conditions throughout the year. The experimental program continued to grow, and at midyear all the experimental beam holes were in use. No major operating difficulties were encountered.

Operation. Scheduled operation of the reactor included eleven 3-wk periods at a power level of 40 MW and one 3-wk period at 30 MW, with a total power output of 9742 MWd for the year. For the 30-MW cycle the reactor operated with only one primary pump and heat exchanger loop while maintenance work was being done on the other pump. Routine operation was interrupted by eight unscheduled shutdowns (see Table 1).

At the end of each operating cycle, 14 fuel elements were discharged from the reactor and replaced with new elements. The average burnup of the U^{235} content of the 172 elements discharged during the year was 24.5%. There were no fuel element failures.

Table 1

HFBR Unscheduled Shutdowns, Fiscal 1968

Date	Cause	Duration
10/ 2/67	Nuclear safety system spurious trip	15 min
11/ 3/67	Electrical power failure	24 min
12/27/67	Operator error	21 min
1/29/68	Water leak in H-1 collimator plug	38½ hr
2/12/68	Partial loss of secondary coolant flow	Refueled
3/20/68	Safety system relay failure	36 hr
5/14/68	Inadvertent tripping of manual scram No. 3	15 min
5/18/68	Electrical power failure	18 min

Seven shipments of spent fuel were made to the AEC's reprocessing plant at Savannah River. Each shipment of 14 fuel elements had been cooled in the canal for more than the required minimum of 270 days.

On July 1, 1967, the isotopic purity of the 86,000 lb of D_2O in the reactor system was 99.574%. On June 30, 1968, it was 99.525%.

The operating limits for the HFBR were updated and submitted to the AEC for approval, which was obtained on March 7, 1968.

Material Surveillance Program. The material surveillance program for the HFBR included the removal of main control-rod blade M-7 after an accumulated exposure of 13,722 MWd. Hot-cell examination of this blade showed no evidence of swelling, bowing, or other changes in dimensions.

Reactor and System Improvements. The process of improving the reactor and its associated systems continued throughout the year and resulted in the following major changes.

1. A new reactor-core flow-reversal valve design was satisfactorily tested, and replacement of the original valves has been initiated. The new valve, which utilizes a bellows seal, has greatly improved the reliability of the system.

2. The thermal shield water-treatment system was modified to allow operation with deoxygenated water at a pH of 10.

3. Improvements in the secondary cooling water system included (a) water treatment of the cooling tower basin water, to prevent system component damage and fouling of heat exchanger tubes, and (b) installation of a holdup tank that will contain cooling tower water in the event of tritium contamination from the primary system D_2O . The tank is not yet connected to the cooling tower system.

4. A fuel cladding failure safety system has been installed which will automatically shut down the reactor in the event of unusually high radiation levels in the primary system.

5. Phase I of the air conditioning modifications program to allow redistribution of the existing air flows within the reactor building has been completed. The project to increase the air flow through the building is under contract.

Research budget	Usage, %	Use charges, fiscal year		
		1968	1967	1966
Physics Department				
Neutron physics	44	\$ 552,000	\$ 511,044	\$ 502,992
Structure of solids	16	201,000	184,972	180,000
Neutron diffraction studies	12	150,996	140,028	140,004
Subtotal	72	\$ 903,996	\$ 836,044	\$ 822,996
Chemistry Department				
Nuclear structure and inorganic chemistry	28	351,996	324,978	320,004
Total	100	\$1,255,992	\$1,161,022	\$1,143,000

Figure 1. Distribution of HFBR support from scientific programs.

Figure 2. Costs associated with operating the HFBR.

Experimental Use. Installation of the experimental hole collimators and shield plugs was completed, and neutron beams have been used on all horizontal experimental holes. Some work still remains to be done to complete the installation of the out-of-pile equipment at H-3, the capture γ experiment operated by the Neutron Structure Group, and at H-1, the polarized neutron experiment operated by the Nuclear Cryogenic Group.

The fast neutron chopper, hole H-2, operated by the Neutron Chopper Group, is now using a flight path of 48.8 meters, with the detector station located outside the reactor building.

The slow neutron chopper in H-9 has been operating on a limited basis because of rotor bearing failure. New bearings have been fabricated, and the machine is shut down pending their installation. Both the fast and slow neutron choppers share a single computer for the collection of data.

The seven spectrometers and a beam pipe, located in beam holes H-4, H-5, H-6, H-7, and H-8 and operated by the Solid State Physics Group, have been in operation throughout the year. The experiments in these facilities are programmed into a single computer which controls and collects data for all the machines at the same time.

Vertical Irradiation Thimbles. The seven vertical irradiation thimbles have all been used for irradiations during the year. The V-13 core-edge thimble and the V-16 in-core thimbles are used almost exclusively for the HFBR materials surveillance experiment and the reactor fuel element cladding development experiment, respectively.

Operating Costs. The distribution of HFBR support from the scientific programs is shown in Figure 1. It should be noted that no support for the operation of BNL research reactors is directly budgeted by the AEC; all such support comes from the budgets established for scientific programs at the Laboratory. The actual and projected direct operating costs for the HFBR are shown in Figure 2. They reflect higher costs for such items as salaries, wages and insurance, direct labor, and electrical costs. These increases more than offset lowered costs for such items as materials and supplies, travel, communications, services, heavy water, health physics coverage, and the procurement of certain special items.

nance of the reactor and experimental equipment. Five unscheduled shutdowns occurred; one was due to failure of electrical power, one to human failure, two to failure of reactor ancillary equipment, and one to experimental equipment failure.

The graphite structure was annealed five times during the year and the results continued to be favorable, as indicated by measurements of the net vertical displacement of the structure and of the width of the central air gap. The over-all cost of annealing the BGRR decreased substantially during the year as the result of the reduced duty cycle.

As of June 10, 1968, the BGRR was placed on standby duty; it will be reactivated only when an experimental program can support the financial burden of operating it.

The support of the BGRR comes almost entirely from the BNL scientific programs. A three-year summary of this support is given in Table 2. The operating costs for the BGRR since 1960 are shown in Figure 3. Each step in lowering costs has meant a curtailment of reactor operations, with associated reductions in staff, electrical power usage, and fuel element usage.

Brookhaven Medical Research Reactor

The Medical Research Reactor (MRR) was operated on 122 days during the year, and 415.659 MWh of operation were accumulated. The total integrated energy to date is 4,229.062 MWh.

During the year the Medical Department was the primary user of the reactor. The main experimental programs consisted of the following:

1. Determination of trace elements in tissue by activation analysis.
2. Activation of protein labeled with I^{127} , I^{129} , and Br^{81} .
3. Investigation of cellular distribution of B^{10} in tissue by neutron autoradiographic techniques.
4. Investigation of U^{235} fission fragment mass distribution with solid state detectors in evacuated aluminum cyclinders.
5. Activation of foils for calibration purposes.
6. Investigation of the efficiency of the $B^{10}(n,\alpha)Li^7$ reaction in treatment of eye tumors in rabbits.
7. Study of reactions of neutral and charged recoil particles following nuclear transformation.
8. Study of the kinetics of halothane- Br^{82} anesthetic.

In addition, the MRR was operated in connection with the training program for Health Physics Fellows during the summer of 1967.

No serious operating difficulties were encountered during the year. The only malfunction of note was an unscheduled shutdown of the reactor on June 26, when a short circuit occurred in the rod magnet power supply.

In the past, operation of the reactor during periods of peak air conditioning needs in the Medical Department has been a problem because of the inability of the two wells to deliver sufficient water for both reactor cooling and air conditioning. This problem has been eliminated by modifications to the reactor's secondary water supply that permit water to be used in reactor heat exchangers after it has been used for air conditioning. Although this re-used water is somewhat higher in temperature, it is available in sufficiently large amounts to preclude the loss of over-all heat exchanger capacity.

An intensive effort has been made to equip the MRR to perform the irradiation services formerly provided by the BGRR. The following changes have been made.

1. Replacement of the "weak"-effect regulating rod with a strong-effect safety rod and appropriate adjustment of the speed of its manual operation.
2. Installation of four irradiation thimbles within the reactor core vessel.
3. Loading of additional fuel to provide sufficient excess reactivity for operation at 3 MW for 7 hr/day, 5 days/wk. To provide space for these additional fuel elements the upper hold-down device was extensively modified.

These changes were completed prior to June 10 when the BGRR went on standby status, and all requests for irradiations since that time have been fulfilled at the MRR. This short experience, however, cannot fully attest to the adequacy of the planning.

Source and Special Nuclear Material Accountability

In Table 3, a three-year summary is presented of the the amounts of source and special nuclear (SS) materials on hand at Brookhaven at the end of each fiscal year. Based on dollar values published by the AEC, the current inventory of SS materials represents a value in the range of \$17.5 million. The increase of about \$2.5 million from the previous year can be attributed mainly to the increase in the inventory of U^{235} enriched to $>75\%$, occasioned by the receipt of some 240 kg of material for the Experimental Reactor Physics Group.

Table 3

Source and Special Nuclear Materials on Hand
at End of Year (in kilograms)

	Fiscal year		
	1968	1967	1966
Station BZA			
Natural uranium	361	505	526
Depleted uranium	23,766	23,144	23,219
U ²³⁵ > 75%	860	633	575
U ²³⁵ < 75%	6,244	3,898	3,878
U ²³³	23	23	23
Pu ²³⁹	58	59	57
Thorium	817	820	825
Heavy water	49,378	53,959	53,190
Station BZB (Graphite Reactor Fuel)			
U ²³⁵ > 75%	79	82	79
Station BZC (Medical Reactor Fuel)			
U ²³⁵ > 75%	5	3	3

The annual audit of SS materials at Brookhaven and the associated accounting records and procedures was performed by the Brookhaven AEC Operations Office from Oct. 16 to Oct. 27, 1967. As a result the AEC recommended that the large amounts of SS material stored by the Experimental Reactor Physics Group be adapted for sealing, after verification, in order to reduce the periodic auditing effort. Modifications to the storage bins were designed for this purpose and have been approved by the AEC. Installation, however, will not be complete until next year.

Also in line with the audit recommendations, efforts have continued to dispose of excess inventory. During the fiscal year, ≈ 43 kg of natural uranium, 580 kg of depleted uranium, 4 kg of thorium, and some small amounts of plutonium and enriched uranium were removed from inventory through waste disposal. In addition, about 1.3 kg of enriched uranium was returned to AEC production channels, and 20 kg of irradiated enriched uranium, in the form of spent HFBR fuel elements, was shipped to the AEC's Savannah River Plant for reprocessing.

As was done last year, requests for quotations for fabrication of BGRR fuel elements were sent out, but no contract was placed because of the decision to place the BGRR on standby. It was

noted, however, that the low bid this year was more than twice that of last year for the same fuel element. Under the contract for HFBR fuel elements with the United Nuclear Corporation, 84 elements were received last year, 112 elements were received this year, and the option for 112 elements next year was exercised.

Revised SS Accountability Procedure Manuals were issued in August 1967 for the two facilities subject to IAEA inspection, i.e., stations BZB and BZC. Only one inspection, the thirteenth, was performed this year by Messrs. C. Buchler, T. Mori, and R. Schaer, inspectors from the IAEA. Both facilities were audited and inventoried, and their usage was reviewed in terms of peaceful purposes, all with satisfactory results.

The publishing of lower critical mass data for plutonium necessitated a review of Laboratory procedures and limits for criticality control of fissile materials used in various research programs. As a result of this review, the accumulation limit for each department was reduced to 125 grams, and specific authorization procedures were established for exceeding this limit.

Procurement of Special Materials and Services

The procurement for the scientific departments of all radioactive and stable isotopes, as well as special materials controlled by the AEC, is a responsibility of the Isotopes and Special Materials Group. In this connection, 301 purchase orders were placed for radioisotopes, 31 for stable isotopes, and 47 for special materials. Against these orders, ≈ 461 shipments were received and processed. The totals for orders placed and shipments received were essentially the same as those for the previous fiscal year. Of the orders placed, 34% were for the Medical Department, 22% for Biology, 21% for Chemistry, 12% for Nuclear Engineering, 10% for Physics, and 1% for Instrumentation and Health Physics. These percentages are similar to those for the past two years.

The Isotopes and Special Materials Group is also responsible for annual inventories of radium sources and purchased stable isotopes and for negotiations for the loan of valuable isotopes. Four very small radium needles with a total value of \$43 were disposed of because of leakage. The number of radium sources on hand, therefore, dropped from 38 to 34, but the total activity of 5.86 curies and the total value of $\approx$ \$39,500 remained un-

changed. The inventory of purchased stable isotopes valued at \$42,204 was almost unchanged from last year's value of \$41,262, since consumption (\$8986) during the year was offset by the cost of purchases (\$9928). The number of stable isotopes on loan remained the same as last year (22), but the value increased to \$1,081,163. In addition, three stable isotopes valued at \$704,275 were on loan to Chalk River Nuclear Laboratory, Chalk River, Ontario, Canada.

Irradiation Services and Isotope Production

Table 4 is a summary of irradiation services to outside organizations during the past three years. Both the volume and the income from these services have continued to decrease significantly because of the AEC's policy of noncompetition and the increasing availability of similar services commercially. Although irradiation services will not be available in the BGRR next year, some irradiation services can be performed in the MRR or in the HFBR. In the near future, therefore, the volume of this type of service is expected to continue at a minimal level.

HEALTH PHYSICS

Radiation exposure control at the Alternating Gradient Synchrotron (AGS) continued to be a major problem: 70% of the Laboratory-wide exposure for calendar year 1967 was accumulated at that machine by 390 individuals. Totals per person for the year were <5 Rem in all cases as a result of careful scheduling of work assignments and an intensive monitoring program.

The work of the Analytical Chemistry Laboratory of the Health Physics Division increased substantially; 5200 analyses were made on 3300 environmental and miscellaneous samples, and 1200 urinalyses for radioisotopes were performed, the majority being for tritium, which is a major exposure control problem at the HFBR.

The air activity alarm system for the HFBR has been redesigned in cooperation with the Instrumentation Division. The Kanne chambers have been located in a low-background area, and alarms have been provided for high air activity, instrument failure, and vacuum failure.

Three programs of training in various aspects of radiation protection were carried out during the year. These were provided for reactor technicians, members of the BNL Fire Group, and Fellows sponsored by the AEC, the U.S. Public Health Service, or other agencies. The fellowship program is an annual one, carried out for nine weeks each summer, providing on-the-job training in all aspects of applied health physics.

Synchrotron Monitoring and Dosimetry

Resolution and gas gain changes in Rossi-type tissue-equivalent proportional counters were studied to improve the performance of sealed versions of this type of detector in portable instruments for determination of dose equivalent. Results indicated that water vapor outgassing from the plastic chamber walls was the principal cause of the changes.

Recombination properties of common tissue-equivalent gases were studied for possible use in mixed radiation dose-equivalent instruments. Re-

Table 4

Summary of Services to Outside Users
(Handling and other charges included)

	Fiscal 1968		Fiscal 1967		Fiscal 1966	
	Number	Volume, \$	Number	Volume, \$	Number	Volume, \$
Reactor irradiations	166	18,341	237	19,484	350	26,139
Processed radioisotopes	67	12,401	269	51,080	868	135,485
Co ⁶⁰ sources	4	*	3	*	6	*
Cyclotron irradiations	0	0	0	0	10	2,889
Total	237	30,742	509	70,564	1,234	164,513

*AEC transfers - Co⁶⁰ not produced by Brookhaven.

sults demonstrated that a linear relation can be obtained between collection efficiency and quality factor by using several alternative mixtures.

Activation of elements contained in "standard man" was studied with use of a man-sized phantom and radiation present in the magnet enclosure of the AGS. Nomographs were developed which relate exposures to mid-chest ion-chamber readings and whole-body monitor scans. A dose of 1 rad delivered in 12 min results in a mid-chest ion-chamber reading of 0.25 mR/hr. Exposure evaluation is accurate to about a factor of two.

Fundamental Dosimetry

Because of its importance in understanding the significance of linear energy transfer in radiation protection, attention has been focused on the radial distribution of dose along the tracks of heavy ions from both the theoretical and experimental points of view. For 100 and 300-keV protons, calculations were made of energy absorbed as a function of radial distance from the track and of integral dose out to various radial distances. These calculations were based on cross sections for production of secondary electrons, differential in angle and energy, and a curve of dE/dx values for 0 to 1-keV electrons generated from available cross-section data.

A 3-ft long, 1-ft diam, cylindrical ionization chamber with segmented collection electrodes was designed and constructed to study the radial distribution experimentally. The chamber is operated at low pressures, which makes it possible to explore the radial distribution of ionization in gases and infer from these measurements what occurs in tissue regions 10 Å in diameter and larger.

Personnel Monitoring

Personnel monitoring service was provided for 2930 persons during calendar year 1967, an 8% decrease from the 1966 figure. Film dosimeters were provided for ≈ 5100 visitors. The distribution of whole-body exposures to penetrating radiation for the 2930 persons regularly monitored is shown in Table 5. All exposures were < 3 Rem per 13-wk period. The total exposure for all individuals monitored was 687 Rem, a substantial decrease from the 1966 value of 901 Rem. This decrease resulted from the sharp reduction in exposures in the 2 to 5 Rem/yr range (see Table 5).

Waste Disposal and Reclamation

Drop tests were performed on three reinforced concrete vaults used for shipping solid wastes to determine whether they met the new "hypothetical accident conditions" of the Department of Transportation. They were dropped on a 12-in.-thick armor plate pad from a height of 30 ft. The vaults with 12 and 17-in. walls passed this test but failed the puncture test. The Mechanical Engineering Division has designed a steel outer container that is expected to meet this requirement.

The last of the natural uranium fuel formerly used in the BGRR was packaged in steel vaults with concrete outer containers and shipped to West Valley, N.Y., for disposal.

A scrubber has been set up at the Waste Disposal Area to facilitate disposal of acid gases and has been very satisfactory in practice. Reclamation of contaminated mercury and decontamination of a wide variety of equipment has continued at about the same level as last year.

Data relating to the liquid waste system are presented in Table 6. The amount of gross β activity, other than tritium, leaving the site in the stream to which the effluent is discharged totaled 24.3 mCi during the fiscal year. The average concentration was 21.1×10^{-8} $\mu\text{Ci/cc}$, which is 2.0% of the applicable AEC standard. Tritium amounting to 15.6 Ci was discharged at a concentration of 1.3×10^{-5} , which is 0.4% of the applicable standard. The activity in the cooling-air effluent from the BGRR stack dropped sharply because of the

Table 5

Distribution of Exposures of Individuals Receiving Regular Personnel Monitoring Service

Exposure range, Rem	Calendar 1967	Calendar 1966
0.00-0.49	2525	2726
0.50-0.99	190	199
1.00-1.49	99	76
1.50-1.99	52	64
2.00-2.49	29	36
2.50-2.99	15	25
3.00-3.49	14	22
3.50-3.99	6	13
4.00-4.49	0	26
4.50-4.99	0	3
5.00 and over	0	0
Total	2930	3190

Table 6
Summary of Liquid Waste Data

	Fiscal 1968		Fiscal 1967	
Input to filter beds, gal/day	960,000		973,300	
Output from filter beds, gal/day	810,000		749,400	
Net loss in filter beds, %	16		21.5	
Stream above discharge point, gal/day	21,200		20,200	
at site boundary, gal/day	834,000		761,500	
Rainfall, in./mo	3.7		4.1	
	Gross β	Tritium	Gross β	Tritium
Activity concentration at input to filter beds, Ci/cc	2.9×10^{-8}	1.4×10^{-5}	6.1×10^{-8}	8.0×10^{-6}
at output from filter beds, Ci/cc	2.1×10^{-8}	1.2×10^{-5}	4.8×10^{-8}	6.5×10^{-6}
at site boundary, Ci/cc	2.1×10^{-8}	1.3×10^{-5}	4.6×10^{-8}	6.3×10^{-6}
Activity at input to filter beds, mCi/mo	3.2	1620	6.8	880
at output from filter beds, mCi/mo	2.8	1180	4.2	560
at site boundary, mCi/mo	2.0	1300	4.0	550

Figures are averages for each fiscal year.

curtailed operating schedule, with an average discharge rate of 5000 Ci of Ar^{41} , 0.0008 Ci of I^{131} , and 0.61 Ci of H^3 per day.

Environmental Monitoring

During fiscal 1968, the highest external radiation level at the site boundary occurred at a point north of the γ forest source and averaged 3.60 mR/wk. This may be separated into three components of 1.76, 0.26, and 1.58 mR/wk due to background, Ar^{41} from the BGRR, and the forest source, respectively. The permissible level above background is 500 mR/yr, or an average of 10 mR/wk.

Samples of air particulates, including both longer-lived natural and fallout isotopes, averaged 0.25 pCi/m³ of gross β activity, while the average activity in precipitation was 157 nCi/m²/mo. As the result of a foreign weapons test, there were substantial peaks in both air and precipitation activity (12.6 pCi/m³ and 1745 nCi/m² for one day) during December 1967, and much of the 1967-68 total fallout in rain and settled dust occurred during December and January, the deposition during these two months totaling 1.84 $\mu\text{Ci}/\text{m}^2$.

An experimental study of stack effluent dispersion was continued in collaboration with the Meteorology Group. The pressurized β scintillation monitor described last year was used to measure ground-level concentrations of Ar^{41} from the BGRR stack, and charcoal canisters were used for

measuring I^{131} concentrations. Short-term variations can be studied by means of the Ar^{41} measurements, while the I^{131} data are used to determine average behavior over longer periods of time.

Profiles of concentrations of γ -emitting isotopes in bottom silt and vegetation were determined for the Peconic River between the outfall of the BNL liquid waste effluent and the river mouth at Riverhead. Most of the deposited activity was found within 1.5 miles of the outfall, and all values were so low as to be of no concern from a public health point of view.

Laboratory Safety

For the fourth consecutive calendar year, the injury frequency rate at BNL remained below 3.00 injuries per million man-hours worked. The 1967 rate of 1.86 set a new record for the best rate in BNL history. The cost for New York State workmen's compensation benefits (borne by the Laboratory) dropped a commensurate amount.

Fire and property damage losses continued low, with the 1967 total of \$26,600 approximating that of the previous year. Incidents included a fire in a trailer in the West Experimental Area of the AGS, a minor "explosion" within the 30-in. bubble-chamber expansion system, and mechanical damage to a spare Van de Graaff accelerating tube that fell as it was being lifted.

During 1967 the BNL Safety Manual was completely revised, updated, and issued to ≈ 500 super-

visors and engineers throughout the Laboratory. Review of the Safety Policy Manual and the Emergency Plan Manual was commenced.

A survey of the fire protection needs of all facilities, including the various computer installations, was prepared and priorities were proposed. Emphasis was placed on providing for life safety in the dormitories, and plans were formulated and implemented prior to occupancy in the summer of 1968.

Emergency evacuation signals were standardized for all buildings on site. The fire alarm bells are used for this purpose, with continuous ringing indicating a warning and intermittent ringing meaning evacuation.

The major function of personnel in the Safety Services Office continues to be that of providing consultant services to the various departments and experimenters. Routine "program" activities are limited to accident investigation and safety inspections.

MECHANICAL ENGINEERING

The number of persons and the assignments in the Mechanical Engineering Division remain essentially the same as in 1967.

The Central Shops are now reporting to the Mechanical Engineering Division and better lines of communication are being established. A Design Standards Group has been set up within the Division to standardize the format of the design packages and to aid in producing designs that are within the capabilities of the Central Shops.

The General Physics Group has the preliminary design of a cold neutron moderator intended for use in beam hole H-9 of the HFBR well under way. This device will consist of a capsule of liquid hydrogen installed behind a window and heat shield and maintained at the liquefaction temperature by heat exchange with a cold helium gas stream. The moderator will serve to produce a flux of cold neutrons at energies of <0.005 eV. Safety problems have been examined and a preliminary safety report has been completed. Some prototype construction work has been started for study of problems in the design of the containment vessel and the internally reflecting beam pipes.

The fast and slow neutron choppers in beam holes H-2 and H-9 of the HFBR have been in partial operation during the past year because of bearing difficulties. A bearing development program to resolve the problems encountered with the

horizontally shafted slow chopper rotor has been successfully completed at the spin-test facility. A horizontally shafted rotor assembly with a lubrication system was set up to provide flooded oil lubrication of the ball bearings. An oil pump from a Welch molecular vacuum pump was modified to pump oil to the rotor bearings within the vacuum housing. Oil was supplied to the bearings at a rate of 100 cc/min per bearing, and the bearing temperatures reached a maximum of 120°F at a speed of 13,500 rpm. The rotor assembly is being installed at beam hole H-9 and should be completed early in fiscal 1969.

The fast neutron chopper, which has been operating at speeds below 10,000 rpm because of problems of grease lubrication, is being redesigned to use the same type of flooded oil lubrication. In addition, the motor drive will be converted from a conventional dc motor to a synchronous motor, which will eliminate problems connected with commutators and brushes.

Installation of the capture γ spectrometer in HFBR beam hole H-3 has been completed and the spectrometer is operational. Performance of the servo system that couples and controls the axis and arm has been excellent, with over-all system accuracy of ± 3 sec of arc.

Installation of the polarization spectrometer has been completed and research started at beam hole H-1. All the major assemblies of the spectrometer are in place. The fore-collimator assembly, which contains three sets of collimators, and the beam stopper for each beam on indexing cylinders, which is located between the reactor face and the first crystal axis, were completed and checked out prior to installation of the spectrometer. A positioning and readout arrangement was incorporated to align the entire fore-collimator assembly (which weighed several tons) to the plug collimator and first axis. During the first checkout, positioning resolution was better than 0.0002 in. Design work at present is concerned with accessory systems to enhance the quality, intensity, energy range, and precision of the monochromatic neutron beam and provide for future unattended operation. The beam rotator is in the early stages of fabrication and should soon be completed.

Personnel attached to the Tandem Van de Graaff Accelerator project have completed work on the insulating gas control panel and electrical control panels for the target and accelerator rooms. The major effort of the group was directed toward

the terminal ion source system which provides a negative ion beam in the insulated terminal of the injector for three-stage operation of the facility. Liaison continues with architect-engineer, and two accelerator tanks have been installed in the building.

Technical assistance was furnished to the Reactor Division in connection with the HFBR primary cooling pumps and the Medical Research Reactor exhaust fans. Dynamic field balancing equipment that had been used in the neutron chopper program was employed to reduce the fan unbalance on the exhaust fans, and a substantial reduction in vibration levels was effected. Analysis of vibration data from the primary pumps indicated that unbalance was not the basic problem, and recommendations were made for structure modifications or the addition of a damping device.

Extensive support was furnished to the high energy physics program. A neon recirculator and purifier system was designed and built and has been in operation for seven months. This recirculator minimizes the loss of neon in wire spark chambers. A second system has been designed and should be operating this year.

A large-angle spectrometer that included eight wire spark chambers was completed. Design work has been started and fabrication is under way on several large, double-gap, optical spark chambers and 16 wire spark chambers. Development work is continuing on the mechanical aspects of wire spark-chamber construction, and improvements have been made in winding techniques, sealing, and electrical connections.

A low-pressure Čerenkov counter was designed and fabricated in collaboration with scientific personnel from the State University of New York at Stony Brook.

Personnel assigned to the Nuclear Engineering Department have been involved in the Department's research and reactor programs.

At the HFBR, work was primarily concerned with the reactor's cooling-water holdup system. All design work, piping within the HFBR building, and the erection of the holdup tank have been completed, and the entire system should be in service within a few months.

The holdup system is an extensive array of piping, several tanks, and instrumentation, both inside the HFBR building and the cooling tower pump-house and basin and in the yard to the north of the HFBR building. This system was devised be-

cause vibration of the HFBR main heat exchanger tubes raised the possibility of tube failure and resultant contamination of the cooling tower with D_2O and possibly with tritium. Modifications were made to the flow in the exchangers to reduce vibration, and the holdup tank system will permit shutting down and blocking the whole water system before any tritium-bearing water can escape to the recharge basins. Means have been developed of dealing with contaminated water, should a leak occur.

A dual-channel irradiation facility was designed and installed in the HFBR in-core location V-16. Designs were prepared for both an ambient and an elevated temperature capsule at $1500^\circ F$ for this facility, which will be used in conjunction with the fast reactor fuel cladding development program.

Engineering assistance to the various capsule irradiation programs included design modifications of both the material surveillance facility in HFBR core-edge location V-13 and the vertical liquid nitrogen facility at the BGRR.

In the experimental reactor physics program, the fast source assembly FS-1 and a test cell, together with a plutonium exponential experiment consisting of a tank and five sets of lattice plates, were designed and fabricated.

A design was completed for a pulsed reactor critical assembly which will be used for the development of information for the pulsed reactor project.

Design work on irradiators, involving both cesium and cobalt sources, was done for the Radiation Division. In addition, much work was done on designing casks with appropriate crash shields for storage and shipment of sources. Among other devices designed were an automatic γ counting pig, a continuous delayed neutron device utilizing a high-speed tape covered with fissile material, two portable cesium irradiators, and a marine irradiator. In addition, standard Mark III sources were manufactured.

Special mention should be made of the blood irradiators designed for the Medical Department. To date two devices for irradiating human blood have been put into operation. Two more that will permit simultaneous irradiation of the blood of four animals are expected to be in operation late in 1968.

For the Heat Transfer Group, the Design Group has laid out numerous loops for mercury, NaK, and boiling potassium. These are impressive struc-

tures that occupy 1000 sq ft of floor space and are 30 to 40 ft high, with a large array of instrument panels. Temperatures as high as 1800°F have been used. With these facilities available the recent practice has been to modify the test sections for different experiments. The only new loop planned (for fiscal 1970) is one for condensing potassium.

The Engineering Group is assisting the research groups in the areas of air pollution, waste processing, water desalination, and hydride chemistry. In the last area the goal is to determine whether the formation and decomposition of certain hydrides can be of practical significance for hydrogen storage and use as a fuel. Demonstration units are being devised.

The Bubble Chamber Section has been involved in the operation of the 30, 31, and 80-in. bubble chambers as well as the design and construction of the 7-ft bubble chamber test facility.

Since the three bubble chambers have all been operated for a major portion of the year, engineering effort in this area has been on specialized modifications. Both the 30 and 31-in. chambers have had new optical designs, and plates have been added in the chamber for specific experiments. The major changes at the 80-in. bubble chamber have been the moving of the refrigerator to a separate building, design and construction of a new piston for use with the hydraulic expansion system, and completion of the design of the hydraulic actuator.

Design of the first phase of the gas storage area has been completed and the first tanks are in place. These tanks should be ready for the storage of $\approx 2\frac{1}{2}$ million standard cu ft of rare and valuable gases late in the fall of 1968.

About 75% of the Mechanical Engineering Division's available manpower has been devoted to the 7-ft test vessel and the 14-ft cryogenic bubble chamber research and development programs. The superconducting coil winding fixture for the 7-ft test facility was completed and all the pancakes have been wound. The magnet contains 16 double-layer pancakes stacked in 2 sets of 8 pancakes each. The coil is nearly 8 ft in i.d. and 8 ft high and will produce a central field of 30,000 G at a current of 6000 A. A full-scale test of the magnet was made in May 1968. The hydrogen vessel and all the cryogenic plumbing are being assembled, with a full-scale test of the complete facility planned for the fall. The helium refrigeration sys-

tem was successfully operated for > 1200 hr while tests on each piece of stabilized superconductor were performed. A complete fisheye lens assembly has been tested to operating pressure at liquid nitrogen temperature.

Based on experience gained in the 7-ft program, a complete review of the 14-ft bubble chamber design has been made, and a new proposal embodying all known improvements and cost-reducing techniques is in preparation for submission to the AEC.

Members of the Mechanical Engineering Division assigned to the Accelerator Department are divided into three groups, each supporting a separate division of the Department. Part of the group connected with the Experimental Planning and Support Division is involved in the design and maintenance of experimental equipment. In the Beam Separator Group the ground shield for dc beam separators was redesigned to reduce the electrical volume within the vacuum enclosure of a dc separator. Tests have shown that there now appears to be no interaction between the electrical and magnetic fields, and the separator operates for longer periods of time between conditionings and at higher electrical fields. For the rf separators a sophisticated polishing tool was developed to clean and polish the irises of the rf structure after arcing had occurred within the cavities. This tool is inserted and indexed to the desired iris, and then lightly clamped to adjacent irises, after which polishing heads are extended to perform the polishing.

In connection with beam transport, a large magnet-transporting device is being designed and fabricated which is capable of lifting, moving, and positioning a 100-ton spectrometer magnet within the necessary alignment tolerances. A new 6×72 -in. C-magnet has been designed and four units are on order for use in the slow external beam. A small septum magnet has been designed and will be purchased with 6N8Q12 quadrupole magnets for use in Phase III of the slow external beam system, and a complete vacuum system has been designed for Phase II.

In the past year the Cryogenic Group has designed and fabricated five new hydrogen targets consisting of Mylar flasks wrapped with multilayer insulation and fitted into a vacuum envelope to conform to the experimenters' requirements. These all have complete auxiliary liquid-hydrogen handling apparatus.

The solid hydrogen superconducting magnet system was operational during the year. Certain problems encountered with the magnet recharging techniques have been resolved. The refrigerator performed for >1600 hr of operating time, the longest period of continuous operation being two weeks.

The warm-bore liquid-helium superconducting quadrupole magnet Dewar and reservoir has been assembled and tested as a liquid helium container. The static heat leak to the system, which will contain a 3½-in.-diam by 24-in.-long focusing quadrupole magnet, was measured at 3 W. A superconducting dipole magnet Dewar system has also been designed.

A contract has been let with the Air Reduction Corp. for the fabrication of a small high-speed gas-bearing turbo expander and compact heat exchanger system. This unit will be part of a helium refrigerator and will be capable of removing 30 W at 4°K without liquid nitrogen precooling. The unit is designed to be mounted with a superconducting magnet Dewar and is to be used to evaluate the gas-bearing turbine for reliability, performance, and sensitivity to gas stream impurities.

Additional services were performed by this group for various BNL activities outside the Accelerator Department. Specification development, solicitation, and facility inspection were done in connection with the purchase of liquid nitrogen, liquid and gaseous hydrogen, liquid and gaseous helium, and deuterium gas.

Assistance was given the Supply and Materiel Division in the maintenance of liquid nitrogen dollies and the setting up of large-volume liquid nitrogen storage equipment. Liquid level measurement equipment for liquid helium Dewars was fabricated and supplied.

Miscellaneous activities included continuing design work on a 20°K neutron moderator for the HFBR. Consultation was provided on the problem of furnishing the Tandem Van de Graaff facility with a large supply of gaseous nitrogen from liquid storage, as well as a large CO₂ supply. A design and test program is under way for the construction of a large neon purification system for a spark chamber. The liquid nitrogen system at the HFBR was made operational. Technical assistance was given to a research group planning to operate a liquid-gaseous hydrogen target system at the HFBR, and an automatic liquid-nitrogen fill system was installed in the Metallurgy Building.

The Conversion Group has continued the design, development, and fabrication of components for the 200-MeV linac and the conversion of the AGS magnet ring. For the linac, the design and development of the drift tubes has been finalized and the first 20 drift tubes are being produced here. Special brazing techniques have been developed to produce brazed joints in a hydrogen atmosphere with a minimum of flow over the adjacent surfaces. The techniques of deep hole drilling for the major drift-tube stem has been perfected, and preliminary contracts have been let as well as contracts for the machining of the copper for the drift-tube bodies.

The copper-clad steel for the linac tanks was manufactured and shipped to the low bidder for tank fabrication. Actual manufacture is expected to take place shortly.

An electron beam welder has been purchased and is being installed. It will be used to perform the final closure of the drift tubes after the quadrupole magnets have been installed.

A packaging design for heavy electronic equipment is under way, and solicitations have been sent out for cabinets and enclosures for this equipment. Development of 12-in. rf transmission line and components has continued and final design is almost completed.

The AGS Ring Conversion Group has placed an order for about 250 main vacuum chambers, and materials for these chambers are currently being measured at the plant of the International Nickel Corp. Matching halves of the chambers have to be paired so that their combined resistance is as nearly equal as the number of pieces will allow. This has been done to better than the 3% tolerance expected. Tooling for the fabrication of the chambers is complete, and fabrication of the prototype chambers should be finished soon.

The Survey Group has been working on the problem of remotely surveying the AGS ring in high radiation areas. A TV camera has been attached to the telescope of a Wild T-2 theodolite. In addition, a commercial design has been purchased from the Kern Instrument Co. which utilizes a Kern theodolite completely equipped with servo controls on all the adjustments. It has been tested and found to be accurate to within 1 sec of arc.

The design of the new ferrite accelerating cavities is almost complete. A slot in the outer casing through which the cooling tubes for the cooling

plates protrude allows external connections to be made to these tubes in a zero-field region, which eliminates the need for organic insulating connections.

Design consultation and review have continued on the Siemens motor-generator set for the conversion, and agreement has been reached on the hold-down arrangement for the set and the details of the machine lubrication system.

The Experimental Area Operations Group of the Experimental Planning and Support Division is involved in the operational aspects of the experimental program. During the year there were, on the average, 10 experimental beams either in operation or under construction in the East, West, and North Experimental Areas. Detailed scheduling allowed continuous construction while the areas were in use.

The Survey Group completed another vertical alignment check on the ring magnets during the fall 1967 shutdown. The total variation was ≈ 0.100 in. The Survey Group did the initial control work on the new linac construction as well as the layout for the electrical service sleeves that were installed during the fall shutdown. Assistance was given the Tandem Van de Graaff Group in preliminary alignment of the Tandem Van de Graaff Accelerator, and beam layout work at the HFBR continues.

An effort has been made to reduce AGS downtime due to magnet failure and to improve the radiation resistance of certain magnets in the G-10 area. Eight of the magnets, those closest to the G-10 target, were provided with wooden skirts to deflect any water spray due to leaks away from adjacent components and down to water detectors that register in the central control room. In addition, coil jumper hoses have been fitted with quick-disconnect fittings to facilitate their regular replacement with minimum exposure of personnel to radiation. Plans are now being made to replace these hoses with ceramic spacers. All magnets in the G-10 area have been fitted with 1¼-in. flexible bronze water supply and return hoses to replace the neoprene rubber hoses that had proved unsatisfactory.

The group working with the AGS Division has been involved in improving the reliability of the AGS as well as in the installation of completely new equipment.

The high-gradient accelerating column, under development for several years, will shortly be opera-

tional. It consists of a stack of 15 ceramic rings, each 2½ in. thick with an outside diameter of 28 in., separated by metal disks. Prior to construction of the first operational column, investigations were carried out to insure the mechanical integrity of the unit. Tests of the metal-to-ceramic bond of epoxy resins were completed and a suitable epoxy and assembly technique was found. A full cross-section mechanical test unit, ⅓ the length of the final column, was constructed to study the adequacy of the materials and methods to be used in the final column. Loads were applied that were three times the normal working load, and the temperature was varied by 40° F to test the effects of stresses caused by thermal expansion. An operational column constructed with use of these techniques has successfully undergone electrical tests. Installation is expected in the fall of 1968.

The high-gradient accelerating column will be able to inject a higher intensity beam into the 50-MeV linac. To provide power for the acceleration of this beam, more rf power is needed for the linac, as well as greater stability. The rf transmission line equipment for a three-port feed arrangement to the linac has been completed and will be installed in the fall of 1968.

A new facility for chemistry experiments has been set up at the G-20 location in the AGS ring. It will enable chemists to carry out experiments in the direct proton beam, away from the high radiation area at G-10. A target box with two target and airlock systems has been installed, and a pneumatic transport system for use in conjunction with one of the airlocks is ready for bench tests. The transport system will enable the experimenters to remove foil targets shortly after exposure, without shutting down the AGS.

Magnetic shields of ¼-in.-thick steel sheets have been installed on the AGS ring magnets. Their primary function is to shield the main ring aperture from the earth's magnetic field, but they will also provide shielding from the stray field of adjacent magnetic apparatus.

Some evapor-ion pumps on the main ring have been replaced with vacuum pumps of the sputter-ion type to reduce maintenance and therefore exposure of personnel to radiation. Fast pumping systems have been installed on the airlocks to provide additional pumping speed when required.

The design, fabrication, and installation of components for the slow external beam in the AGS has been a major project. Water-cooled backleg wind-

ings have been installed on eight ring magnets to provide the orbit bump for the extraction system. Septum and ejector magnets, complete with vacuum boxes and remote moving and sensing mechanisms, were installed in the F-5 and F-10 straight sections. The ejector magnet can operate at currents up to 6400 A and for a duration of 600 msec. After the beam is extracted it passes through an extraction channel and beam transport system. The transport magnet's vacuum system and instrumentation to study the beam are remotely controlled. Suitable flags and other devices can be mounted on the extraction line, and viewing ports allow TV cameras to view flags of various sensitivities.

New wide-aperture ferrite magnets in the fast kicker at L-10 and larger multiturn bump coils have been installed to reduce aperture restrictions in the AGS and increase beam intensity. In the continuing effort to replace organic materials with more radiation-resistant ones, metal C-rings are replacing O-rings as vacuum seals and ceramic materials are being introduced as insulation for AGS machine components.

For the Chemistry Department many small instruments, shields, and devices were designed by the resident staff, modifications were completed on several larger pieces of equipment, and engineering assistance was given for proposed experiments.

A velocity selector has been designed to provide a beam of radioactive molecules of known velocities for use in the radioactive molecular beam apparatus. Slotted disks, each with 360 windows, rotate at controlled speeds up to 16,000 rpm and select velocity bands to a resolution of $\approx 3\%$. A nonradioactive crossed beam is used as a target, and the velocity spectrum of the radioactive species from the velocity-selected beam is analyzed by time-of-flight methods. Since the velocity selector must operate in an evacuated chamber, problems of lubrication, gas contamination, and remote movement of the rotating disk carriage were encountered.

A new type of x-ray diffractometer, the Automatic Equi-inclination Spectrometer Operating in Parallel (AESOP), is under development. The diffractometer should be capable of collecting Bragg diffraction data from protein crystals ≈ 10 times faster than is possible with present techniques, a factor of great importance because protein crystals tend to decompose under x-radiation. Data will be collected and fed into a small digital computer by 128 silicon diffuse junction detectors, mounted in

a semicircular array in a vacuum-insulated box. The computer will also be used to position the crystal and detector bank. The monochromator, test crystals, and detector array must be precisely aligned and this alignment maintained as crystal layers are scanned. Design to close tolerances, problems of cooling the detectors to liquid nitrogen temperatures, and provision of a compact and clean vacuum system have presented many challenges.

MACHINE SHOPS

As of January 1st of this year the Central Shops, which provide the Laboratory with on-site fabrication and repair of experimental equipment, vendor fabrication, inspection and quality control, and repair and maintenance of machine tools, became a part of the Mechanical Engineering Division. This organizational change has offered the many scientific and supporting activities increased technical assistance and greater fabrication potential through closer communication and a better understanding of fabrication capabilities. Administration of the Laboratory's machine-tool acquisitions and replacements, the machine-tool and small-tool standards programs, plus the selection, training, and placement of all machinists, welders, and sheet metal mechanics, are also the responsibility of the Central Shops.

Shop services offered to the many areas of the Laboratory accounted for 156,514 productive man-hours in fiscal 1968. Table 7 shows the distribution of this time among the various departments. A total of 11,363 hr were charged to intra-

Table 7
Contributions to Machine Shops Workload
(% man-hours)

	Fiscal year		
	1968	1967	1966
Accelerator	26.3	25.3	20.2
Biology	1.7	1.6	4.0
Chemistry	3.5	3.9	4.7
Instrumentation and Health Physics	0.8	0.5	0.9
Medical	2.2	2.5	3.1
Nuclear Engineering	18.1	21.8	22.1
Physics	39.8	36.4	35.9
Reactors	5.4	5.3	7.2
Miscellaneous	1.5	2.2	1.4
Outside contracts	0.7	0.5	0.5

Laboratory requisitions for men on loan to perform work within departments that could not be handled feasibly within the shops. Short-order work of 15 hr or less accounted for 14.6% of the productive time. The backlog of work in the machining, welding, and sheet-metal shops averaged 20,768 hr/mo for fiscal 1968.

During 1968, as in past years, the Division workload was varied. Some jobs were quite routine in nature while others required unique fabrication techniques. The pieces of equipment illustrated here display a cross section of the complex and exacting work handled in the Central Shops.

The magnetic shielding shown in Figure 4 was cut to size with plasma-arc equipment. This 6-in.-thick steel plate shields four large wire spark chambers from the fringe field of a 48D48 magnet. Edges of the rectangular opening in the center of the plate have been cut to the desired angle and to exact size by utilizing the photocell line tracing and angular offset capability of the welding shop's plasma-arc cutting machine. One-piece fabrication with the required accuracy and surface finish could not have been achieved by conventional flame-cutting methods.

The unit receiving final welding in Figure 5 is an all-stainless-steel piston for the expansion system of the 80-in. bubble chamber. Tolerances and design required that the many stages of machining and welding be performed under close surveillance of Division inspectors. A 54-in. vertical lathe is being used to establish proper alignment in this instance with welding equipment moved to the job, the reverse of normal procedures. Upon completion the unit will operate in liquid hydrogen and must withstand a pressure of 200 psi.

A crash shield for transporting a shipboard irradiator is shown in Figure 6. This 7½-ton shield was designed to meet current Department of Transportation and IAEA regulations pertaining to the transporting of radioactive materials. Fabricated in the welding shop from structural steels, it must withstand the equivalent of a 30-ft fall and protect the 34,000-lb irradiator from damage.

Occasionally work is performed for research groups outside the Laboratory. The gas differential Čerenkov counter in Figure 7 was made in its entirety by Central Shops for the State University of New York at Stony Brook. The vessel, consisting of a 126×30×6-in. aluminum chamber with a highly reflective interior, an aluminum riser column, and a steel phototube housing, plus com-

ponent small parts, will be used in conjunction with a 30D72 magnet at the AGS. This 3000-lb assembly represents vacuum and pressure-tight welding, sheet-metal forming to exacting dimensions, and precision heavy machining.

Numerically controlled equipment continued to be a most valuable asset to the machine shops in both the saving of time and minimizing of machine operator errors. Typical of the work that can be handled very efficiently on the shops' numerically controlled equipment are the several low-temperature control panels for the 7-ft test facility, one of which is illustrated in Figure 8. This 48×120-in. aluminum sheet contains a total of 203 drilled, tapped, and countersunk holes varying in diameter from ⅝ to 4⅞ in. During the year >2500 parts, involving the drilling of >63,000 holes plus milling, boring, and tapping, were made on tape-controlled machines. A total of 425 new tapes were programmed and added to the existing storage file of 965 tapes. A catalogue listing of this information has been distributed to all design groups and shop foremen to enable them to design around existing tapes whenever possible.

The Division's Vendor Fabrication Section, which is part of the Laboratory Vendor-Survey Group, is responsible for the fabrication of parts off-site to help reduce Central and Staff Shops' backlog. It also arranges for services for which no on-site facilities are available, maintains awareness of vendor capabilities, and administers the Laboratory's open contracts for short-order machining, plating, and anodizing. During 1968, 252 orders were placed with 51 different vendor companies. Fabricated parts and services worth \$165,705 were purchased.

The Inspection and Quality Control Section has continued to provide 100% inspection of all parts fabricated within the shops and complete inspection of all vendor-fabricated items contracted through the Division. Requests for in-process field inspections and acceptance inspection of scientific apparatus have increased appreciably during 1968. Source inspection of 1068 copper forgings, witnessing the magnafluxing of large steel castings at a steel foundry, and inspecting four sets of optics manufactured for the 7-ft test facility are typical of these requests. Calibration of precision measuring tools, assistance with the installation of research equipment, and qualification testing of welders are a few of the other services offered by this group.

Figure 4. A piece of magnetic shielding for use with a wire spark chamber experiment.

Figure 5. Stainless steel piston for the expansion system of the 80-in. bubble chamber.

Figure 6. Crash shield for protection of a shipboard irradiator during transportation.

During the year, \$160,000 was spent on replacements and additions to the Laboratory's machine tools, with an additional \$17,600 used to rebuild two machines assigned to the heavy machine shop. In this instance, the cost of rebuilding represents about $\frac{1}{3}$ the cost of two new comparable machines. The requests to handle larger pieces of material in the fabrication of experimental equipment account for acquisition this year of a second electric discharge machine and a second numerically controlled horizontal boring, milling, and drilling machine. These machines are of greater capacity than the older equipment in both work size and cutting ability.

Additions and modifications to the Central Shops' buildings continued into 1968 and have provided the Machine Maintenance Group with an enlarged shop and a crane-serviced machine overhaul area. Increased storage room for machine-tool replacement parts and improved lighting were included. Additional space for precision machining, welding, engraving, and tool and cutter grinding at the heavy machine shop, plus a new tool crib, has increased the efficiency of operation and made possible better utilization of the equipment.

Figure 7. Gas chamber, phototube housing, and component parts of Čerenkov counter made for the State University of New York at Stony Brook.

Figure 8. Numerically controlled machining of a typical low-temperature control panel for the 7-ft test facility.

TECHNICAL INFORMATION

The responsibilities of the Information Division include the operation of the Research and Classified Libraries, the editing, processing, and distribution of Laboratory reports, patent review, and some of the aspects of public information and education. These activities are discussed below.

The construction of an addition to the Research Library to provide 2700 sq ft of stack space started

in November. This marked the beginning of a 12-month construction and renovation program to expand and modernize the Library. Phase I, providing for a 30 × 90-ft addition and the erection of new metal stacks, was completed in April. The entire collection of books, journals, and reports has been moved into the new wing. Nearly 100,000 volumes will have to be moved a second time when the last phase is completed. The first half of the renovation, to be completed shortly after the end of fiscal 1968, will include relocation of the Xerox and microreproduction equipment and of the administrative and technical processing staff.

The confusion and noise accompanying the construction have not discouraged use of the Library. Circulation of literature, particularly of books, has increased. The total of interlibrary loan transactions has remained at the previous annual level, with the number borrowed by other institutions exceeding by $\frac{1}{3}$ the number borrowed by the Research Library. A significant increase has been noted in the use of the copying service provided by the Library and the Quick Copy Center.

Interest in Soviet Union literature remains high. Although many of the translated Russian scientific journals are received here, the Library, through the services of its translator, provided full translations of 60 scientific articles.

The Library continues to participate in programs sponsored by the New York State Library and the Long Island Library Resources Council. The latter organization has recently appointed an executive director and its plans should soon become operative. The Research Library is expected to make a major contribution, as a special library, to this cooperative program, which is conducted by the public, academic, and special libraries of Nassau and Suffolk Counties.

The Classified Library received 464 documents, 45 of which are secret, during the past year. As the new Safeguards and Materials Program at BNL gets under way, increased activity in the volume of incoming classified reports is anticipated. Some 45 reports have been declassified, and >2700 older documents have been destroyed. As of December 31, the total holdings consisted of $\approx 15,000$ documents, 5400 of which were secret.

During the year a total of 1109 scientific and technical manuscripts resulting from BNL-supported research were processed by the Division, for publication in the open literature. This compares with a total of 1240 in the previous year. The activities of the Editorial Section in processing formal Laboratory reports remained at about the same level as in previous years.

The film library, a comprehensive collection of 16-mm motion pictures on many aspects of nuclear energy at both popular and professional levels, was very active, particularly during the winter months. Films are lent, free of charge, to schools, civic groups, and research institutions on Long Island. During the year 535 such loans were arranged, an increase of 163 over the previous year.

The BNL Patent Office is responsible for the review and clearance for patent matters of all scientific and technical manuscripts covering the Laboratory's research. The number of inventions reported by this office during fiscal 1968 dropped from the unusual high of the previous year to the long-term average. This decrease probably results in part from the decrease in the number of scientific manuscripts processed. The number of patent applications was $\approx 18\%$ less than in the previous year, but still above the long-term average. A summary of the activities of the Patent Office during fiscal 1968 and the two previous years is given in Table 8.

INTERNATIONAL COOPERATION

The spirit of international cooperation in science is greatly fostered by the many arrangements whereby foreign scientists come to work at Brookhaven and Laboratory scientists attend overseas meetings and conferences. In addition, BNL is involved in formal programs of cooperation with the Greek Nuclear Research Center (Demokritos) and the Puerto Rico Nuclear Center.

Table 8

	Fiscal year		
	1968	1967	1966
Patent clearances	1218	1367	1155
Preliminary invention reports	—	—	3*
Records of invention	38	54	39
Patent applications	18	22	22

*Discontinued during fiscal 1966.

The first of these programs, initiated late in 1965, has continued during the past year with exchanges of scientists between the two laboratories. The purposes of this program, which is carried out under the auspices of the US AEC's Division of International Affairs, are to exchange ideas and to cooperate in scientific problems of mutual interest. Regular visits of scientific personnel from BNL to Demokritos have been arranged, and several items of surplus BNL scientific equipment have been lent to the Greek Center. Greek scientists have also been encouraged to visit and work at BNL. The areas of cooperation include medicine, biology, isotope production, high energy physics, solid state physics, and chemistry.

BNL scientists are advising Demokritos on the installation of an advanced flying-spot digitizing system for measuring bubble chamber photographs, on the production of the isotope Tc^{99} for medical applications, and on the diagnostic applications of neutron activation analysis. During the year BNL has assisted Demokritos' research programs by supplying, on loan, a spectrophotometer with a flame photometry attachment, a fluorometer for the study of fluorescence of organic compounds, and collimators for the radioisotopic scanning of body organs.

In a novel extension of the program, a group of five graduate students from Demokritos are visiting BNL for a two-month period in the summer of 1968. Financed in part by both institutions, the summer research program is expected to broaden the practical research experience of these students and to enrich the cosmopolitan atmosphere at BNL.

During the period of this report, July 1967 through June 1968, eight BNL staff scientists visited Demokritos under the auspices of the cooperative program.

The second of these cooperative programs, with the Puerto Rico Nuclear Center, was established

in 1961. Since that time the Laboratory has provided scientific and technical assistance in the development of two research groups in solid state physics at the Center. The first group started work in 1962 using the Mayagüez reactor for neutron diffraction studies. The second group, established three years later at the Center's Rio Piedras Laboratory in San Juan, has been concerned with fundamental properties of organic semiconductors. Scientists in both programs have for several years been publishing their work regularly in recognized scientific journals.

Contact between Brookhaven and the Center is now maintained principally through joint research projects, and work at the two laboratories is often complementary in nature. The latter is especially true in the area of organic semiconductors. The two laboratories have continued an exchange of visiting scientists. Although now at a much reduced level from that of the early days of the cooperative program, this exchange of visitors is still very useful in overcoming the problem of the geographical isolation of Puerto Rico and in contributing to the effectiveness of joint research efforts.

While the solid state programs at the Center are now largely self-sustaining, continued cooperative assistance can be very beneficial in certain areas. Computing facilities in Puerto Rico have improved, but by the standards of modern scientific laboratories they are still quite limited. Technical problems with equipment constitute another main area in which continued assistance is needed. In addition, continuation of the cooperative and professional contacts that have been established on a more limited basis in other research activities, particularly in chemistry and in reactor physics, will help to promote the general development of science at the Center and at the University of Puerto Rico.

During April and May the Head of BNL's Information Division served as Director of the Technical Information Center at the Atoms in Action Exhibit at Taipei, Taiwan, Republic of China. This exhibit, one of the US AEC's Demonstration Centers in foreign countries, is designed to stimulate public interest in the peaceful uses of atomic energy, as well as to assist scientists in the host country in the development of their own research programs.

Administration and Operations

The management operations reviewed in this section have been designed to facilitate and encourage the research activities of the Laboratory's scientific staff.

PERSONNEL

Scientific Staff and Students

As shown in Table 1, the number of regular staff members increased by $\approx 2\frac{1}{2}\%$ during the 12 months ending May 31, 1968. This is about one-half the rate of increase during each of the three previous years. As in the past, turnover remained significantly high: 51 scientists and engineers were appointed to the staff, and 39 terminated their appointments.

The number of salaried visitors decreased to the lowest total since 1960. This was due to a reduc-

tion in the number of postdoctoral Research Associates, which reached an eight-year low. During the year, 40 recent graduates began salaried appointments as Research Associates, and 50 completed their postdoctoral investigations. Of the latter, 11 were promoted to the regular staff.

The number of scientists and students holding nonsalaried appointments continued to increase, with some 10% of the total using the Laboratory facilities on a regular, full-time basis. More than 750 individuals in this category participate intermittently, for periods of up to several weeks at a time.

May 31, instead of June 30, was used in Table 1 to exclude from the statistics those who work at Brookhaven only during the summer months. Similarly, May 31 was used in Table 2 to avoid including participants in two summer programs.

Table 1

Scientific Staff and Students on May 31, 1968 and 1967

	Visitors					
	Regular staff		Salaried		Nonsalaried	
	1968	1967	1968	1967	1968	1967
By appointment category						
Staff						
Senior Scientist	85	83	2	1	65	66
Scientist	182	166	2	3	143	135
Associate Scientist	149	150	8	11	198	163
Assistant Scientist	60	65	10	9	106	110
Research Associate	—	—	72	82	76	75
Students						
Junior Research Associate	—	—	6	3	144	135
Research Assistant	—	—	0	0	98	81
Total	476	464	100	109	830*	765**
By academic degree						
Ph.D. or M.D.	347	330	90	102	554	525
Master	59	58	6	3	104	82
Bachelor	64	70	4	4	154	148
No degree	6	6	0	0	18	10

*66 of these appointees were at BNL on a full-time basis as of May 31, 1968.

**56 of these appointees were at BNL on a full-time basis as of May 31, 1967.

Table 2

Classification of Visiting Scientists and Students Participating in BNL Program
for one Month or More, June 1, 1967 - May 31, 1968

	Guests and salaried visitors				1967 Summer program		Total	
	More than 3 months		Less than 3 months		Salaried	Guest	Individuals	Institutions
	Salaried	Guest	Salaried	Guest				
University staff	21	47	6	76	75	35	260	105
Thesis students	7	28	0	31	5	6	77	31
Student Research Assistants	0	20	1	24	137	39	221	87
Subtotal	28	95	7	131	217	80	558	155 different
Industry	0	1	0	1	0	1	3	3
Other institutions	14	35	4	21	3	6	83	48
Total	42	131	11	153	220	87	644	206 different

Table 2 lists the number of visiting scientists (exclusive of salaried Research Associates) and students who worked at the Laboratory for cumulative periods of one month or more. The total of 644 individuals compares with 596 last year and represents an all-time high. The over-all increase is due to increased participation by students.

Table 3 shows the extent to which consultants' services have been employed during each of the past three years.

Summer Program for 1968

Arrangements have been made for 274 visiting scientists and students to work at the Laboratory during the summer of 1968. Of this number, 120 are staff members from colleges, universities, and other institutions, and 154 are students.

Special groups include 115 students in the Laboratory's 17th annual summer student program and 13 Health Physics Fellows.

Employment

Throughout fiscal 1968 the Laboratory employed a total of 363 persons. As of June 30, the population, exclusive of guests, research collaborators, and temporary appointees, numbered 3337, a net increase of 4 over last year (Figure 1). Table 4 details the employment experience for the year.

Utilizing the guidelines established by President Johnson in his nationwide campaign to provide meaningful employment for disadvantaged young people, the Laboratory participated, for the third

Table 3
Consultants' Services

	Fiscal year		
	1968	1967	1966
Total contracts in effect June 30	104	109	98
Number of consultants used	74	58	59
Number of man-days of service	617	478	472

summer, in the Youth Opportunity Campaign. A total of 23 trainees were employed in technical and clerical positions, with excellent results.

A second program, administered by the Laboratory in conjunction with the Board of Cooperative Educational Services, offered part-time employment to 13 local high school students. In selecting these youngsters, particular emphasis was placed on those who were truly disadvantaged and expressed a desire to learn skills that would better equip them for employment after graduation.

In June 1967 an Equal Opportunity Advisory Committee, consisting of five members, was appointed by the Director to aid in the evaluation of the Laboratory's policy on equal opportunity. The Committee's advisory function in areas of employment, training, and recruitment continues to strengthen the affirmative actions taken by the Laboratory to ensure equality of opportunity.

The Laboratory's voluntary participation in the Plans for Progress program has served to establish

Figure 1. Laboratory growth.

close liaison with some 20 local organizations specializing in minority group referrals. In addition to these recruitment efforts, teams visited local high schools with predominantly high percentages of minority and disadvantaged youngsters to instruct them on employment procedures and career goals. Students from these schools subsequently visited the Laboratory for further insight into employment situations in which they would soon find themselves.

Training, Education, and Communications

The supervisory training program continued throughout the year and dealt with such topics as labor relations, wage and salary administration, employment, and benefit programs.

The new tuition refund policy, which became effective July 1, 1967, increased reimbursements to 178 employees by 24.5% over the preceding year.

Two AEC Technical Scholarships were awarded to Laboratory employees in April. The program allows selected employees the opportunity to complete their undergraduate education on a full-time basis while still receiving total employment benefits. The highly competitive program, which operates throughout six laboratories of the AEC, awards 12 scholarships per year valued at more than \$25,000 each. Since the beginning of this program in 1966, six laboratory employees have been selected for the award.

On June 3, 1967, the Laboratory established an on-site curriculum for about 50 employees interested in obtaining their high school equivalency diplomas. The course, representing some 80 hours

Table 4				
Employment Statistics*				
	June 30, 1968		June 30, 1967	
Scientific staff**	555		563	
Scientific				
professional staff	393		389	
Nonscientific staff	2389		2381	
Total	3337		3333	
Turnover data	Number	1968 Annual rate (%)	Number	1967 Annual rate (%)
<u>Accessions</u>				
Scientific staff**	91	16	114	21
Scientific				
professional staff	52	13	56	14
Nonscientific staff	247	10	238	10
Total	390	12	408	12
<u>Separations</u>				
Scientific staff**	99	18	98	18
Scientific				
professional staff	48	12	57	15
Nonscientific staff	239	10	263	11
Total	386	12	418	13
<u>Net Accessions</u>				
Scientific staff**	-8	-1	16	3
Scientific				
professional staff	4	1	-1	-1
Nonscientific staff	8	0.3	-25	-1
Total	4	0.1	-10	-1

*Figures do not include 63 temporary summer non-student employees. Guests and temporary student employees are included in Table 2.

**Including Research Associates and visitors.

of instruction by certified high school teachers, is yet another part of the Laboratory's program of educational development.

In November 1967 the first edition of *Notes 'N Quotes*, a newsletter for supervisors, was distributed. The periodical, published quarterly by the Personnel Office, presents informative supervisory material drawn from various sources throughout industry and the Laboratory.

In March 1968 a Personnel Liaison Committee consisting of one scientific staff member from each

of the scientific departments was appointed by the Director to meet periodically with the Personnel Manager. These meetings are meant to encourage interdepartmental communication and to aid in the understanding of any personnel problems that may arise within these departments.

Labor Relations

Subsequent to a transfer of membership from the Directly Affiliated Local Union No. 24426 to the International Brotherhood of Electrical Workers (IBEW) in April 1967, a campaign was launched by the IBEW to enlarge its membership at the Laboratory. The campaign lasted into the summer of 1968 and was aimed at organizing the Laboratory's technical and clerical wage personnel. The Oil, Chemical, and Atomic Workers International Union (OCAW), representing 25 employees at the Laboratory, competed with the IBEW in an attempt to attract technicians to their organization. As of this writing their campaigns have been unsuccessful.

In October 1967 an unfair labor practice charge was filed against the Laboratory with the National Labor Relations Board (NLRB). The charge was filed by a former employee who had been discharged during his probationary period. Both the IBEW and the employee contended that the reason for termination was based on his membership in the Union and his activities in behalf of that organization. The NLRB denied the charge.

Contract negotiations between the Laboratory and the Long Island Guards Union, representing 30 patrolmen, resulted in settlement of a one-year contract agreement with a pay increase of 4.7% effective March 4, 1968.

Employee Services

The Group Medical Insurance Plan was modified to extend coverage to employees retiring on or after their 60th birthday. Formerly, the benefit applied only at age 62 or over.

During the year 12 employees retired, 142 received 10-year service awards, and 155 received similar recognition on the anniversary of their 20th year with the Laboratory.

PLANT ENGINEERING AND PLANNING

Plant planning, design, construction, operation, maintenance, and repair were consolidated in the new Plant Engineering and Planning Department.

This organization consists of a staff planning group and three operating Divisions, whose reports follow.

Plant Planning

The function of this new staff group is to study the adequacy of the Laboratory's physical and environmental systems for both present and future needs and to lead the design of their upgrading as necessary. Investigations have gone forward of the water and waste systems to assure conservation and adequate supply and to obviate pollution. A study of long-term heating and cooling requirements has been initiated to determine optimum installations now and in the future. The third five-year Master Plan was prepared and distributed. The group is collaborating with other Laboratory research, service, and administrative departments: with Biology and Meteorology in the ecological aspects of an environmental study; with Management Services in developing computer simulation models of the physical, environmental, and administrative systems; and with Nuclear Engineering and Meteorology in utilization of the steam plant stack in their Atmospheric Diagnostic Program.

Operation and Maintenance

This new division was formerly the Plant Maintenance Division. Under the direction of the Plant Engineer, the Division maintains all buildings and services and plant equipment in all buildings and outside, keeps the grounds, and operates, maintains, and repairs all plant utilities. In addition, it provides personnel on a chargeable basis to various departments to perform skilled labor for the scientific effort in the form of contributed technical services. Table 5 presents the breakdown of manpower utilization in fiscal 1967 and 1968.

Total expenses of the Division in fiscal 1968 were \$5,749,000. Of this amount, \$3,567,743 is directly chargeable to repairs, maintenance, and operation of Laboratory facilities. Table 6 gives a distribution of expenses for this year and last.

A review of BNL's cost reduction reports indicates that the Operation and Maintenance Division has taken an active part in the cost reduction program. For fiscal 1968 a cost reduction of \$160,510 was reported, the result of changes in operating procedures, use of less expensive materials, buying at minimum cost consistent with needs, and accelerating process improvements.

Table 5
Manpower Utilization

Type of work	Fiscal 1968		Fiscal 1967	
	Productive man-years	Percent of total work	Productive man-years	Percent of total work
Maintenance, repairs, and utilities operations	154	42.2	154	41.4
Major maintenance programs	—	—	2	0.5
Facility improvements	3	0.8	4	1.1
Research program support	107	29.3	110	29.6
Building janitor services	93	25.5	94	25.3
Decontamination	2	0.6	2	0.5
Hot Laundry operation	6	1.6	6	1.6
Total	365	100.0	372	100.0

Table 6
Costs of Supplies, Materials, and Contracts

	Fiscal 1968	Fiscal 1967
Maintenance and utilities materials	\$ 355,026	\$ 356,509
Major maintenance materials and contracts	421,012	512,729
Facility improvement materials	450,029	436,598
Building janitor supplies	69,508	70,419
Decontamination	499	976
Hot Laundry	9,283	9,252
Fuel oil	433,810	464,871
Electricity	1,828,576	1,838,201
Total	\$3,567,743	\$3,689,555

The Division seeks to maintain sufficient standard procedures, records, and reports to allow effective control of the maintenance operation, without becoming unnecessarily restrictive or over-emphasizing clerical operations. To implement this policy, a review of the present cost accounting systems is being conducted and will be developed in cooperation with the Management Services Group. A system of programmed maintenance is being designed in which a central file of all equipment maintained by the Division will be readily available to help evaluate equipment. In this way, equipment requiring excessive maintenance can be reviewed for ways of reducing maintenance costs, and data can be accumulated for benefit/cost and cost effectiveness studies.

Electrical Work

The new, vertically structured Electrical Division is responsible for design, construction, maintenance, and operation of the electric distribution

system. Under the Plant Electrical Engineer, the Division includes 58 engineers, designers, supervisors, electricians, and linemen recruited from the Accelerator Department and the former Plant Maintenance and Architectural Planning Divisions.

The purpose of the new divisional structure is to maintain close coordination in electrical work, from planning and design to operation and maintenance. The new structure provides for application of uniform electrical standards, greater depth of engineering competence, and prevention of duplication and conflict in electrical installations. An additional advantage is greater flexibility in utilization of electrical engineering and design manpower for the entire Laboratory.

During fiscal 1968 the Electrical Division prepared all contract drawings and specifications for construction work originating within Plant Engineering and Planning and for certain work requested by other departments. The Division handled the operation of the electric distribution

system, including emergency repairs in several instances of cable failure. Further progress was made in removal of overhead power and telephone lines. On Cornell and Brookhaven Avenues, 2500 ft of pole lines were replaced by underground facilities.

Detailed studies were made by the Division of the applicability of electric heat. A trial installation of infrared heaters was made in a maintenance shop area, and infrared and resistance heating systems were designed for installation in two new similar 5000-sq-ft warehouses.

A beginning was made in establishing uniform standards for electrical installation. Training was carried out through a 14-hr course in the National Electrical Code, instruction in artificial resuscitation, and several meetings on electrical equipment and methods.

Design and Construction

This Division, formerly Architectural Planning, acquired its present title because its responsibilities are principally in design and construction.

Five major facility projects with a total value of slightly less than \$65,000,000 were under construction or completed during fiscal 1968:

- Tandem Van de Graaff facility
- AGS Service Building addition
- Animal laboratories
- Lecture Hall-Cafeteria
- AGS conversion

The contracts for architect-engineer and construction work are held by the AEC and administered by its Brookhaven office, except for the AGS building and conversion projects, which are held by Associated Universities, Inc., and administered at BNL by the Accelerator Department. Certain portions of the AGS Service Building addition, the animal laboratories, and the Lecture Hall-Cafeteria were administered by the Design and Construction Division, which also acted on behalf of BNL in all other work to provide the liaison required from early planning through construction.

Small projects initiated or undertaken during the year amounted to \$1,395,000 under the General Plant Projects program. There were about 125 of these additions to, or modifications of, facilities, as well as miscellaneous site improvements. Many of these presented special engineering problems and required considerable design effort. As in the past, the Design and Construction and Operation and Maintenance Divisions worked closely to coordinate many of these projects; in

several cases Operation and Maintenance undertook management of the construction. The projects exceeding \$50,000 included modification and addition, Supply and Materiel Office Building; stockroom and stores building, bubble chamber area; site work and utilities, summer houses (phase III); shop addition, High Flux Beam Research Reactor; and an addition for the Physics Department's Design and Engineering Group.

The Design and Construction Division coordinates the issuance and reporting of all proposals for accelerator and reactor additions and modifications (ARAM projects) and participates to a considerable degree in the design of a number of these projects.

Early in 1968 the Division began preparing the data sheets for construction projects in the budget request for fiscal 1970. Work included site selections, preliminary building plans, cost estimates, and description for the projects listed below (total estimated cost, \$14,400,000).

- Applied Science Building, phase II
- Metallurgy Building addition
- Electron accelerator
- Bio-Medical adjunct facility
- General plant projects, fiscal 1970

During fiscal 1968, the Division continued to assist the Physics Department in delineating the scope of future large-scale bubble chamber facilities and building construction. Assistance was given to the Accelerator Department in connection with evaluation of Title I, II, and III design for the AGS conversion.

PLANT PROTECTION AND SECURITY

The Plant Protection and Security Division continued to perform its assigned functions during fiscal 1968.

Although the scope of the security function at the Laboratory has contracted substantially since Brookhaven's early days, the Laboratory continues to maintain an extremely active security clearance program. At the end of fiscal 1968, about 450 employees and affiliates required active "Q" clearance, and about 275 had active "L" clearances. These clearances are required in connection with classified material and documents at the Laboratory; they also give Brookhaven scientists and technical personnel full access, when necessary, to restricted data at BNL and at other laboratories and institutions.

The physical growth of the Laboratory and the expansion of its research programs have necessitated ever-increasing emphasis upon the Laboratory's plant protection program. The increase in this aspect of the Division's functions has been met through adaptation of industrial plant protection techniques and practices to the specialized requirements of Brookhaven. During fiscal 1968, the use of closed circuit television continued in the reactor complex, with gratifying results in effectiveness of operation and economy of manpower, until the standby status of the BGRR was effected in June. The number of Laboratory employees, coupled with a substantial increase in the number of persons visiting the Laboratory, has given rise to automobile traffic and parking problems, which have been effectively resolved.

The Laboratory's professional Fire Group maintained its excellent record in meeting potentially dangerous fire situations at the Laboratory. An active fire-inspection and fire-prevention program is a continuing and important aspect of the Fire Group's activities; close liaison with scientific and technical personnel engaged in research experiments and other activities presenting potential fire hazards is regularly maintained, with excellent results. During fiscal 1968, fire-fighting equipment has been increased and modernized, mutual aid fire-fighting agreements with nearby communities have been continued, and training in fire-fighting has been accelerated.

There were two major structural fires at the Laboratory during the year, as well as two large brush fires. Responses to fire alarms are tabulated below.

	1968	1967	1966
Responses on site	195	213	196
Responses off site	6	6	7
Investigations	60	67	106
Total	261	286	309

BUSINESS MANAGEMENT AND ADMINISTRATION

As a result of personnel turnover in the Supply and Materiel Division, the Assistant Supply and Materiel Manager was promoted to the post of Manager and a new Assistant Manager was appointed. A new Management Services Office was established to assist Laboratory organizational units in the areas of planning, administrative systems, and general management studies. Earlier in the year the Technical Photography and Graphic

Arts Division was transferred and became the responsibility of the Assistant Director for Business Management and Administration.

Comparative studies for the business management and administrative functions are presented in Tables 7 through 10.

Purchasing

One of the most significant events in the Purchasing Division during the past year was an invitation to appear before a hearing of the United States Congress conducted by the House Technical Program Subcommittee. W. J. Catacosinos was invited to explain the Brookhaven Offer of Sale concept. His report was favorably received by the Subcommittee, which recommended that the Department of Defense, the General Services Administration, and other Government agencies investigate the use of this concept in their procurement activities.

Automation was extended during the year to include computer preparation of all reports on Purchasing Division statistics required by management and the AEC. The preparation of these reports by computer rather than manually has reduced the amount of clerical time needed to prepare them and has also yielded more accurate statistical information.

Another computer application in Purchasing, reported previously in its trial stage, is the analysis of quotations for large numbers of stock items that are solicited from many suppliers. This has proved to be a significant and valuable use of the computer for Purchasing activities. Buyers had often been required to expend as much as 30 man-hours in manually analyzing one of these solicitations. With the aid of the computer, such an analysis now requires about three man-hours.

A more efficient filing scheme was instituted for the central file containing all open purchase-order documents. Previously arranged alphabetically by vendor, the file is now arranged numerically by BNL order number. The change has significantly reduced the time required for filing open orders and associated correspondence.

All Purchasing Division personnel continued their efforts to obtain cost savings in the face of rising prices, with a resultant reduction in documented costs of more than \$750,000. A sizable reduction in the price of deuterium gas was achieved through the use of a Brookhaven beneficiary-type contract which included Argonne

National Laboratory and the Pennsylvania-Princeton Accelerator. The price reduction was obtained by combining the separate quantities required by the three organizations.

As part of the Division's continuing programs for improving the professional capabilities of its personnel, two members of the Division attended a three-day training seminar in March at AEC Headquarters in Germantown, Md. The seminar was attended by representatives from all major AEC contractors, who exchanged information about procurement methods and presented case studies of unusual procurements. Other aspects of the Division's staff-training programs have been continued, and new programs that may be useful are being investigated.

Supply and Materiel

The Supply and Materiel Division is consolidating the majority of its functions into a centralized supply-depot type of operation. For this purpose, the necessary operational functions, together with their supporting administrative and clerical forces, are being relocated in a single convenient area of the Laboratory. This centralization effort is a result of the Division's established program for improving the effectiveness and efficiency of its working operations through continual analysis and re-evaluation of key functions.

The Inventory Management Section has continued its policy of including all inventory items on extended-term procurement actions. In a related effort, this section has also established preset delivery dates for vendors in order to reduce lead-times and stock-outages. The amount of additional typing formerly needed in the preparation of release orders has been greatly reduced through the use of reproduction equipment.

As a result of efforts by the Quality Control Section, purchases through the General Services Administration have increased by $\approx 30\%$ during the past three years. This section is also establishing nomenclature for all direct purchase items for the Accelerator Department. When completed, nomenclature for these items will be coded as input for a computer program to extract those repetitive items that can be included in the regular Supply and Materiel inventory. After the nomenclature has been established for these items, the same service will be extended to other major departments.

The Property Management Section, in cooperation with the Technical Photography and Graphic

Table 7

Distribution of Personnel

Division	Staff	Technical and clerical	Fiscal 1968 total	Fiscal 1967 total
Purchasing	24	17	41	42
Supply and Materiel	11	80	91	92
Systems and Data Processing	21	12	33	32
Technical Photography and Graphic Arts	10	46	56	—
Total	66	155	221	161

Table 8

Purchasing and Supply Operations

	Fiscal 1968	Fiscal 1967
Number of procurements	34,853	38,316
Value of procurements	\$32,505,002	\$24,694,049
Number of receiving actions	42,687	46,992
Number of stores issues	330,619	368,681
Value of inventory turnover	\$3,615,219	\$3,990,725

Table 9

Technical Photography Operations

	Fiscal year		
	1968	1967	1966
Photographs	18,058	14,565	12,979
Photomicrographs	8,728	9,682	6,201
Lantern slides	20,437	14,952	13,840
Prints	53,526	60,231	51,258
Film processed, ft	5,228,415	5,810,049	3,815,853
Charts & graphs drawn	4,904	5,433	4,348
Motion picture footage	25,372	20,706	32,011

Table 10

Graphic Arts Operations

	Fiscal year		
	1968	1967	1966
Photo-offset impressions	11,410,856	14,850,193	14,390,880
Quick Copy impressions	6,413,952	6,586,014	5,335,952
Reports and booklets, copies produced	53,150	86,355	80,625

Arts Division, is organizing a pool to promote the maximum utilization of photographic equipment. Full nomenclature will be established for all such equipment and recorded on edge-punched cards which can be conveniently used to publish updated lists of available photographic equipment on a periodic basis.

Systems and Data Processing

The need to continue Univac data-processing activities in parallel with those for the new IBM 360 severely taxed the capabilities of the Systems and Data Processing Division during the fiscal year. The Division handled ≈ 200 requests during the year for improvements in Univac programs and operations. These improvements, which affected all phases of Univac operations, entailed one man-year of systems design and two man-years of programming effort. Since nearly all Univac programs were in the process of being converted for use on the new IBM 360, a further comparable expenditure of manpower was required to incorporate these improvements in the conversion programs.

The IBM 360 Model 30 tape-and-disk computer system was installed on November 1. A new line of 80-column card equipment, required for IBM 360 support operations, was also installed. The new card support equipment includes a sorter, an interpreter, six key punches, and three card verifiers. An operator training program for the new computer and support equipment was successfully completed. Appropriate new operational procedures were instituted for the new equipment, and operating personnel were correspondingly shifted to new areas of responsibility. A regular operational schedule, incorporating nearly three dozen programs, has already been established for the IBM 360 computer. Extraordinary demands are now being imposed upon the Department's control and keypunch facilities because of the more exacting requirements of IBM 360 application systems and the need to support two computer installations during the conversion period. Arrangements for backup facilities have been established for both computer installations and will remain in effect throughout the conversion period.

In accordance with plans for utilizing the new IBM 360 computer, system designs were completed for the following major applications: supply and materiel inventory, payroll/personnel, job labor and material cost, capital equipment, and accounting and budget control. The inventory sys-

tem has been installed and final refinements are being made. IBM 360 programs needed in the remaining four major application areas are now being coded, tested, and debugged. Systems for two other IBM 360 applications, purchasing invitation bid and award analysis and purchasing statistical reporting, were designed and programmed during the year and are now operational. Recent additions to the IBM 360 applications plan are systems to be developed for personnel inventory and accounts payable applications.

The teleprocessing capability of Brookhaven's IBM 360 was utilized to establish a pilot remote-inquiry feature for the inventory system. This feature provides for the immediate retrieval of information such as quantity on hand, dollar value on hand, quantity on order, location, unit of measure, and class code for any inventory stock item. The turn-around time, from a remote console to the computer and back, averages 15 sec/inquiry. An even more elaborate inquiry feature was also developed for the payroll/personnel system. The Division's future plans include the development of similar teleprocessing inquiry features for all major IBM 360 application areas.

Although some necessary improvements are still being made in Univac programs, most of the Division's programmers are engaged primarily in IBM 360 conversion work. During the year, ≈ 4 man-years were expended on programmer training for the IBM 360. This continuing training effort, which will extend into fiscal 1969, is essential to the full and effective utilization of the sophisticated capabilities of the new computer installation.

Technical Photography and Graphic Arts

A decrease in photographic services to the Laboratory's scientific departments, a reflection of budgetary limitations, has been offset by increased still and motion picture activities in the areas of documentation and public relations.

To provide an accurate means of assigning charges for Technical Photography services, three distinct categories were established: photography, film processing, and illustration. This permits an appropriate separate hourly rate to be charged for work in each classification.

A Motion Picture Section was established for the preparation of documentary films on construction and research activities at Brookhaven. A film record of the construction of Brookhaven's 80-in. bubble chamber has been completed and assem-

bled into a 35-minute film. Another film record, now in preparation, will document the fabrication of the superconducting magnet coil for the 7-ft bubble chamber test facility. Work has also started on other film reports which will be concerned with research activities at Brookhaven. Film footage concerning the Laboratory's activities in the bio-satellite program was supplied by the Motion Picture Section to NBC for a 5-minute news spot on television. This footage included art work prepared by the Division's Illustration Section.

The Illustration Section was moved to a new location in a wing of the former Chemistry Building. Although the move further separates the Division's facilities, the new quarters are far more habitable than the old. The Illustration Section has added to its services the preparation of art work for motion pictures.

Advantage was taken of an AGS shutdown period to completely overhaul the film-processing machines and add the following planned improvements: an automatic hypo-transfer system, an automatic pH controller, and an air-operated end-of-film detector and brake.

An existing quality control procedure for film processing was refined to improve density control. The acceptable density range has been decreased for the five or six control strips processed and measured daily. Corrective action is taken at the time the density of a control strip is found to lie outside the acceptable range. To ensure uniformity of photographic composition, a new quality-control procedure was established which involves a twice-daily monitoring of Fotosetter light sources with a calibrated light meter.

Some of the larger reports produced within the BNL printing plant this year are listed below.

Title	Total	
	Pages	impressions
<i>A Data Compendium of Linear Graphs With Application to the Heisenberg Model</i> , BNL 50053 (T-460)	256	268,800
<i>Annual Report, July 1, 1967</i> , BNL 50057 (AS-21)	260	650,000
<i>ENDF/B, Specifications for an Evaluated Nuclear Data File for Reactor Applications</i> , BNL 50066 (T-467), ENDF 102	120	141,000
<i>Annual Report, Nuclear Engineering Department, December 31, 1967</i> , BNL 50082 (S-70)	202	181,800
<i>Proceedings of the International Conference on Solid State Physics Research With Accelerators</i> , BNL 50083 (C-52)	472	472,000

The Quick Copy Service Center now provides the Laboratory with 24-hr service for most quick copy jobs. This was achieved by reorganizing and integrating its Photo-Direct and Bruning duplicating services, its Xerox 2400 copy service, and its radio-directed pickup and delivery service.

A Bruning electrostatic copier, purchased last year for the purpose of making offset plates, has proved more economical and useful than expected. During fiscal 1968 it was used to make 21,455 plates at an estimated saving of \$5363. Although used primarily as a platemaker, it has also been found useful for copying computer print-outs. As recommended in an AEC appraisal of the printing plant, collating facilities were improved by the addition of a fast Rotomatic collator. Also installed was a new vertical film processor that can develop, fix, and wash film positives or negatives as large as 50 × 72 in. Its size now makes it possible to use the full capability of the 40 × 40-in. process camera.

STAFF SERVICES

The Staff Services Division provides the following services for members of the Laboratory staff and visitors.

Housing

On-site housing includes 1 to 4-bedroom family units, men's and women's residences, and a guest house. Housing facilities have been increased during the past year by the addition of 10 detached dwelling units for summer use. Total capacity (nearly 880 persons) is fully utilized each summer. Assignment, billing, and janitorial services are the responsibilities of the Housing Office.

Travel

A complete Travel Office is maintained. Tickets, reconfirmations, travel reservations, and accommodations are obtained for all personnel traveling in an official capacity. Tickets and associated reservations for space and cars for more than 6945 trips were processed this year. The Laboratory makes use of agreements that result in reduced rates for hotel and motel reservations and car rentals under certain circumstances for Laboratory employees on official travel status.

Telecommunications

Telephone, telegram, and teletype services for the Laboratory are operated by the Division. At

present 1860 lines and 3150 telephones are installed. The increase in lines and telephones from the previous year is due mainly to the completion and occupancy of the addition to the AGS Service Building.

Mail and Wire Service

Mail distribution service is maintained to effect frequent pickup and delivery of United States and interoffice mail at each of 90 Laboratory mail drops. In addition, standard distribution lists are maintained and an Elliott Dymatic 7000 addressing machine is used to facilitate efficient distribution of material to appropriate personnel. Three types of wire services are in daily use at the Laboratory: telegraph, teletype, and the Secure Automatic Data Information System (SADIE).

Transportation

About 22 vehicles are available on a trip basis for official business. Limited driver service is also available when use of a passenger-operated vehicle is not practical.

Motor Vehicles

The entire fleet of about 250 vehicles is acquired, maintained, assigned for use, rotated in assignment, and readied for disposal by the Division. Most vehicles are assigned to user departments or divisions and operated on a subpool basis to eliminate the need for drivers, dispatchers, and radios. Total mileage this year was 1.49 million.

Food Service

Food service is provided for Laboratory staff members and guests by a concessionaire from the new cafeteria, the Brookhaven Center, and vending machines. These operations are responsibilities of the Division.

Special Staff Services

The Laboratory is host annually to more than 120 scientific seminars, conferences, meetings, and special events that bring visitors to the Laboratory. A similar number of intra-Laboratory functions are conducted. Each requires all or some of the above services and in some instances additional services unique to the situation. The necessary planning, acquisition, and coordination of these services are additional functions of the Division.

Personnel

The Division is composed of 62 persons, consisting of housing, travel, and mail clerks, telephone and teletype operators, automobile and truck mechanics, janitors and matrons, and appropriate supervisory personnel.

CONFERENCES, PUBLIC INFORMATION, PUBLIC RELATIONS, AND EDUCATION

The 1967 annual series of George B. Pegram Lectures was planned for October of that year. The invited speaker was André Maurois, Man of Letters, who was preparing three lectures, collectively entitled "The Illusions." The first lecture was to be entitled "The Illusions of the Senses and the Sentiments," the second, "The Illusions of the Intellect and of Science," and the third, "The Conscious Illusions or the Fine Arts." Death occurred as he was about to come to Brookhaven to deliver these lectures. He had, however, prepared them fully, and his family sent them to the Laboratory for presentation and publication. The text was delivered in an abbreviated form in two lectures, May 13 and 15, by Dr. Jacques Barzun, University Professor of Columbia University, a distinguished historian and author in his own right.

The fifth AUI Distinguished Lecture was delivered on February 5 by Ian L. McHarg, Chairman of the Department of Landscape Architecture and Regional Planning at the University of Pennsylvania. His talk was entitled "Values, Process, and Form." The sixth AUI Distinguished Lecture was delivered on March 26 by Daniel S. Greenberg, News Editor of *Science*. The subject of his talk was "Scientists and Politicians: A View From the Press Box."

Eight major conferences were held at BNL during fiscal 1968: the International Conference on Solid State Physics Research With Accelerators, Sept. 25-28; the Woodland-Water Working Group of the International Biological Program, Dec. 28-29; Future Bubble Chamber Processing Conference, Jan. 24-25; Organic Solid-State Chemistry Symposium sponsored by BNL and the State University of New York at Stony Brook, March 25-28; Conference on Industrial Needs and Academic Research in Reactor Kinetics, April 8-9; Proton Linear Accelerator Conference, May 20-24; Biology Symposium No. 21, entitled "Structure, Function, and Evolution in Proteins," June 3-5; and

the Summer Study on Superconducting Devices and Accelerators, June 10-July 19.

In addition, a number of smaller conferences were held: Industrial Traffic Conference, Oct. 17-18; Semiannual AEC Computer Information Meeting, Nov. 1-2; National Neutron Cross Section Center Advisory Committee Meeting, Nov. 28-29; Cross Section Evaluation Group Meeting, Jan. 16-17; and the 14th meeting of the Advisory Committee on Isotopes and Radiation Development to the AEC, March 14-15.

The following meetings took place during the fiscal year: annual meeting of AEC Laboratory Directors, July 8-9; Bio-Medical Program Directors' Meeting, Oct. 1-10; Safety Review Committee for 14-foot Cryogenic Bubble Chamber Project, Oct. 21-22; Planning Board of International Commission on Radiation Units and Measurements, March 25-29; and the 11th meeting of the European-American Committee on Reactor Physics, June 3-5.

The 14th annual High School Visitors' Day, held October 21, was attended by about 4500 students representing 179 high schools and 56 junior high schools. This year College Visitors' Day was combined with Visitors' Day, held October 28, which was attended by about 6000 persons. College students from 45 colleges were represented.

On February 13, BNL observed the 12th Science Youth Day in commemoration of Thomas Alva Edison's birthday. The program was an in-depth study of chemistry research as conducted at BNL. The event was attended by 133 selected students and 29 teachers from 33 Suffolk County high schools.

Eight lectures in the BNL Lecture Series were delivered during the year by staff members, who discussed their work.

Three National Science Foundation teachers-in-training seminars, comprising 102 persons, were given talks on the Laboratory's research and tours through the major facilities. In addition, 4 groups of teachers totaling 56 persons toured the Laboratory. At various times during the year, 96 senior

engineering students from the U.S. Military Academy at West Point came to the Laboratory. A total of 267 students visited BNL in 19 groups, and the Medical Department was host to 62 nurses during fiscal 1968.

During the year the following foreign groups visited BNL: 4 students from the University of Mexico, July 11; 33 French students participating in the People-to-People Program, July 14; 10 German students participating in the People-to-People Program, Aug. 8; 25 engineering students from Chalmers Institute of Technology, Sweden, Aug. 18; 6 foreign students living at International House, April 2; and 14 Fulbright scholars from abroad, most of them in the medical profession, May 10.

Nineteen professional groups totaling 472 persons came for one-day visits to BNL. In addition, participants in Columbia University's Advanced Science Writing Program of the Graduate School of Journalism made their annual two-day visit on February 5-6.

Twelve speeches were delivered by Laboratory staff members to civic, church, and educational groups.

Twenty-nine experts in the organization and leading of extracurricular scientific activities for young people toured the research facilities.

On Nov. 3, staff members of Nassau County's Planning Commission visited BNL, and on Dec. 1 its commissioners and officers visited the Laboratory.

A U.S. Naval Reserve research symposium entitled "Hazards Control in Nuclear Research" was held during a training weekend, June 8-9.

A total of 603 foreign scientists visited BNL during fiscal 1968.

The Public Information Office experienced a steady increase in requests for information and advice from students and teachers. Most of these are requests for assistance in the preparation of science projects and term papers. An extensive stock of booklets and information sheets suffices in the majority of cases, but some require specialized attention.

Appendix A

PUBLICATIONS, JULY 1, 1967 - JUNE 30, 1968

This list includes official Laboratory publications, abstracts of papers which were or will be presented at scientific meetings, and publications by staff members, consultants, and guests. 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 publications is designated by (in press).

GENERAL PUBLICATIONS

Annual Report, July 1, 1967. BNL 50057 (AS-21).

Annual Report, Nuclear Engineering Department, Dec. 31, 1967. BNL 50082 (S-70).

Conference Reports:

Brookhaven Symposia in Biology No. 20. *Recovery and Repair Mechanisms in Radiobiology*. BNL 50058 (C-51).

Proceedings of the International Conference on Solid State Physics Research With Accelerators, Sept. 25-28, 1967. BNL 50083 (C-52).

Proceedings of the Brookhaven Conference on Industrial Needs and Academic Research in Reactor Kinetics, April 8-9, 1968. BNL 50117 (T-497). (Official Use Only.)

Brookhaven Lecture Series:

44. *Talking to Computers*, J.E. DENES. BNL 50074 (T-472).

48. *Extracorporeal Irradiation of the Blood and Lymph in the Study of Normal and Leukemic Cell Proliferation*, E.P. CRONKITE. BNL 50088 (T-480).

56. *Gamma Rays for Fun and Profit*, B. MANOWITZ. BNL 50084 (T-477).

59. *The Dynamic Structure of Liquids*, A. PASKIN. BNL 50080 (T-475).

63. *The Cellular Basis of Acute Radiation Death in the Mammal*, V.P. BOND. BNL 50064 (T-465).

64. *The Rise and Stability of the Earth's Atmosphere*, L.V. BERKNER, Southwest Center for Advanced Studies, and L.C. MARSHALL, Southern Illinois University. BNL 50114 (T-496).

67. *The Mechanisms of Oxidation-Reduction Reactions in Solution*, N. SUTIN. BNL 50070 (T-469).

70. *Radiation and Organic Liquids*, D.J. METZ. BNL 50110 (T-493).

71. *Tampering With Heredity: The Genetic Transformation of Bacteria by DNA*, S. LACKS. BNL 50101 (T-488).

72. *The Atomic Electrons and Nuclear Transition: Some Interrelationships*, M.L. PERLMAN. BNL 50100 (T-487).

*Also included are those listings from the last annual report [BNL 50057 (AS-21)] for which complete reference information was not then available.

High-Temperature Liquid-Metal Technology Review:

Vol. 5, No. 4, Aug. 1967. BNL 50077 (PR-28).

Vol. 5, No. 5, Oct. 1967. BNL 50089 (PR-29).

Vol. 5, No. 6, Dec. 1967. BNL 50096 (PR-30).

Vol. 6, No. 1, Feb. 1968. BNL 50107 (PR-31).

Vol. 6, No. 2, April 1968. BNL 50115 (PR-32).

Vol. 6, No. 3, June 1968. BNL 50127 (PR-33).

Informal Reports:

The 14-Foot Cryogenic Bubble Chamber Research and Development Program. The 7-Foot Test Facility. BNL 11810.

Scaling Studies of Large Cryogenic Bubble Chambers. BNL 12336.

Miscellaneous:

Dose-Effect Modifying Factors in Radiation Protection, Report of Subcommittee M-4 (Relative Biological Effectiveness) of the National Commission on Radiation Protection, Aug. 1967. BNL 50073 (T-471).

Progress Report of Work Sponsored by the Fuels and Materials Branch, Division of Reactor Development and Technology, United States Atomic Energy Commission (Official Use Only):

Quarterly, July 1-Sept. 30, 1967. BNL 50078 (T-474).

Annual, Jan. 1-Dec. 31, 1967. BNL 50092 (T-482).

Quarterly, Jan. 1-March 31, 1968. BNL 50111 (T-494).

Quarterly, April 1-June 30, 1968. BNL 50123 (T-501).

Weekly Bulletin 21, No. 4-52; 22, No. 1-3.

Weekly Selected Reading List 20, No. 10-52; 21, No. 1-7.

STAFF PUBLICATIONS AND ABSTRACTS

Accelerator Department

ADAIR, R.K. A diffraction disassociation model of very high energy nucleon-nucleon interactions and the diffusion of cosmic rays through the atmosphere. Submitted to *Phys. Rev.*

ADAIR, R.K. - See also KASHA, H.; STEFANSKI, R.J.

ADAMS, R.R., CASSEL, R.L., DISTENFELD, C.H., FORSYTH, E.B., FRANKEL, R.S., GEFFERS, W.E., GREEN, G.K.,

- GRISOLI, J.J., MASCHKE, A.W., RAKA, E.C., SPIRO, J., AND VAN STEENBERGEN, A. Performance report on the AGS. In *Proc. 6th Int. Conf. High Energy Accelerators, Cambridge, Mass., Sept. 1967*, pp. 436-44, R.A. Mack, Editor, CEAL-2000, Cambridge Electron Accelerator, Cambridge, Mass., Dec. 1967.
- ALLINGER, J.E. - See DANBY, G.T.
- BERLEY, D. - See MAYNARD, J.
- BETH, R.A. Energy and forces in two-dimensional magnetic fields. In *Proc. 2nd Int. Conf. Magnet Technology, Oxford, July 1967*, pp. 135-9, H. Hadley, Editor, Rutherford High Energy Laboratory, Chilton, England, 1967.
- BETH, R.A. An integral formula for two-dimensional fields. *J. Appl. Phys.* **38**, 4689-92 (1967).
- BETH, R.A. Some extensions of complex methods for two-dimensional fields. In *Proc. 6th Int. Conf. High Energy Accelerators, Cambridge, Mass., Sept. 1967*, pp. 387-90, R.A. Mack, Editor, CEAL-2000, Cambridge Electron Accelerator, Cambridge, Mass., Dec. 1967.
- BLEWETT, J.P. The history of linear accelerators. In *Linear Accelerators*, Chap. I, P. Lapostolle and A. Septier, Editors, North-Holland, Amsterdam (in press).
- BLEWETT, J.P. Interactions between elementary particle research and engineering. In *Interactions of Elementary Particle Research in Science and Technology*, L.C.L. Yuan, Editor, Academic, New York (in press).
- BRITTON, R.B. - See MORGAN, G.H.; SAMPSON, W.B.
- CAMPBELL, D. - See MAYNARD, J.
- CARIDES, T., COTTINGHAM, J.G., FELTMAN, A.V., GROSSMAN, A.S., LEIPUNER, L.B., MARINUZZI, J.G., AND SCHWENDER, G.E. Cathode ray film scanner. *Rev. Sci. Instr.* **38**, 1425-9 (1967).
- CARTER, D. Field stabilization in periodic systems. Informal Report BNL 11841.
- CARTER, D. Linac phase error calculations. Informal Report BNL 11817.
- CASSEL, R.L. - See ADAMS, R.R.
- CHASMAN, R. Outline of a six-dimensional particle motion program with space-charge forces for linacs. Informal Report BNL 12307.
- CLAUS, J. Preliminary space-charge considerations in the AGS. Informal Report BNL 12356.
- COTTINGHAM, J.G. - See CARIDES, T.
- COURANT, E.D. Accelerators for high intensities and high energies. *Ann. Rev. Nucl. Sci.* (in press).
- DAHL, P.F. - See MORGAN, G.H.; SAMPSON, W.B.
- DANBY, G.T., ALLINGER, J.E., AND JACKSON, J.W. A separated function magnet lattice for a very high energy synchrotron. In *Proc. 2nd Int. Conf. Magnet Technology, Oxford, July 1967*, pp. 87-101, H. Hadley, Editor, Rutherford High Energy Laboratory, Chilton, England, 1967.
- DANBY, G.T., ALLINGER, J.E., AND JACKSON, J.W. Separated function synchrotrons. In *Proc. 6th Int. Conf. High Energy Accelerators, Cambridge, Mass., Sept. 1967*, pp. 49-53, R.A. Mack, Editor, CEAL-2000, Cambridge Electron Accelerator, Cambridge, Mass., Dec. 1967.
- FELTMAN, A.V. - See CARIDES, T.
- FERBEL, T. AND FOELSCH, H.W.J. Top energy π^+p separation in beam No. 4 at the AGS. Informal Report BNL 12459.
- FOELSCH, H.W.J. - See FERBEL, T.
- FORSYTH, E.B. Modulator applications in high energy accelerators. In *Proc. 10th Modulator Symposium, New York, May 1968* (in press).
- FORSYTH, E.B. - See also ADAMS, R.R.
- FOSTER, E.H. - See HAHN, H.
- FRANKEL, R. Automatic measurement of equilibrium orbits at the Brookhaven AGS. Submitted to *Rev. Sci. Instr.*
- FRANKEL, R. - See also ADAMS, R.R.
- FULLING, S.A. Superperiod gradient perturbations in the AGS studied to second order. Informal Report BNL 11760.
- FULLING, S.A. AND MONTH, M. Theoretical analysis of gradient perturbations in the AGS. Informal Report BNL 11818.
- GEFERS, W.E. - See ADAMS, R.R.
- GREEN, G.K. - See ADAMS, R.R.
- GRISOLI, J.J. - See ADAMS, R.R.
- GROSSMAN, A.S. - See CARIDES, T.
- HAHN, H. Analysis of iris-loaded deflectors in the small-hole approximation. Informal Report BNL 12143.
- HAHN, H. Optimization of alternating-periodic iris-loaded deflectors for superconducting rf beam separators. In *Proc. 1968 Proton Linear Accelerator Conference, Brookhaven National Laboratory, May 1968* (in press).
- HAHN, H. AND HALAMA, H.J. Experimental study of superconducting TE₀₁₁ cavities at 2.868 GHz. (A) Presented at Applied Superconductivity Conference and Exhibition, Austin, Texas, Nov. 1967.
- HAHN, H. AND HALAMA, H.J. Perturbation measurement of transverse R/Q in iris-loaded waveguides. *IEEE Trans. Microwave Theory Tech.* **MTT-16**, 20-9 (1968).
- HAHN, H. AND HALAMA, H.J. Q measurements of superconducting cavities at 2.868 GHz. (A) In *Proc. 1968 Summer Study on Superconducting Devices and Accelerators, Brookhaven National Laboratory, June 10-July 19, 1968* (in press).
- HAHN, H., HALAMA, H.J., AND FOSTER, F.H. Measurement of the surface resistance of superconducting lead at 2.868 GHz. *J. Appl. Phys.* **39**, 2606-9 (1968).
- HAHN, H., HALAMA, H.J., AND FOSTER, E.H. Measurement of Q of superconducting TE₀₁₁ cavities by frequency sweep technique. In *Proc. 6th Int. Conf. High Energy Accelerators, Cambridge, Mass., Sept. 1967*, pp. A139-43, R.A. Mack, Editor, CEAL-2000, Cambridge Electron Accelerator, Cambridge, Mass., Dec. 1967.
- HALAMA, H.J. - See HAHN, H.
- HAWKINS, C.B.J. - See KASHA, H.
- JACKSON, J.W. - See DANBY, G.T.
- JELLETT, K. AND PARZEN, G. The electric field on linac drift tube surfaces. Informal Report BNL 12434.
- KASDEN, A. - See MAYNARD, J.
- KASHA, H., HAWKINS, C.B.J., AND STEFANSKI, R.J. Momentum spectrum and charge excess of cosmic ray muons at large zenith angles. *Can. J. Phys.* **46**, Pt. 2, s306-8 (1968).
- KASHA, H., HAWKINS, C.B.J., AND STEFANSKI, R.J. Search for heavy singly charged particles in cosmic rays. *Ibid.*, Pt. 3, s727-9.
- KASHA, H., LARSEN, R.C., LEIPUNER, L.B., AND ADAIR, R.K. Search for particles with charge $\frac{2}{3}e$ in cosmic rays. *Ibid.*, Pt. 3, s730-3.

- KASHA, H., LARSEN, R.C., LEIPUNER, L.B., AND ADAIR, R.K. Search for particles with fractional charge $\geq \frac{1}{2}e$ in cosmic rays. (L) *Phys. Rev. Letters* **20**, 217-20 (1968).
- KASHA, H. AND STEFANSKI, R. J. Limit on the presence of heavy stable fundamental particles in the primary cosmic radiation. (L) *Ibid.* 1256-8 (1968).
- KASHA, H. AND STEFANSKI, R. J. Search for heavy triplets in cosmic rays. *Phys. Rev.* (in press).
- KASHA, H. - See also STEFANSKI, R. J.
- KOVARIK, V. J. AND SLUYTERS, T. J.M. Discussion of H.V. power supply units connected with high gradient tubes in linac preinjectors. In *Proc. 6th Proton Linear Accelerator Conference, Brookhaven National Laboratory, May 1968* (in press).
- KOVARIK, V. J. - See also SLUYTERS, T. J.M.
- LARSEN, R.C. - See KASHA, H.; STEFANSKI, R. J.
- LEE, M. J. Steady-state beam loading of a standing wave linac rf system. In *Proc. 6th Proton Linear Accelerator Conference, Brookhaven National Laboratory, May 1968* (in press).
- LEE, M. J. Steady-state beam loading of the linac rf system. Informal Report BNL 12418.
- LEE, M. J. Transient beam loading in standing wave linacs. In *Proc. 6th Proton Linear Accelerator Conference, Brookhaven National Laboratory, May 1968* (in press); Informal Report BNL 12231.
- LEIPUNER, L.B. - See CARIDES, T.; KASHA, H.
- LEVINE, G.S., CASEY, W.R., DISTENFELD, C.H., MOORE, W.H., AND SMITH, L.W. Sand as a side shield for 30-GeV protons stopping in the Brookhaven AGS. *Nucl. Instr. Methods* **55**, 253-68 (1967).
- MAJESTIC, R. - See MAYNARD, J.
- MARINUZZI, J.G. - See CARIDES, T.
- MASCHKE, A.W. - See ADAMS, R.R.
- MAYNARD, J., BERLEY, D., CAMPBELL, D., KASDEN, A., KOEHLER, J., MAJESTIC, R., NAUENBERG, U., AND RADLHAMMER, G. A magnetic field fit to the 30-in. BNL bubble chamber. Informal Report BNL 12374.
- MCINTURFF, A.D. Magnetization studies of Nb₃Sn and Ti (22%-60% Nb). (A) *Bull. Amer. Phys. Soc.* **13**, 730 (1968).
- MONTH, M. Effects of sextupoles near a one-third integral ν value in the AGS: An example. Informal Report BNL 11759.
- MONTH, M. Effects of sextupoles near a one-third integral ν value in the AGS: Theory. Informal Report BNL 11614.
- MONTH, M. - See also FULLING, S.A.
- MOORE, W.H. - See JESSEPH, J.E. (Medical); LEVINE, G.S.; NORMAN, B.A.; TISLJAR-LENTULIS, G.M. (Medical).
- MORGAN, G.H., DAHL, P.F., SAMPSON, W.B., AND BRITTON, R.B. Measurements of energy losses in pulsed superconducting magnets. Submitted to *J. Appl. Phys.*
- MORGAN, G.H. - See also SAMPSON, W.B.
- NAUENBERG, U. - See MAYNARD, J.
- NORMAN, B.A. AND MOORE, W.H. Theory and design of beam transport systems. Informal Report BNL 12138.
- PARZEN, G. A mesh-iteration program for field calculations in linac cavities. In *Proc. 6th Proton Linear Accelerator Conference, Brookhaven National Laboratory, May 1968* (in press).
- PARZEN, G. Perturbation and tolerances in a 200-MeV proton linac. In *Proc. 6th Int. Conf. High Energy Accelerators, Cambridge, Mass., Sept. 1967*, pp. A34-8, R.A. Mack, Editor, CEAL-2000, Cambridge Electron Accelerator, Cambridge, Mass., Dec. 1967.
- PARZEN, G. Superconducting FFAG accelerators. Informal Report 12060; (A) In *Proc. 1968 Summer Study on Superconducting Devices and Accelerators, Brookhaven National Laboratory, June 10-July 19, 1968* (in press).
- PARZEN, G. Superconducting magnetic dipoles. (A) *Ibid.*
- PARZEN, G. - See also JELLETT, K.
- RADLHAMMER, G. - See MAYNARD, J.
- RAKA, E.C. Measurement of the shift in frequency of the coherent vertical betatron oscillations at injection as a function of beam current in the AGS. Informal Report BNL 11631.
- RAKA, E.C. Measuring betatron frequencies in the Brookhaven AGS. Informal Report BNL 11703.
- RAKA, E.C. The nature of the transverse instability in the Brookhaven AGS. In *Proc. 6th Int. Conf. High Energy Accelerators, Cambridge, Mass., Sept. 1967*, pp. 428-30, R.A. Mack, Editor, CEAL-2000, Cambridge Electron Accelerator, Cambridge, Mass., Dec. 1967.
- RAKA, E.C. - See also ADAMS, R.R.
- SAMPSON, W.B. Superconducting magnets for beam handling and accelerators. In *Proc. 2nd Int. Conf. Magnet Technology, Oxford, July 1967*, pp. 574-8, H. Hadley, Editor, Rutherford High Energy Laboratory, Chilton, England, 1967.
- SAMPSON, W.B., BRITTON, R.B., MORGAN, G.H., AND DAHL, P.F. Superconducting synchrotron magnets. In *Proc. 6th Int. Conf. High Energy Accelerators, Cambridge, Mass., Sept. 1967*, pp. 393-6, R.A. Mack, Editor, CEAL-2000, Cambridge Electron Accelerator, Cambridge, Mass., Dec. 1967.
- SAMPSON, W.B. - See also MORGAN, G.H.
- SCHWENDER, G.E. - See CARIDES, T.
- SLUYTERS, T. J.M. Recent progress in linac pre-accelerators. In *6th Proton Linear Accelerator Conference, Brookhaven National Laboratory, May 1968* (in press).
- SLUYTERS, T. J.M. AND KOVARIK, V. J. Large brightness beams up to 200 mA in a 750-kV high gradient preinjector. In *Proc. 6th Int. Conf. High Energy Accelerators, Cambridge, Mass., Sept. 1967*, pp. 275-83, R.A. Mack, Editor, CEAL-2000, Cambridge Electron Accelerator, Cambridge, Mass., Dec. 1967.
- SLUYTERS, T. J.M. - See also KOVARIK, V. J.
- SMITH, L.W. - See LEVINE, G.S.
- SPIRO, J. - See ADAMS, R.R.
- STEFANSKI, R. J., ADAIR, R.K., AND KASHA, H. Spectrum of high-energy cosmic-ray muons at a zenith angle of 75°. (L) *Phys. Rev. Letters* **20**, 950-2 (1968).
- STEFANSKI, R. J., ADAIR, R.K., KASHA, H., AND LARSEN, R.C. Large area time-of-flight counter system. *Rev. Sci. Instr.* **38**, 1792-3 (1967).
- STEFANSKI, R. J. - See also KASHA, H.
- VAN STEENBERGEN, A. Effective transverse phase dilution and beam density distribution in the AGS. In *Proc. 6th Int. Conf. High Energy Accelerators, Cambridge, Mass., Sept. 1967*, pp. 431-5, R.A. Mack, Editor, CEAL-2000, Cambridge Electron Accelerator, Cambridge, Mass., Dec. 1967.
- VAN STEENBERGEN, A. - See also ADAMS, R.R.
- VOGEL, U. Beam deflecting elements and their effect on closed orbits in the AGS. Method of calculation with illustrative examples. Informal Report BNL 12375.

WHEELER, G.W. Progress report on the AGS conversion project. In *Proc. 6th Int. Conf. High Energy Accelerators*, Cambridge, Mass., Sept. 1967, pp. 414-18, R.A. Mack, Editor, CEAL-2000, Cambridge Electron Accelerator, Cambridge, Mass., Dec. 1967.

Applied Mathematics Department

- BAKER, G.A. JR. Best error bounds for Padé approximants to convergent series of Stieltjes. Submitted to *J. Math. Phys.*
- BAKER, G.A. JR. A certain unfolding problem. Submitted to *Math. Computation*.
- BAKER, G.A. JR. Convergent, bounding approximation procedures with applications to the ferromagnetic Ising model. *Phys. Rev.* **161**, 434-45 (1957); *J. Appl. Phys.* **39**, 616-18 (1968).
- BAKER, G.A. JR. Some rigorous inequalities satisfied by the ferromagnetic Ising model in a magnetic field. (*L*) *Phys. Rev. Letters* **20**, 990-2 (1968).
- BAKER, G.A. JR., GILBERT, H.E., EVE, J., AND RUSHBROOKE, G.S. *A Data Compendium of Linear Graphs With Application to the Heisenberg Model*. BNL 50053 (T-460), May 1967.
- BAKER, G.A. JR., GILBERT, H.E., EVE, J., AND RUSHBROOKE, G.S. High-temperature expansions for the spin- $\frac{1}{2}$ Heisenberg model. *Phys. Rev.* **164**, 800-17 (1967).
- BAKER, G.A. JR. AND KAHANE, J. Critical point singularities of the perturbation series for the ground state of a many-fermion system. Submitted to *J. Math. Phys.*
- CAMPBELL, G., FUCHEL, K., AND HELLER, S. Extended core storage as an adjunct to multiprogramming operating systems. Presented at Nat. Conf. and Exposition, Ass. for Computing Machinery, Las Vegas, Nev., Aug. 1968.
- CANNON, J.R. AND CECCHI, M.M. Numerical experiments on the solution of some biharmonic problems by mathematical programming techniques. *SIAM J. Numerical Analysis* **4**, 147-54 (1967).
- CANNON, J.R. AND DOUGLAS, J. JR. The Cauchy problem for the heat equation. *Ibid.*, 317-36 (1967).
- CANNON, J.R. AND FILMER, D.L. The determination of unknown parameters in analytic systems of ordinary differential equations. *SIAM J. Appl. Math.* **15**, 799-809 (1967).
- CANNON, J.R. AND HILL, C.D. Continuous dependence of bonded solutions of a linear parabolic partial differential equation upon interior Cauchy data. *Duke Math. J.* **35**, 217-30 (1968).
- CANNON, J.R. - See also FILMER, D.L.
- CECCHI, M.M. - See CANNON, J.R.
- COLEMAN, P.R. - See LICK, D.W.
- DENES, J.E. BROOKNET - An extended core storage oriented network of computers at Brookhaven National Laboratory. In *Proc. 4th Congr. Int. Fed. for Information Processing*, Edinburgh, Aug. 1968 (in press).
- DENES, J.E. *Talking to Computers*, Brookhaven Lecture Series No. 44, Feb. 24, 1965. BNL 50074 (T-472).
- DOMB, C. Self-avoiding walks on lattices. Submitted to *Advan. Chem. Phys.*
- DOUGLAS, J. JR. - See CANNON, J.R.
- EICKER, F. On the probability that a sample distribution function lies below a polygon. Submitted to *Ann. Math. Statistics*.
- EISEN, D. Consistency conditions for difference schemes with singular coefficients. *Math. Computation* **22**, 247-51 (1968).
- EISEN, D. The equivalence of stability and convergence for finite difference schemes with singular coefficients. *Numerische Math.* **10**, 20-9 (1967).
- EISEN, D. On the construction of consistent finite difference schemes with certain invariant subspaces. *SIAM J. Numerical Analysis* **4**, 349-56 (1967).
- EISEN, D. On the numerical analysis of a fourth order wave equation. *Ibid.*, 457-64 (1967).
- EISEN, D. On the numerical solution of $u_t = u_{rr} + (2/r)u_r$. *Numerische Math.* **10**, 397-409 (1967).
- EVE, J. - See BAKER, G.A. JR.
- FANNIN, K.R. The Brookhaven digital communications network. In *Proc 4th Congr. Int. Fed. for Information Processing*, Edinburgh, Aug. 1968.
- FILMER, D.L., CANNON, J. R., AND REISS, N. A method for the determination of rate constants in enzyme reactions. *J. Theoret. Biol.* **16**, 280-93 (1967).
- FILMER, D.L. - See also CANNON, J.R.
- FRIEDMANN, M., GILLIS, J., AND LIRON, N. Laminar flow in a pipe at low and moderate Reynolds numbers. *Appl. Sci. Res.* (in press).
- FUCHEL, K. AND HELLER, S. Consideration in the design of a multiple computer system with extended core storage. *Commun. Ass. for Computing Machinery* **11**, 334-40 (1968).
- FUCHEL, K. AND HELLER, S. FORTRAN for Brookhaven's CDC 6600 computer. Informal Report BNL 11584.
- FUCHEL, K. - See also CAMPBELL, G.
- GILBERT, H.E. - See BAKER, G.A. JR.
- GILLIS, J. - See FRIEDMANN, M.
- GOLDSTEIN, C.I. Analytic perturbations of the operator $-\Delta$. Submitted to *J. Appl. Math. Analysis Appl.*
- GOLDSTEIN, C.I. Eigenfunction expansions and scattering theory for certain infinite domains. (A) Submitted to *Amer. Math. Soc. Notices*.
- GOLDSTEIN, C.I. Eigenfunction expansions associated with the Laplacian for certain domains with infinite boundaries. Pts. I and II, *Trans. Amer. Math. Soc.* (in press); Pt. III, submitted to *Trans. Amer. Math. Soc.*
- HALTON, J.H. Some properties associated with square Fibonacci numbers. *Fibonacci Quart.* **5**, 347-56 (1967).
- HELLER, S. On the uniform positivity of a certain finite difference matrix. *Numerische Math.* **11**, 46-52 (1968).
- HELLER, S. - See also CAMPBELL, G.; FUCHEL, K.
- HILL, C.D. - See CANNON, J.R.
- JENKS, R.D. On automatic general solutions to all-integer inequalities. Informal Report BNL 12279.
- JOHNSON, W.R. AND KAHANE, J. The Ω^- as a $\Xi \bar{K}$ bound state. *Nuovo Cimento* **52**, 746-71 (1967).
- KAHANE, J. An algorithm for reducing contracted products of γ -matrices. *J. Math. Phys.* (in press).
- KAHANE, J. - See also BAKER, G.A. JR.; JOHNSON, W.R.
- KAWAGUTI, M. A proposal for a new digitizer of bubble chamber photographs. *Nucl. Instr. Methods* (in press).
- KLEINMAN, B.S. Gaussian transform evaluation of multi-center integrals with a shielded-coulomb potential: e^{-r}/r . Submitted to *J. Chem. Phys.*

- LICK, D.W. A divergence theorem for a nonlinear Dirichlet problem. Submitted to *J. Computational Phys.*
- LICK, D.W. Existence-uniqueness theorems for nonlinear Dirichlet problems. (A) *Amer. Math. Soc. Notices* 15, 95 (1968).
- LICK, D.W. A nonlinear Dirichlet problem with application to quasi-linear problems. Informal Report BNL 11811.
- LICK, D.W. A note on a nonlinear Dirichlet problem. Informal Report BNL 11809.
- LICK, D.W. On restricted nonlinear Dirichlet problems. Submitted to *J. London Math. Soc.*
- LICK, D.W. The remarkable Bernoulli family. Submitted to *Math. Teacher.*
- LICK, D.W. Why not mathematics? *Ibid.*
- LICK, D.W. AND COLEMAN, P.R. The approximate solution of a quasi-linear Dirichlet problem. Informal Report BNL 12015.
- LICK, D.W. AND TUNSTALL, J.N. A nonlinear elliptic boundary value problem. Informal Report BNL 12014.
- LICK, D.W. AND TUNSTALL, J.N. The numerical solution of a diffusion-convective corrosion problem. *Nucl. Sci. Eng.* 33, 1-6 (1968).
- LICK, D.W. AND TUNSTALL, J.N. *A Study of Nonlinear Dirichlet Problems.* AEC Research and Development Report K-1737, Feb. 27, 1968.
- LICK, D.W. - See also STEWART, G.W. III
- LIRON, N. - See FRIEDMANN, M.
- OSHER, S.J. Necessary conditions for similarity of certain Volterra integral operators. *Amer. Math. Soc. Mem.* 73, 1-22 (1967).
- OSHER, S.J. On systems of difference equations with wrong boundary values. Submitted to *Math. Computation.*
- OSHER, S.J. Stability of difference approximations of dissipative type for mixed initial-boundary value problems. I. *Ibid.*
- OSHER, S.J. Stability of mixed implicit difference schemes. (A) Submitted to *Amer. Math. Soc. Notices.*
- OSHER, S.J. Sufficient conditions for similarity of certain Volterra integral operators. *Amer. Math. Soc. Mem.* 73, 23-47 (1967).
- OSHER, S.J. Systems of difference equations with general homogeneous boundary conditions. *Trans. Amer. Math. Soc.* (in press.)
- PINCUS, J.D. Commutators and systems of singular integral equations. I. *Acta Math.* (in press).
- PINCUS, J.D. AND ROVNYAK, J. A spectral theory for some unbounded self-adjoint singular integral operators. *Amer. J. Math.* (in press).
- REISS, N. - See FILMER, D.L.
- ROVNYAK, J. - See PINCUS, J.D.
- RUSHBROOKE, G.S. - See BAKER, G.A. JR.
- SHIMAMOTO, Y. - See CHEN, K. (Chemistry).
- SIROVICH, L. - See THURBER, J.K.
- SKIBINSKY, M. The class of distributions on $[0,1]$ all of whose normalized moments are equal. (A) Presented at 74th Ann. Meet. Amer. Math. Soc., San Francisco, Jan. 1968.
- SKIBINSKY, M. Extreme n th moments for distributions on $[0,1]$ and the inverse of a moment space map. Submitted to *J. Appl. Probability.*
- SKIBINSKY, M. Extreme n th moments for distributions on $[0,1]$ and the inverse of a moment space map to the n -dimensional unit cube. (A) Submitted to *Ann. Math. Statistics.*
- SKIBINSKY, M. Minimax estimation of a random probability whose first N moments are known. *Ann. Math. Statistics* 39, 492-501 (1968).
- SKIBINSKY, M. Minimax prediction of random probabilities. *SIAM J. Appl. Math.* (in press).
- SKIBINSKY, M. Some known results concerning zero-one sets. Submitted to *Ann. Math. Statistics.*
- SKIBINSKY, M. Some striking properties of binomial and beta moments. *Ibid.*
- STEWART, G.W. III AND LICK, D.W. The numerical solution of a thin plate heat transfer problem. *Commun. Ass. for Computing Machinery* (in press).
- TAINITER, M. Generating functions on idempotent semigroups with application to combinatorial analysis. *J. Combinatorial Theory* (in press).
- TAINITER, M. Remarks on idempotents in semigroups. *Ibid.*
- TAINITER, M. Semicharacters and Mobius functions on commutative semigroups of idempotents. Presented at Soc. Ind. Appl. Math. Meet., Santa Barbara, Calif., Nov. 1967.
- THURBER, J.K. An algorithm for the solution of the homogeneous Hilbert problem in several unknown functions for a system of smooth closed curves and arcs containing at least one end point. Informal Report BNL 12509.
- THURBER, J.K. On limit points for roots of dispersion laws of model equations. (A) In *Proc. 6th Symp. Rarefied Gas Dynamics, MIT, Cambridge, Mass., July 1968* (in press).
- THURBER, J.K. The solution of programming problems by generating functions. In *Proc. Int. Symp. Mathematical Programming, Princeton, N. J., Aug. 1967.*
- THURBER, J.K. AND SIROVICH, L. On some mathematical aspects of kinetic model equations. *Quart. Appl. Math.* 25, 175-86 (1967).
- THURBER, J.K. AND SIROVICH, L. Plane wave propagation in kinetic theory. *J. Math. Phys.* 8, 888-95 (1967); Pt. II, *J. Math. Phys.* (in press).
- THURBER, J.K. - See also DORNING, J. J. (Nuclear Engineering).
- TUNSTALL, J.N. - See LICK, D.W.

Biology Department

- ABATA, J. J. AND BAKER, D.G. Liver RNA synthesis in continuously irradiated rats. (A) In *Proc. 16th Annu. Meet. Radiat. Res. Soc., Houston, Texas, April 1968* (in press).
- ABATA, J. J. AND BAKER, D.G. Nucleic acid changes in liver and intestine during chronic irradiation. (A) *Radiat. Res.* 31, 662 (1967).
- AKOYUNOGLU, G.A. AND SIEGELMAN, H.W. Protochlorophyll resynthesis in dark-grown bean leaves. *Plant Physiol.* 43, 66-8 (1968).
- ALONZO, N. AND HIRS, C.H.W. Automation of sample application in amino acid analyzers. *Anal. Biochem.* 23, 272-88 (1968).
- ALONZO, N. - See also KYCIA, J.H.
- ALTSZULER, N. - See STEELE, R.

- AMES, I.H. AND MITRA, J. Distribution of heterochromatin in the chromosomes of *Haplopappus gracilis*. *Can. J. Genet. Cytol.* (in press).
- AMES, I.H. AND MITRA, J. DNA replication pattern in somatic chromosomes of *Haplopappus gracilis*. *Bull. Torrey Botan. Club* (in press).
- AMES, I.H. AND MITRA, J. Heterochromatin in mitotic chromosomes of *Haplopappus gracilis*. (A) In *Proc. 12th Int. Congr. Genetics, Tokyo, Aug. 1968* (in press).
- AMES, I.H. AND SMITH, H.H. Effects of mercaptoethanol on tumor induction in a *Nicotiana* amphiploid. Submitted to *Can. J. Botany*.
- ARCHAMBEAU, J. - See MOUTSCHEN, J.
- BAETCKE, K.P., SPARROW, A.H., AND NAUMAN, C.H. Correlations between nuclear parameters and radiosensitivities of woody and herbaceous plants. (A) In *Proc. 16th Annu. Meet. Radiat. Res. Soc., Houston, Texas, April 1968* (in press).
- BAETCKE, K.P., SPARROW, A.H., NAUMAN, C.H., AND SCHWEMMER, S.S. The relationship of DNA content to nuclear and chromosome volumes and to radiosensitivity (LD_{50}). *Proc. Nat. Acad. Sci. U.S.* **58**, 533-40 (1967).
- BAETCKE, K.P. - See also SPARROW, A.H.
- BAI, D. Radioactive contamination of the atmosphere, soils and agricultural products in Korea, 1961-1966. In *Proc. 2nd Nat. Symp. Radioecology, Ann Arbor, Mich., May 1967* (in press).
- BAKER, D.G. Recovery and repair mechanisms in radiobiology. *BioScience* **17**, 741-2 (1967).
- BAKER, D.G., CARSTEN, A., JAHN, A., AND MCFADYEN, D. Plasma protein synthesis following neutron irradiation. *Radiat. Res.* **32**, 265-76 (1967).
- BAKER, D.G. AND HOPPER, A.F. Crypt cell population changes in the rat intestine during injury and repair after fast neutron irradiation. *Radiat. Res.* **34**, 555-69 (1968).
- BAKER, D.G., MCFADYEN, D.M., AND CARSTEN, A.L. The effect of storage on the composition of plasma proteins. *Can. J. Physiol. Pharmacol.* **45**, 873-9 (1967).
- BAKER, D.G. AND VALERIOTE, F.A. The effect of x-irradiation and thermal burn on the intestinal mucosa. *Ibid.* **46**, 533-6 (1968).
- BAKER, D.G. - See also ABATA, J.J.; CLARK, G.M.; COHN, S.H. (Medical); DONNELLY, G.M.; MCFADYEN, D.M.
- BANKES, D.A. AND SPARROW, A.H. Effect of acute gamma irradiation on the incidence of tumor-like structures and adventitious roots in lettuce plants. (A) Presented at Ohio Acad. Sci. Meet., Bowling Green, Ohio, April 1968.
- BARTELT, D.C. - See GREENE, L.J.
- BARTSCH, R.G. - See CUSANOVICH, M.A.
- BHATIA, C.R. A molecular approach to the phylogeny of wheat. (N) *Wheat Inform. Serv. Nos.* **23-24**, 16-17 (1967).
- BHATIA, C.R., BUIATTI, M., AND SMITH, H.H. Electrophoretic variation in proteins and enzymes of the tumor forming hybrid *Nicotiana glauca* $\times$ *N. langsdorffii* and its parent species. *Amer. J. Botany* **54**, 1237-41 (1967).
- BHATIA, C.R. AND NILSON, J.P. Isoenzyme changes accompanying germination of wheat seeds. Submitted to *Biochem. Genet.*
- BHATIA, C.R. AND SMITH, H.H. Adaptation and growth response of *Arabidopsis thaliana* to deuterium. *Planta* **80**, 176-84 (1968).
- BJERKNES, S. - See STEELE, R.
- BODLAENDER, P., FEINSTEIN, G., AND SHAW, E. Isoxazolium salts for carboxyl-group modification in proteins. (A) *Fed. Proc.* **27**, 291 (1968).
- BRIGGS, R.W. Effects of post-treatment hydration and dehydration of ethyl methanesulfonate-treated maize seeds. In *Mutations in Plant Breeding (Proc. IAEA Panel Meet., Vienna, Sept. 1967)*, Vol. II, pp. 47-55, IAEA, Vienna, 1968.
- BRIGGS, R.W. Genetic recombination among spontaneous and ethyl methanesulfonate-induced waxy mutants in maize. *Maize Genet. News Letter* **42**, 16-19 (1968).
- BRIGGS, R.W. Modification of the efficiency and effectiveness of ethyl methanesulfonate treatments in maize. (A) In *Proc. 12th Int. Congr. Genetics, Tokyo, Aug. 1968* (in press).
- BRIGGS, R.W. Neutrons and other ionizing radiations in the Brookhaven mutations program. In *Neutron Irradiation of Seeds, IAEA Tech. Rep. Ser.* **76**, 5-6 (1967).
- BROKER, T.R. - See GHOSH, A.K.
- BROWER, J.H. - See WOODWELL, G.M.
- BUIATTI, M. Cytological observations on tumor tissue of the hybrid *Nicotiana suaveolens* $\times$ *N. langsdorffii*. *Caryologia* **20**, 187-90 (1968).
- BUIATTI, M. The induction of tumors in the hybrid *Nicotiana glauca* $\times$ *N. langsdorffii* plants by 6-azauracil and its reversal by uracil and actinomycin D. *Cancer Res.* **28**, 166-9 (1968).
- BUIATTI, M. - See also BHATIA, C.R.
- BUNTING, W.R. - See CLARK, G.M.
- BURTON, A.J. AND LEDBETTER, M.C. Electron microscopy of bacteriophage ϕ R: A comparison of negatively stained and untreated particles. (L) *J. Mol. Biol.* **31**, 143-4 (1968).
- BURTON, A.J. AND YAGI, S. The intracellular development of bacteriophage ϕ R. I. Host modification of the replicative process. *Ibid.* **34**, 481-96.
- CARLSON, K. - See LACKS, S.
- CARTY, R.P. AND HIRS, C.H.W. Modification of bovine pancreatic ribonuclease A with 4-sulfonyloxy-2-nitrofluorobenzene: Effect of pH and temperature on the rate of reaction; Isolation and identification of modified proteins. *J. Biol. Chem.* (in press).
- CHAPMAN, D.J., COLE, W.J., AND SIEGELMAN, H.W. Chromophores of allophycocyanin and R-phycocyanin. *Biochem. J.* **105**, 903-5 (1967).
- CHAPMAN, D.J., COLE, W.J., AND SIEGELMAN, H.W. Cleavage of phycocyanobilin from C-phycocyanin. *Biochim. Biophys. Acta* **153**, 692-8 (1968).
- CHAPMAN, D.J., COLE, W.J., AND SIEGELMAN, H.W. A comparative study of the phycoerythrin chromophore. *Phytochemistry* (in press).
- CHAPMAN, D.J., COLE, W.J., AND SIEGELMAN, H.W. Phylogenetic implications of phycocyanobilin and C-phycocyanin. *Amer. J. Botany* **55**, 314-16 (1968).
- CHAPMAN, D.J., COLE, W.J., AND SIEGELMAN, H.W. The structure of phycoerythrobilin. (L) *J. Amer. Chem. Soc.* **89**, 5976-7 (1967).
- CHAPMAN, D.J. - See also COLE, W.J.; SIEGELMAN, H.W.
- CHASE, T. JR. AND SHAW, E. *p*-Nitrophenyl-*p'*-guanidinobenzoate HCl: A new active site titrant for trypsin. *Biochem. Biophys. Res. Commun.* **29**, 508-14 (1967).

- CLARK, G.M., SWEANEY, W.P., BUNTING, W.R., AND BAKER, D.G. Germination and survival of conifers following chronic gamma irradiation of seed. *Radiat. Botany* 8, 59-66 (1968).
- CLARKSON, D.T. AND HILLMAN, W.S. Stable concentrations of phytochrome in *Pisum* under continuous illumination with red light. *Plant Physiol.* 43, 88-92 (1968).
- COLE, W.J., CHAPMAN, D.J., AND SIEGELMAN, H.W. Fluorescence spectrophotometry of zinc complexes of bile pigments. (L) Submitted to *Nature*.
- COLE, W.J., CHAPMAN, D.J., AND SIEGELMAN, H.W. The structure and properties of phycocyanobilin and related biliterienes. *Biochemistry* (in press).
- COLE, W.J. - See also CHAPMAN, D.J.; SIEGELMAN, H.W.
- COMBATTI, N.C. - See SMITH, H.H.
- CONGER, A.D. AND CURTIS, H.J. Abnormal anaphases in regenerating mouse livers. *Radiat. Res.* 33, 150-61 (1968).
- CONKLIN, M.E. AND SMITH, H.H. Endogenous beta irradiation and tumor production in an amphiploid *Nicotiana* hybrid. *Amer. J. Botany* 55, 473-6 (1968).
- CONKLIN, M.E., SMITH, H.H., AND KESHISHIAN, N.A. Effects of fast neutrons vs x rays on tumorous and normal growth in *Nicotiana*. (A) In *Proc. 12th Int. Congr. Genetics, Tokyo, Aug. 1968* (in press).
- CROCKETT, L.J. The effects of chronic gamma radiation on the internal apical configurations of the vegetative shoot apex of *Coleus blumei*. *Amer. J. Botany* 55, 265-8 (1968).
- CURTIS, H.J. Aging. In *Animals and Nutrition*, Chap. 9, E.S.E. Hafey and I.A. Dyer, Editors, Lea and Febiger, Philadelphia (in press).
- CURTIS, H.J. Aging in replicating cell systems *in vivo*. (A) Presented at Gerontol. Soc. Meet., Denver, Oct. 1968.
- CURTIS, H.J. Biological effects of heavy cosmic ray particles. In *Radiobiological Factors in Manned Space Flight*, pp. 197-201, W. Langham, Editor, Nat. Acad. Sci.-Nat. Res. Council, Washington, D.C., 1967.
- CURTIS, H.J. Biological mechanisms of aging. (A) Presented at 11th Nat. Med. Chem. Symp., Frontiers in Medicinal Chemistry, Quebec, June 1968.
- CURTIS, H.J. General life shortening. In *Radiobiological Factors in Manned Space Flight*, pp. 157-69, W. Langham, Editor, Nat. Acad. Sci.-Nat. Res. Council, Washington, D.C., 1967.
- CURTIS, H.J. The interpretation of microbeam experiments for manned space flight. *Radiat. Res. Suppl.* 7, 258-64 (1967).
- CURTIS, H.J. The use of a deuteron microbeam for simulating the biological effects of heavy cosmic-ray particles. *Ibid.*, 250-7.
- CURTIS, H.J., CZERNIK, C., AND TILLEY, J. Tumor induction as a measure of genetic damage and repair in somatic cells of mice. *Radiat. Res.* 34, 315-19 (1968).
- CURTIS, H.J. AND TILLEY, J. Chromosome aberrations in liver forced to regenerate by chemical or surgical methods. *J. Gerontol.* 23, 140-1 (1968).
- CURTIS, H.J. - See also CONGER, A.D.; CUTLER, R.G.; ORDY, J.M.; SAMORAJSKI, T.
- CUSANOVICH, M.A., BARTSCH, R.G., AND OLSON, J.M. Light-induced reactions in *Chromatium chromatophores* under controlled redox conditions. In *Comparative Biochemistry and Biophysics of Photosynthesis*, pp. 186-95, K. Shibata et al., Editors, Univ. of Tokyo Press, 1968.
- CUTLER, R.G., MEDLEY, B.J., AND CURTIS, H.J. Information flow from DNA via RNA as a function of age in C57 BL6J mice. (A) Presented at Gerontol. Soc. Meet., Denver, Oct. 1968.
- CZERNIK, C. - See CURTIS, H.J.
- DEBODO, R.C. - See STEELE, R.
- DEMEREK, M. - See GILLESPIE, D.; INO, I.; ITAKAWA, H.; ST. PIERRE, M.L.
- DICARLO, J.J. - See GREENE, L.J.
- DONINI, B.; SPARROW, A.H., SCHAIRER, L.A., AND SPARROW, R.C. The relative biological efficiency of gamma rays and fission neutrons in plant species with different nuclear and chromosome volumes. *Radiat. Res.* 32, 692-705 (1967).
- DONNELLY, G.M., SPARROW, A.H., NAUMAN, C.H., AND BAKER, D.G. Radiosensitivity of selected amphibians. (A) In *Proc. 16th Annu. Meet. Radiat. Res. Soc., Houston, Texas, April 1968* (in press).
- DOSCHER, M.S. The preparation of ribonuclease S and its component parts, S-peptide and S-protein. *Methods Enzymol.* 11, 640-8 (1967).
- ELZINGA, M.G. AND HIRS, C.H.W. Primary structure of bovine carboxypeptidase B. II. Tryptic peptides from the reduced, aminoethylated protein; IV. Amino acid sequence of a disulfide-containing loop. *Arch. Biochem. Biophys.* 123, 343-52, 361-7 (1968).
- ELZINGA, M.G., LAI, C.Y., AND HIRS, C.H.W. Primary structure of bovine carboxypeptidase B. III. The carboxyl-terminal sequence. *Ibid.*, 353-60.
- ELZINGA, M.G. - See also KYCIA, J.H.
- ETTINGER, M.J. AND HIRS, C.H.W. On the structure of 41-dinitrophenyl ribonuclease A. Solvent perturbation, thermal transition, optical rotatory dispersion, and binding studies. Submitted to *Biochemistry*.
- FEINSTEIN, G. - See BODLAENDER, P.
- FOX, L.R. AND HILLMAN, W.S. Response of tissue with different phytochrome contents to various initial photo-stationary states. *Plant Physiol.* 43, 823-6 (1968).
- FURUYA, M. - See SPARROW, A.H.
- GANNUTZ, T.P. - See WOODWELL, G.M.
- GHOSH, A.K., BROKER, T.R., AND OLSON, J.M. A kinetic study of bacteriochlorophyll pheophytinization in the protein complex from a green photosynthetic bacterium. Submitted to *Biochim. Biophys. Acta*.
- GHOSH, A.K. AND OLSON, J.M. Effects of denaturants on the absorption spectrum of the bacteriochlorophyll-protein from the photosynthetic bacterium *Chloropseudomonas ethylicum*. *Biochim. Biophys. Acta* (in press).
- GILLESPIE, D., DEMEREK, M., AND ITAKAWA, H. Appearance of double mutants in aged cultures of *Salmonella typhimurium* cysteine-requiring strains. Submitted to *Genetics*.
- GILOT, J. - See MOUTSCHEN, J.
- GREENBERG, B. - See LACKS, S.
- GREENE, L.J. Discussion of M. Laskoski Sr.'s paper, "Mechanism of Formation of a Trypsin-Trypsin Inhibitor Complex." In *Proc. Conf. Chemistry, Pharmacology and Clinical Applications of Proteinase Inhibitors, N.Y. Acad. Sci., New York, Sept. 1966* (in press).
- GREENE, L.J., DICARLO, J.J., SUSSMAN, A.J., BARTELT, D.C., AND ROARK, D.E. Two trypsin inhibitors from porcine pancreatic juice. *J. Biol. Chem.* 243, 1804-15 (1968).

- GREENE, L.J. - See also RIGBI, M.
 HALL, C.A. - See SANDERSON, K.E.
 HEATH, R.L. AND HIND, G. Fluorescence in chloride-depleted chloroplasts. (A) *Fed. Proc.* **27**, 343 (1968).
 HEATH, R.L. - See also HIND, G.
 HILLMAN, W.S. Blue light, phytochrome and the flowering of *Lemna perpusilla* 6746. *Plant Cell Physiol.* **8**, 467-73 (1967).
 HILLMAN, W.S. AND KOUKKARI, W.L. Phytochrome effects in the nyctinastic leaf movements of *Albizia julibrissin* and some other legumes. *Plant Physiol.* **42**, 1413-18 (1967).
 HILLMAN, W.S. - See also CLARKSON, D.T.; FOX, L.R.; KOUKKARI, W.L.
 HINCKLEY, A.D. Survival of oak leafminers in gamma-irradiated forest. (A) In *Proc. 12th Int. Congr. Entomology, Moscow, Aug. 1968* (in press).
 HIND, G. Light-induced changes in cytochrome *b-559* in spinach chloroplasts. *Phytochem. Phytohiol.* **7**, 369-75 (1968).
 HIND, G. The site of action of plastocyanin in chloroplasts treated with detergent. *Biochim. Biophys. Acta* **153**, 235-40 (1968).
 HIND, G., HEATH, R.L. AND IZAWA, S. The role of chloride ion in photosynthesis. In *Proc. Int. Congr. Photosynthesis Research, Freudstadt, West Germany, June 1968* (in press).
 HIND, G. AND OLSON, J.M. Electron transport pathways in photosynthesis. *Annu. Rev. Plant Physiol.* **19**, 249-82 (1968).
 HIND, G. - See also HEATH, R.L.; IZAWA, S.
 HIRONO, Y. AND SMITH, H.H. Mutations induced in *Arabidopsis* following treatment with DNA base analogs. Submitted to *Genetics*.
 HIRONO, Y. AND SMITH, H.H. Mutations induced with a base analog. (N) *Arabidopsis Inform. Serv. No.* **5**, 32 (1968).
 HIRONO, Y. AND SMITH, H.H. Mutations induced with a DNA base analog in a higher plant, *Arabidopsis*. (A) In *Proc. 12th Int. Congr. Genetics, Tokyo, Aug. 1968* (in press).
 HIRONO, Y., SMITH, H.H., AND LYMAN, J. Biological effectiveness of heavy ionizing particles relative to x rays. (N) *Arabidopsis Inform. Serv. No.* **5**, 47 (1968).
 HIRONO, Y., SMITH, H.H., AND LYMAN, J. Tumor induction by heavy ionizing particles and x rays in *Arabidopsis*. Submitted to *Radiat. Botany*.
 HIRS, C.H.W. Automatic computation of amino acid analyzer data. *Methods Enzymol.* **11**, 27-31 (1967).
 HIRS, C.H.W. Automation in protein chromatography. In *Automation in Analytical Chemistry (Proc. Technicon Symp., 1966)*, Vol. 1, pp. 450-2, N. Scova, Editor, Mediad, Inc., White Plains, N.Y., 1967.
 HIRS, C.H.W. Cystine peptides, *Methods Enzymol.* **11**, 475-8 (1967); Desalting of peptides, *ibid.*, 386-90; Detection of peptides: Chemical methods, *ibid.* 325-9; Determination of cystine as cysteic acid, *ibid.*, 59-62; Glycopeptides, *ibid.*, 411-13; Performic acid oxidation, *ibid.*, 197-9; Reactions with reactive aryl halides, *ibid.*, 548-55; Reduction and S-carboxymethylation of proteins, *ibid.*, 199-203.
 HIRS, C.H.W. - See also ALONZO, N.; CARTY, R.P.; ELZINGA, M.G.; ETTINGER, M.J.; JACKSON, R.L.; KYCIA, J.H.
 HOPPER, A.F. - See BAKER, D.G.
 HORROCKS, L.A. - See ORDY, J.M.
 HORTON, H.R. AND KOSHLAND, D.E. JR. Reactions with reactive alkyl halides. *Methods Enzymol.* **11**, 556-65 (1967).
 ICHIKAWA, S. AND SPARROW, A.H. Analyses of radiation-induced loss of reproductive integrity in *Tradescantia* stamen hairs, an essentially single-meristematic-cell system. (A) In *Proc. 12th Int. Congr. Genetics, Tokyo, Aug. 1968* (in press).
 ICHIKAWA, S. AND SPARROW, A.H. Nuclear and interphase chromosome volumes of four *Triticum* species and of eight species from related genera. (N) *Wheat Inform. Serv. Nos.* **23-24**, 18-20 (1967).
 ICHIKAWA, S. AND SPARROW, A.H. Radiation-induced loss of reproductive integrity in the stamen hairs of a polyploid series of *Tradescantia* species. *Radiat. Botany* **7**, 429-41 (1967).
 ICHIKAWA, S. AND SPARROW, A.H. Radiation-induced loss of reproductive integrity, morphologically abnormal cells, and somatic mutations in *Tradescantia* stamen hairs. (A) In *Proc. 12th Int. Congr. Genetics, Tokyo, Aug. 1968* (in press).
 ICHIKAWA, S. AND SPARROW, A.H. The use of induced somatic mutations to study cell division rates in irradiated stamen hairs of *Tradescantia virginiana* L. *Jap. J. Genet.* **43**, 57-63 (1968).
 INO, I. AND DEMEREC, M. Enteric hybrids. II. *S. typhimurium*-*E. coli* hybrids for the *trp-cysB-pyrF* region. Submitted to *Genetics*.
 INO, I. - See also YOURNO, J.
 ITIKAWA, H. AND DEMEREC, M. *Salmonella typhimurium* proline mutants. (N) *J. Bacteriol.* **95**, 1189-90 (1968).
 ITIKAWA, H. - See also GILLESPIE, D.
 IZAWA, S. AND HIND, G. The kinetics of the pH rise in illuminated chloroplast suspensions. *Biochim. Biophys. Acta* **143**, 377-90 (1967).
 IZAWA, S. - See also HIND, G.
 JACKSON, R.L., REINHOLD, V.N., AND HIRS, C.H.W. Isolation of porcine ribonuclease, a glycoprotein, from pancreatic juice. (A) *Fed. Proc.* **27**, 529 (1968).
 JAHN, A. - See COHN, S.H. (Medical).
 JENNINGS, W.H. - See OLSON, J.M.; OLSON, R.A.
 JOHNSON, N.M. - See WOODLEY, R.G.
 KESHISHIAN, N.A. - See CONKLIN, M.E.
 KLEIN, J.R. Free porphyrin concentrations and porphyrin synthesis in duck tissues. *Proc. Soc. Exp. Biol. Med.* **127**, 220-2 (1968).
 KLEIN, J.R. Heme and globin synthesis and related parameters in blood from the x-irradiated duck. Submitted to *Radiat. Res.*
 KLEIN, J.R. Incorporation of glycine-2-¹⁴C into the free protoporphyrin of duck erythrocytes *in vivo*. *Arch. Biochem. Biophys.* (in press).
 KOENIG, D.F. - See KREBS, V.B.; OLSON, J.M.
 KOSHLAND, D.E. JR. - See HORTON, H.R.
 KOUKKARI, W.L. AND HILLMAN, W.S. Effects of temperature and aeration on phytochrome transformations in *Pastinaca sativa* root tissue. *Amer. J. Botany* **54**, 1118-22 (1967).
 KOUKKARI, W.L. AND HILLMAN, W.S. Pulvini as the photoreceptors in the phytochrome effect on nyctinasty in *Albizia julibrissin*. *Plant Physiol.* **43**, 698-704 (1968).

- KOUKKARI, W.L. - See also HILLMAN, W.S.
- KREBS, B. AND KOENIG, D.F. Crystal and molecular structure of 4,5-dioxo-2-thioxo-1,3-dithiolan. Submitted to *Z. Naturforsch.*
- KREBS, B. AND KOENIG, D.F. Crystal and molecular structure of 4,5-dioxo-2-thioxo-1,3-dithiolan (β -modification). Submitted to *Acta Cryst.*
- KYCIA, J.H., ELZINGA, M.G., ALONZO, N., AND HIRS, C.H.W. Primary structure of bovine carboxypeptidase B. I. Preparation of enzyme from pancreatic juice. *Arch. Biochem. Biophys.* 123, 336-42 (1968).
- LACKS, S. Genetic regulation of maltosaccharide utilization in pneumococcus. Submitted to *Genetics*.
- LACKS, S. A regulatory gene for the maltose utilization pathway of pneumococcus. (A) In *Proc. 12th Int. Congr. Genetics, Tokyo, Aug. 1968* (in press).
- LACKS, S. *Tampering With Heredity: The Genetic Transformation of Bacteria by DNA*, Brookhaven Lecture Series No. 71, Jan. 17, 1968. BNL 50101 (T-488).
- LACKS, S. Theoretical relationship between probability of marker integration and length of donor DNA in pneumococcal transformation. *J. Mol. Biol.* (in press).
- LACKS, S., GREENBERG, B., AND CARLSON, K. Fate of donor DNA in pneumococcal transformation. *J. Mol. Biol.* 29, 327-47 (1967).
- LACKS, S. - See also MOUTSCHEN, J.
- LAI, C.Y. - See ELZINGA, M.G.
- LEDBETTER, M.C. The Casparian strip: A site of a functional tight junction in plant roots. (A) *J. Cell Biol.* 35, 79A (1967).
- LEDBETTER, M.C. The disposition of microtubules in plant cells during interphase and mitosis. In *Formation and Fate of Cell Organelles (Proc. Symp., Cambridge, England, Sept., 1966)*, Vol. 6, pp. 55-70, K.B. Warren, Editor, Academic, New York, 1968.
- LEDBETTER, M.C. - See also BURTON, A.J.; OLSON, J.M.
- LYMAN, J.T. - See HIRONO, Y.
- MARES-GUIA, M. AND SHAW, E. The specific inactivation of trypsin by ethyl *p*-guanidinobenzoate. *J. Biol. Chem.* 242, 5782-8 (1967).
- MARIMUTHU, K.M. - See SPARROW, A.H.
- MARPLES, T.G. - See WOODWELL, G.M.
- McFADYEN, D.M. AND BAKER, D.G. Alterations in the subcellular acid phosphatase and β -glucuronidase in rat mucosa after various doses of x irradiation. Submitted to *Gastroenterology*.
- McFADYEN, D.M. AND BAKER, D.G. Lysosome activity in radiation induced intestinal injury. In *Excerpta Med. Monogr. Nucl. Med. Biol. No. 1, Gastrointestinal Radiation Injury (Proc. Symp., Richland, Wash., Sept. 1966)*, pp. 401-12.
- McFADYEN, D. - See also BAKER, D.G.
- McMILLAN, B. - See VAN'T HOF, J.
- MEDLEY, B.J. - See CUTLER, R.G.
- MERGEN, F. AND THIELGES, B.A. Radiation-induced damage in vegetative tissues of *Pinus rigida* Mill. *Cytologia* 32, 248-54 (1967).
- MITRA, J. - See AMES, I.H.
- MOFFAT, G.H. The growth of hair follicles and its relation to the adjacent dermal structures. *J. Anat.* 102, 527-40 (1968).
- MOUTSCHEN, J. AND LACKS, S. Implications of pyrimidine nucleoside catabolism for cytological investigation of germinating seeds. *Exp. Cell Res.* (in press).
- MOUTSCHEN, J., MOUTSCHEN-DAHMAN, M., WOODLEY, R., AND ARCHAMBEAU, J. The RBE of heavy particles from the reaction $B^{10}(n,\alpha)Li^7$ for chromosome aberrations in *Nigella damascena* L. *Radiat. Res.* 34, 488-500 (1968).
- MOUTSCHEN, J., MOUTSCHEN-DAHMAN, M., WOODLEY, R., AND GILOT, J. The relative biological effectiveness of different kinds of radiations on chromosome aberrations in *Nigella damascena* seed. Submitted to *Radiat. Res.*
- MOUTSCHEN-DAHMAN, M. - See MOUTSCHEN, J.
- MULCAHY, D.L. The significance of delayed pistillate anthesis in *Silene alba*. *Bull. Torrey Botan. Club* 95, 135-9 (1968).
- NAUMAN, C.H. - See BAETCKE, K.P.; DONNELLY, G.M.
- NILSON, J.P. - See BHATIA, C.R.
- NIMS, L.F. Chemical currents, circulation, and cross coefficients in the description of material transfer in biological systems. *Yale J. Biol. Med.* 40, 131-47 (1967).
- NIMS, L.F. Membranes, material transfer and enzymes. *Curr. Mod. Biol.* 1, 353-65 (1968).
- OLSON, J.M. Evolution of photosynthetic electron transport systems. (A) Presented at NSF-ASPP Advan. Sci. Seminar Physical Concepts and Methodologies in the Study of Photosynthesis, Cornell Univ., March 1968.
- OLSON, J.M., KOENIG, D.F., AND LEDBETTER, M.C. A model of the bacteriochlorophyll-protein from green photosynthetic bacteria. Submitted to *Arch. Biochem. Biophys.*
- OLSON, J.M., KOENIG, D.F., AND LEDBETTER, M.C. Revised model of the bacteriochlorophyll-protein from green bacteria. (A) In *Abstr. 12th Annu. Meet. Biophys. Soc., Pittsburgh, Feb. 1968*, p. A-195.
- OLSON, J.M., KOENIG, D.F., LEDBETTER, M.C., OLSON, R.A., AND JENNINGS, W.H. Chlorophyll arrangement in the bacteriochlorophyll-protein from green bacteria. (A) In *Proc. 5th Int. Congr. Photobiology, Hanover, N.H., Aug. 1968* (in press).
- OLSON, J.M., THORNER, J.P., KOENIG, D.F., LEDBETTER, M.C., OLSON, R.A., AND JENNINGS, W.H. The bacteriochlorophyll-protein of green photosynthetic bacteria. In *Proc. Int. Congr. Photosynthesis Research, Freudenstadt, West Germany, June 1968* (in press).
- OLSON, J.M. - See also CUSANOVICH, M.A.; GHOSH, A.K.; HIND, G.; OLSON, R.A.; THORNER, J.P.
- OLSON, R.A., JENNINGS, W.H., AND OLSON, J.M. Chlorophyll orientation in crystals of bacteriochlorophyll-protein from green photosynthetic bacteria. Submitted to *Arch. Biochem. Biophys.*
- OLSON, R.A. - See also OLSON, J.M.
- ORDY, J.M., SAMORAJSKI, T., HORROCKS, L.A., ZEMAN, W., AND CURTIS, H.J. Changes in memory, electrophysiology, neurochemistry and neuronal ultrastructure after deuteron irradiation of the brain in C57BL/10 mice. Submitted to *J. Neurochem.*
- ORDY, J.M., SAMORAJSKI, T., ZEMAN, W., AND CURTIS, H.J. Interaction effects of environmental stress and deuteron irradiation of the brain on mortality and longevity of C57BL/10 mice. *Proc. Soc. Exp. Biol. Med.* 126, 184-90 (1967).
- ORDY, J.M. - See also SAMORAJSKI, T.
- OWENS, R.A. - See UNDERBRINK, A.G.
- POND, V. - See SPARROW, A.H.; UNDERBRINK, A.G.
- RATHGEB, I. - See STEELE, R.

- REINHOLD, V.N. - See JACKSON, R.L.
- RIGBI, M. AND GREENE, L.J. Limited proteolysis of the bovine pancreatic secretory trypsin inhibitor at acid pH. Submitted to *J. Biol. Chem.*
- ROARK, D.E. - See GREENE, L.J.
- ROGERS, A.F. - See SPARROW, A.H.
- ROSSI, H.H. - See SMITH, H.H.
- ST. PIERRE, M.L. AND DEMEREC, M. Hybrids of enteric bacteria. I. *S. typhimurium*-*S. montevideo* hybrids for the histidine loci. *Genetics* 59, 1-9 (1968).
- SAMORAJSKI, T., ORDY, J.M., ZEMAN, W., AND CURTIS, H.J. Early and long term effects of deuteron irradiation on cells in the cerebellum of adult mice. *J. Cell Biol.* 38, 213-20 (1968).
- SAMORAJSKI, T. - See also ORDY, J.M.
- SAND, S.A. AND SMITH, H.H. Somatic mutational transients: Response to acute gamma irradiation by two genes in a clone of *Nicotina*. *Genetics* 58, 607-24 (1968).
- SANDERSON, K.E. AND HALL, C.A. F-prime factors of *Salmonella typhimurium* and an inversion between *S. typhimurium* and *Escherichia coli*. Submitted to *Genetics*.
- SCHAIER, L.A. - See DONINI, B.; SPARROW, A.H.
- SCHOENBORN, B.P. The structure of alkaline met myoglobin. (A) Presented at Amer. Chem. Soc. Meet., Atlantic City, Sept. 1968.
- SCHOPFER, P. AND SIEGELMAN, H.W. Purification of protochlorophyllide holochrome. In *Proc. Int. Congr. Photosynthesis Research, Freudenstadt, West Germany, June 1968* (in press); *Plant Physiol.* 43, 990-6 (1968).
- SCHROEDER, D. AND SHAW, E. The chromatographic separation of active trypsin species. (A) Presented at Amer. Chem. Soc. Meet., Chicago, Sept. 1967.
- SCHROEDER, D. AND SHAW, E. Chromatography of trypsin and its derivatives. Characterization of a new active form of bovine trypsin. *J. Biol. Chem.* 243, 2943-9 (1968).
- SCHWEMMER, S.S. - See BAETCKE, K.P.; SPARROW, A.H.
- SHAVER, D.L. - See SPARROW, A.H.
- SHAW, E. The active center histidine in subtilisin. (A) In *Proc. 4th Symp. Fed. Eur. Biochem. Soc., Prague, July 1968* (in press).
- SHAW, E. - See also BODLAENDER, P.; CHASE, T. JR.; MARES-GUIA, M.; SCHROEDER, D.D.
- SIEGELMAN, H.W. Preparation of phycocyanobilin peptides from C-phycocyanin. (A) In *Proc. 5th Int. Congr. Photobiology, Hanover, N.H., Aug. 1968* (in press).
- SIEGELMAN, H.W., CHAPMAN, D.J., AND COLE, W.J. The bile pigments of plants. In *Proc. Biochem. Soc. Symp. Porphyrin and Related Compounds, London, April 1968* (in press).
- SIEGELMAN, H.W., CHAPMAN, D.J., AND COLE, W.J. Enzymatic cleavage of phycocyanobilin. (L) *Arch. Biochem. Biophys.* 122, 261 (1967).
- SIEGELMAN, H.W. - See also AKOYUNOGLU, G.A.; CHAPMAN, D.J.; COLE, W.J.; SCHOPFER, P.
- SMITH, H.H. Recent cytogenetic studies in the genus *Nicotiana*. *Advan. Genet.* 14, 1-54 (1968).
- SMITH, H.H. Relative biological effectiveness of different types of ionizing radiations: Cytogenetic effects in maize. *Radiat. Res. Suppl.* 7, 190-5 (1967).
- SMITH, H.H. Relative response of maize to x rays vs. neutrons over a wide range of doses. *Maize Genet. News Letter* 42, 19-21 (1968).
- SMITH, H.H., COMBATTI, N.C., AND ROSSI, H.H. A constant relation of neutron to x-ray effects in *Zea mays* L. (A) In *Proc. 12th Int. Congr. Genetics, Tokyo, Aug. 1968* (in press).
- SMITH, H.H., COMBATTI, N.C., AND ROSSI, H.H. Relative response to irradiation of seeds with x rays vs. neutrons over a wide range of doses. *IAEA Tech. Rep. Ser.* (in press).
- SMITH, H.H. - See also AMES, I.H.; BHATIA, C.R.; CONKLIN, M.E.; HIRONO, Y.; SAND, S.A.
- SPARROW, A.H., BAETCKE, K.P., SHAVER, D.L., AND POND, V. The relationship of mutation rate per roentgen to DNA content per chromosome and to interphase chromosome volume. *Genetics* 59, 65-78 (1968).
- SPARROW, A.H., FURUYA, M., AND SCHWEMMER, S.S. Effect of x- and gamma radiation on anthocyanin synthesis in leaves of *Rumex* and other plant genera. *Radiat. Botany* 8, 7-16 (1968).
- SPARROW, A.H., ROGERS, A.F., AND SCHWEMMER, S.S. Acute gamma radiosensitivity of 28 woody plant species. (A) In *Proc. 16th Annu. Meet. Radiat. Res. Soc., Houston, Texas, April 1968* (in press).
- SPARROW, A.H., ROGERS, A.F., AND SCHWEMMER, S.S. Radiosensitivity studies with woody plants. I. Acute gamma irradiation survival data for 28 species and predictions for 190 species. *Radiat. Botany* 8, 149-86 (1968).
- SPARROW, A.H., SCHAIER, L.A., AND MARIMUTHU, K.M. Genetic and cytological studies of *Tradescantia* irradiated during orbital flight. *BioScience* 18, 582-90 (1968); (A) in *Proc. 12th Int. Congr. Genetics, Tokyo, Aug. 1968* (in press).
- SPARROW, A.H., SCHAIER, L.A., AND MARIMUTHU, K.M. Radiobiological studies of *Tradescantia* plants orbited in Biosatellite II. (A) In *Proc. 16th Annu. Meet. Radiat. Res. Soc., Houston, Texas, April 1968* (in press).
- SPARROW, A.H., UNDERBRINK, A.G., AND BAETCKE, K.P. Chromosome volume, nucleic acid content and phylogeny. (A) In *Proc. 12th Int. Congr. Genetics, Tokyo, Aug. 1968* (in press).
- SPARROW, A.H., UNDERBRINK, A.G., AND SPARROW, R.C. Chromosomes and cellular radiosensitivity. I. The relationship of D_{07} to chromosome volume and complexity in seventy-nine different organisms. *Radiat. Res.* 32, 915-45 (1967).
- SPARROW, A.H. - See also BAETCKE, K.P.; BANKS, D.A.; DONINI, B.; DONNELLY, G.M.; ICHIKAWA, S.; UNDERBRINK, A.G.
- SPARROW, R.C. - See DONINI, B.; SPARROW, A.H.
- STEELE, R., ALTSZULER, N., RATHGEB, I., AND DEBODO, R.C. Influence of growth hormone on glucose metabolism and plasma insulin levels in the dog. In *Proc. Int. Symp. Growth Hormone, Milan, Italy, Sept. 1967*, Excerpta Med. Found. (in press).
- STEELE, R., ALTSZULER, N., RATHGEB, I., WINKLER, B., AND DEBODO, R.C. The effects of growth hormone on carbohydrate and lipid metabolism in the dog. *Ann. N.Y. Acad. Sci.* 148, 441-58 (1968).
- STEELE, R., BJERKNES, C., RATHGEB, I., AND ALTSZULER, N. Some factors influencing the oral glucose tolerance test. *Diabetes* 17, 415-21 (1968).
- STEELE, R., WINKLER, B., AND ALTSZULER, N. Relationship of glycerol uptake to plasma glycerol concentration in the normal dog. Submitted to *Amer. J. Physiol.*
- STEELE, R., WINKLER, B., BJERKNES, C., RATHGEB, I., AND ALTSZULER, N. Isolation of a pure glycerol- C^{14} deriva-

- tive for measurement of glycerol turnover. *J. Appl. Physiol.* **23**, 752-6 (1967).
- STEELE, R., WINKLER, B., RATHGEB, I., BJERKNES, C., AND ALTSZULER, N. Plasma glucose and free fatty acid metabolism in normal and long-fasted dogs. *Amer. J. Physiol.* **214**, 313-9 (1968).
- SUSSMAN, A. J. - See GREENE, L. J.
- SWEANEY, W. P. - See CLARK, G. M.
- THIELGES, B. A. - See MERGEN, F.
- THORNBER, J. P. Chlorophyll containing proteins of photosynthesis organisms. (A) In *Proc. 5th Int. Congr. Photobiology, Hanover, N.H., Aug. 1968* (in press).
- THORNBER, J. P. Chlorophyll containing proteins of photosynthetic organisms. (A) Presented at Meet. North East Sect. Amer. Soc. Plant Physiologists, Yonkers, N.Y., May 1968.
- THORNBER, J. P. A comparison of some chlorophyll-protein complexes. (A) *Fed. Proc.* **27**, 829 (1968).
- THORNBER, J. P. AND OLSON, J. M. The chemical composition of a crystalline bacteriochlorophyll-protein complex isolated from the green bacterium, *Chloropseudomonas ethylicum*. *Biochemistry* **7**, 2242-9 (1968).
- THORNBER, J. P. - See also OLSON, J. M.
- TILLEY, J. - See CURTIS, H. J.
- TING, Y. C. - See UNDERBRINK, A. G.
- UNDERBRINK, A. G. AND SPARROW, A. H. Chromosomes and cellular radiosensitivity: Considerations of nucleic acid base ratios and fine structural damage. (A) In *Proc. 16th Annu. Meet. Radiat. Res. Soc., Houston, Texas, April 1968* (in press).
- UNDERBRINK, A. G. AND SPARROW, A. H. Chromosomes and cellular radiosensitivity. III. Note on the inability to demonstrate a correlation between nucleic acid base ratios and radiation response at D_0 in several diverse organisms. *Radiat. Res.* (in press).
- UNDERBRINK, A. G., SPARROW, A. H., AND OWENS, R. A. The fine structure of the alga *Brachiomonas submarina* Bohlin after x- and γ -irradiation. Submitted to *Radiat. Botany*.
- UNDERBRINK, A. G., SPARROW, A. H., AND POND, V. Chromosomes and cellular radiosensitivity. II. Use of interrelationships among chromosome volume, nucleotide content and D_0 of 120 diverse organisms in predicting radiosensitivity. *Radiat. Botany* **8**, 205-37 (1968).
- UNDERBRINK, A. G., TING, Y. C., AND SPARROW, A. H. Note on the occurrence of a synaptonemal complex at meiotic prophase in *Zea mays* L. *Can. J. Genet. Cytol.* **9**, 606-9 (1967).
- UNDERBRINK, A. G. - See also SPARROW, A. H.
- VALERIOTE, F. A. - See BAKER, D. G.
- VAN'T HOF, J. Control of cell progression through the mitotic cycle by carbohydrate provision. I. Regulation of cell division in excised plant tissue. *J. Cell. Biol.* **37**, 773-80 (1968).
- VAN'T HOF, J. Control of progression through the mitotic cycle of root meristem cells. (A) *Amer. J. Botany* **55**, 703 (1968).
- VAN'T HOF, J. Experimental procedures for measuring cell population kinetic parameters in plant root meristems. *Methods Cell Physiol.* **3** (in press).
- VAN'T HOF, J. Recovery enhancement of G_1 and G_2 meristematic cells in excised pea roots during an induced postirradiation stationary phase. *Radiat. Res.* **32**, 792-803 (1967).
- VAN'T HOF, J. The site of action of IAA and kinetin in the mitotic cycle of proliferative and stationary phase excised root meristems. *Exp. Cell Res.* (in press).
- VAN'T HOF, J. Some kinetic aspects of recovery of G_1 and G_2 cells in stationary phase excised pea roots. *Radiat. Res.* **34**, 626-36 (1968).
- VAN'T HOF, J. AND McMILLAN, B. Cell population kinetics in callus tissue of cultured pea root segments. Submitted to *Amer. J. Botany*.
- VAN'T HOF, J. AND WEBSTER, P. L. Anaerobiosis and the initiation of cell differentiation in root meristem cells. (A) *Amer. J. Botany* **55**, 703 (1968).
- VAN'T HOF, J. - See also WEBSTER, P. L.
- WEBSTER, P. L. AND VAN'T HOF, J. Variation of energy requirements in the mitotic cycle of root meristem cells. (A) *Amer. J. Botany* **55**, 703 (1968).
- WEBSTER, P. L. - See also VAN'T HOF, J.
- WHITTAKER, R. H. Ecological implications of weather modification. In *Ground Level Climatology*, pp. 367-84, AAAS, Washington, D.C., 1967.
- WHITTAKER, R. H. Gradient analysis of vegetation. *Biol. Rev.* **49**, 207-64 (1967).
- WHITTAKER, R. H. AND WOODWELL, G. M. Dimension and production relations of trees and shrubs in the Brookhaven forest, New York. *J. Ecol.* **56**, 1-25 (1968).
- WHITTAKER, R. H. AND WOODWELL, G. M. Surface area relations of woody plants and forest communities. *Amer. J. Botany* **54**, 931-9 (1967).
- WHITTAKER, R. H. - See also WOODWELL, G. M.
- WINKLER, B. - See STEELE, R.
- WOODLEY, R. G. AND JOHNSON, N. M. Thermoluminescence induced by low energy alpha particles. In *Luminescence Dosimetry (Proc. Int. Conf., Stanford, Calif., June 1965)*, pp. 502-6, F. H. Attix, Editor, US AEC, 1967.
- WOODLEY, R. - See also MOUTSCHEN, J.
- WOODWELL, G. M. Ionizing radiation and forests. In *1968 McGraw-Hill Yearbook of Science and Technology*, pp. 185-7, McGraw-Hill, New York, 1968.
- WOODWELL, G. M. Radioactivity and fallout: The model pollution. In *Proc. Rockefeller Univ.-N.Y. Bot. Garden Symp. Challenge for Survival, New York, April 1968* (in press).
- WOODWELL, G. M. AND BROWER, J. H. An aphid population explosion induced by chronic gamma irradiation of a forest. *Ecology* **48**, 680-3 (1967).
- WOODWELL, G. M. AND GANNUTZ, T. P. Effects of chronic gamma irradiation on lichen communities of a forest. *Amer. J. Botany* **54**, 1210-15 (1967).
- WOODWELL, G. M. AND MARPLES, T. G. The influence of chronic gamma irradiation on production and decay of litter and humus in an oak-pine forest. *Ecology* (in press).
- WOODWELL, G. M. AND WHITTAKER, R. H. Effects of chronic gamma irradiation on plant communities. *Quart. Rev. Biol.* **43**, 42-55 (1968).
- WOODWELL, G. M. AND WHITTAKER, R. H. Primary production and the cation budget of the Brookhaven forest. In *Proc. Symp. Primary Productivity and Mineral Cycling in Natural Ecosystems, New York, Dec. 1967*, pp. 151-66, AAAS, 1968.

- WOODWELL, G.M. AND WHITTAKER, R.H. Primary production in terrestrial communities. *Amer. Zoologist* **8**, 19-30 (1968).
- WOODWELL, G.M. AND WHITTAKER, R.H. Production and cycling in the Long Island oak-pine forest. (A) *Bull. Ecol. Soc. Amer.* **48**, 119 (1967).
- WOODWELL, G.M. - See also WHITTAKER, R.H.
- YAGI, S. - See BURTON, A.J.
- YOURNO, J. Composition and subunit structure of histidinol dehydrogenase from *Salmonella typhimurium*. *J. Biol. Chem.* **243**, 3277-88 (1968).
- YOURNO, J. Histidinol dehydrogenase. (N) *Methods Enzymol.* **10** (in press).
- YOURNO, J. AND INO, I. Purification and crystallization of histidinol dehydrogenase from *Salmonella typhimurium* LT-2. *J. Biol. Chem.* **243**, 3273-6 (1968).
- ZEMAN, W. - See ORDY, J.M.; SAMORAJSKI, T.

Chemistry Department

- ABRAHAMS, S.C., HAMILTON, W.C., AND MATHIESON, A.M. International Union of Crystallography Commission on Crystallographic Apparatus: Single crystal intensity project report. I. Interexperimental agreement. Presented at Int. Meet. Accurate Determination of X-Ray Intensities and Structure Factors, Cambridge, England, June 1968.
- ABRAHAMS, S.C., HAMILTON, W.C., AND SEQUEIRA, A. Ferroelectric lithium tantalate. II. Single crystal neutron diffraction study at 24°C. *J. Phys. Chem. Solids* **28**, 1693-8 (1967).
- ABRAHAMS, S.C. - See also HAMILTON, W.C.
- ACHE, H.J. AND WOLF, A.P. The effect of radiation on the reactions of recoil carbon-11 in the nitrogen-oxygen system. *J. Phys. Chem.* **72**, 1988-93 (1968).
- ACHE, H.J. AND WOLF, A.P. Reactions of energetic carbon-11 atoms in fluorohydrocarbon systems. *Radiochim. Acta* (in press).
- AL KITAL, R.A., CHAN, L.H., AND SAYRE, E.V. Neutron activation analysis of pottery sherds from Hajar bin Humeid and related areas. Appendix to *Hajar bin Humeid, an Archaeological Investigation of a Pre-Islamic Town in South Arabia*, G.W. Van Beek, Johns Hopkins Press, Baltimore (in press).
- ALLEN, A.O. Radiation chemistry of hydrocarbons. *Curr. Top. Radiat. Res.* **4**, 3-42 (1968).
- ALLEN, A.O. Radiation chemistry today. *J. Chem. Educ.* **45**, 290-5 (1968).
- ALLEN, A.O. - See also BIELSKI, B.H.J.; CAPELLOS, C.; RAO, K.N.; SCHMIDT, W.F.
- ARDON, M. AND SUTIN, N. The formation constant and aquation rate of the nitratopentaquo-chromium(III) ion. (N) *Inorg. Chem.* **6**, 2268-9 (1967).
- BAKER, B.R., SUTIN, N., AND WELCH, T.J. The kinetics of the formation and aquation of the monothiocyanate complex of vanadium(III). *Ibid.*, 1948-51.
- BAKER, E.W. - See GROVER, J.R.
- BAKER, W.A. JR. - See REIFF, W.M.
- BANKS, E. - See KUNNMANN, W.
- BEDNOWITZ, A.L., HAMILTON, W.C., BROWN, R., DONARUMA, L.G., SOUTHWICK, P.L., KROPF, R., AND STANFIELD, R.A. The crystal and molecular structure of 14c-hydro-5a-phenylbenz [a] indeno [2,1-c]-fluorene-5,10-dione (C₃₀H₁₈O₂). *J. Amer. Chem. Soc.* **90**, 291-6 (1968).
- BEDNOWITZ, A.L. - See also VOGT, L.H. JR.
- BERKEBILE, C.A. - See SEQUEIRA, A.
- BERNAL, I. The crystal structure and magnetic properties of some iron(II, III and IV) complexes with sulfur ligands. (A) Presented at Amer. Chem. Soc. Meet., San Francisco, April 1968.
- BERNAL, I., ELLIOTT, N., LALANCETTE, R.A., AND BRENNAN, T. Pentacoordination in transition metal ions: The magnetic and structural properties of MnCl₅²⁻ and CuCl₅³⁻. (A) In *Proc. 11th Int. Conf. Coordination Chemistry, Haifa and Jerusalem, Israel, Sept. 1968* (in press).
- BERNAL, I. - See also HAMILTON, W.C.; RICCI, J.S. JR.; SEQUEIRA, A.
- BIELSKI, B.H. J. Kinetics of D₂O₃ in D₂O. (A) Presented at Amer. Chem. Soc. Meet., Atlantic City, Sept. 1968.
- BIELSKI, B.H. J. AND ALLEN, A.O. Radiation chemistry of aqueous tetranitromethane solutions in the presence of air. *J. Phys. Chem.* **71**, 4544-9 (1967).
- BIELSKI, B.H. J. AND ALLEN, A.O. The radiolytic yield of reducing radicals in neutral aqueous solution. Submitted to *Int. J. Radiat. Phys. Chem.*
- BIELSKI, B.H. J., FREEMAN, J. J., AND GEBICKI, J.M. Electron spin resonance of nitrogen dioxide in frozen solutions. *J. Phys. Chem.* **72**, 1721-5 (1968).
- BIELSKI, B.H. J. AND SCHWARZ, H.A. The absorption spectra and kinetics of hydrogen sesquioxide and the perhydroxyl radical. *J. Phys. Chem.* (in press).
- BIELSKI, B.H. J. AND SCHWARZ, H.A. The absorption spectra of HO₂ and H₂O₃. (A) Presented at Symp. Radiation Chemistry and Photochemistry, Natick, Mass., April 1968.
- BIELSKI, B.H. J. - See also FAJER, J. (Nuclear Engineering).
- BIGEISEN, J. Isotope separation practice. *Advan. Chem. Ser.* (in press).
- BIGEISEN, J. Solids and liquids: Some differences revealed by isotope effects. (A) Presented at Amer. Chem. Soc. Meet., Atlantic City, Sept. 1968.
- BIGEISEN, J. Theoretical principles of isotope effects. (A) Presented at 5th Symp. Stable Isotopes, Leipzig, East Germany, Oct. 1967.
- BIGEISEN, J., BROOKS, F.P., ISHIDA, T., AND RIBNIKAR, S.V. Cryostat for thermal measurements between 2-300°K. *Rev. Sci. Instr.* **39**, 353-6 (1968).
- BIGEISEN, J., CRAGG, C.B., AND JEEVANANDAM, M. Vapor pressures of isotopic methanes: Evidence for hindered rotation. *J. Chem. Phys.* **47**, 4335-46 (1967).
- BIGEISEN, J. AND ISHIDA, T. Application of finite orthogonal polynomials to the thermal functions of harmonic oscillators. I. Reduced partition function of isotopic molecules. *J. Chem. Phys.* **48**, 1311-30 (1968).
- BIGEISEN, J. AND WOLFSBERG, M. Comment on A.F. Grigor and W.A. Steele's paper, "Physical properties of fluid CH₄ and CD₄: Theory." (N) Submitted to *J. Chem. Phys.*
- BIGEISEN, J. - See also ISHIDA, T.; RIBNIKAR, S.V.
- BLADE-FONT, A. - See McEWEN, W.E.
- BOCQUET, J.-P., CHU, Y.Y., EMERY, G.T., AND PERLMAN, M.L. Internal-conversion studies with Sn^{119m} and Sn^{117m}. *Phys. Rev.* **167**, 1117-21 (1968).
- BRENNAN, T. - See BERNAL, I.

- BROOKS, F.P. - See BIGEISEN, J.
- BROWN, R. - See BEDNOWITZ, A.L.
- BUTTERWORTH, J.S. AND HARBOTTLE, G. Chemical effects of gamma irradiation on ^{204}Tl incorporated in KCl crystals. *Radiochim. Acta* (in press).
- CAPELLOS, C. AND ALLEN, A.O. Ionization of liquids by radiation: Measurement by charge scavenging. (N) *Science* **160**, 302-3 (1968).
- CAPELLOS, C. AND ALLEN, A.O. Ionization of liquids by radiation studied by the method of pulse radiolysis. I. Solutions of TMPD in hydrocarbons. Submitted to *J. Phys. Chem.*
- CEFOLA, M., KAZIMIR, E., AND ERICKSON, N.E. Mössbauer spectroscopy investigation of tin *cis-trans* isomerism. (A) Presented at Amer. Chem. Soc. Meet., San Francisco, April 1968.
- CEFOLA, M. - See also KAZIMIR, E.; LALANCETTE, R.A.; SNYDER, R.L.
- CHAN, L.H. AND SAYRE, E.V. Fossil alpha recoil track dating of ancient glass. (A) In *Proc. 8th Int. Congr. Glass, London, July 1968* (in press).
- CHAN, L.H. - See also AL KITAL, R.A.; SAYRE, E.V.
- CHEN, K., FRAENKEL, Z., FRIEDLANDER, G., GROVER, J.R., MILLER, J.M., AND SHIMAMOTO, Y. VEGAS: A Monte Carlo simulation of intranuclear cascades. *Phys. Rev.* **166**, 949-67 (1968).
- CHU, Y.Y., FRANZ, E.-M., FRIEDLANDER, G., AND HECHTL, E. A new isomer of Tb^{147} . (A) Presented at Amer. Chem. Soc. Meet., San Francisco, April 1968.
- CHU, Y.Y., FRANZ, E.-M., FRIEDLANDER, G., AND KAROL, P. J. The study of charge dispersion in the rare-earth region for interaction of heavy elements with 30 GeV protons. (A) *Ibid.*
- CHU, Y.Y. AND HAHN, R.L. Production cross sections of some I, Te, Ba and Cs isotopes from the interaction of 1, 2, and 2.9-GeV protons with uranium. *J. Inorg. Nucl. Chem.* (in press).
- CHU, Y.Y. - See also BOCQUET, J.-P.
- COPPENS, P. Comparative x-ray and neutron diffraction study of bonding effects in *s*-triazine. *Science* **158**, 1577-9 (1967).
- COPPENS, P. Diffraction studies of the chemical bond. Submitted to *Mol. Cryst.*
- COPPENS, P. The elimination of multiple reflection on the four-circle diffractometer. *Acta Cryst.* **A24**, 253-7 (1968).
- COPPENS, P. Errors in the calculated structure factors caused by the free-atom form factor model. Presented at Int. Meet. Accurate Determination of X-ray Intensities and Structure Factors, Cambridge, England, June 1968.
- COPPENS, P. Evidence for systematic errors in x-ray temperature parameters resulting from bonding effects. *Acta Cryst.* (in press).
- COPPENS, P. Influence of bonding effects on thermal parameters as determined by x-ray diffraction. (A) Presented at 2nd Mater. Res. Symp. Molecular Dynamics and Structure of Solids, Gaithersburg, Md., Oct. 1967.
- COPPENS, P. The significance of discrepancies between x-ray and neutron thermal parameters. (A) Presented at Amer. Cryst. Ass. Meet., Tucson, Ariz., Feb. 1968.
- COPPENS, P. AND COULSON, C.A. The effects of asymmetry of the atomic charge distribution on the positions of terminal atoms as determined with x-rays. *Acta Cryst.* **23**, 718-20 (1967).
- COPPENS, P., GODEL, J.B., AND SABINE, T.M. The use of a Joule-Thomson refrigerator for neutron diffraction at liquid nitrogen temperatures. *Rev. Sci. Instr.* **38**, 1333-4 (1967).
- COPPENS, P. AND HAMILTON, W.C. Anisotropic extinction in the Zachariasen approximation. (A) Presented at Amer. Cryst. Ass. Meet., Buffalo, N.Y., Aug. 1968.
- COPPENS, P. AND HAMILTON, W.C. Errors in electron density maps and the use of integrated densities in the study of charge density distributions. *Acta Cryst.* (in press).
- COPPENS, P. AND SABINE, T.M. A low-temperature phase transition in *s*-triazine. *Mol. Cryst.* **3**, 507-12 (1968).
- COPPENS, P. AND SABINE, T.M. Neutron diffraction study of hydrogen bonding and thermal motion in deuterated α and β oxalic acid dihydrate. Submitted to *Acta Cryst.*
- COPPENS, P., SABINE, T.M., VOS, A., DELAPLANE, R.G., AND IBERS, J.A. Comparison of x-ray and neutron diffraction results at room temperature and at liquid nitrogen temperature. (A) Presented at Amer. Cryst. Ass. Meet., Buffalo, N.Y., Aug. 1968.
- COPPENS, P. - See also SNYDER, R.L.; STEWART, R.F.
- CORLISS, L.M. AND HASTINGS, J.M. Neutron-diffraction study of MnSn_2 . *J. Appl. Phys.* **39**, 461-2 (1968).
- CORLISS, L.M. - See also HASTINGS, J.M.; KUNNMANN, W.; NORVELL, J.C.
- COULSON, C.A. - See COPPENS, P.
- CRAGG, C.B. - See BIGEISEN, J.
- CRESPO, V.P., CUMMING, J.B., AND POSKANZER, A.M. Fission of U^{238} by 2.2-GeV protons. Submitted to *Phys. Rev.*
- CRESPO, V.P. - See also CUMMING, J.B.
- CUMMING, J.B. AND CRESPO, V.P. Energy loss and range of fission fragments in solid media. *Phys. Rev.* **161**, 287-93 (1967).
- CUMMING, J.B. - See also CRESPO, V.P.; PLASIL, F.; POSKANZER, A.M.
- DAVIS, R. JR., HARMER, D.S., AND HOFFMAN, K.C. A search for neutrinos from the sun. (L) *Phys. Rev. Letters* **20**, 1205-9 (1968).
- DELAPLANE, R.G. - See COPPENS, P.
- DENNEY, D.B., GARTH, B.H., O'FARRELL, C.P., SELTZER, S., AND TSOLIS, A. Solvolysis of carbalkoxyphosphonium salts. (A) Presented at Amer. Chem. Soc. Meet., San Francisco, April 1968.
- DIEHN, B., ROWLAND, F.S., AND WOLF, A.P. Zone refining for the separation of radioactive trace contaminants from organic compounds. *Anal. Chem.* **40**, 60-4 (1968).
- DONARUMA, L.G. - See BEDNOWITZ, A.L.
- EHRENSON, S. Environmental effects in the MO treatment of the trimethylamine-trimethylboron addition reaction. *Theoret. Chim. Acta* **10**, 209-21 (1968).
- EHRENSON, S. Theory of electronic effects in the formation of the trimethylamine-trimethylboron addition complex. *Ibid.*, 193-208.
- EHRENSON, S. - See also WELLS, P.R.
- ELLIOTT, N. - See BERNAL, I.
- ERICKSON, N.E. Interpretation of Mössbauer chemical isomeric shift data. (A) Presented at Chem. Soc. Meet., London, Sept. 1967.

- ERICKSON, N.E. Mössbauer spectroscopy of iron compounds. *Advan. Chem. Ser.* **68**, 86-104 (1967).
- ERICKSON, N.E., MARTIN, H.R., AND PERLMAN, M.L. Mössbauer studies of some Te^{125} compounds. (A) Presented at Amer. Chem. Soc. Meet., Atlantic City, Sept. 1968.
- ERICKSON, N.E. - See also CEFOLA, M.; KAZIMIR, E.O.; REIFF, W.M.
- FICKEL, H.R. - See KATCOFF, S.
- FRAENKEL, Z. - See CHEN, K.
- FRANZ, E.-M. - See CHU, Y.Y.
- FREEMAN, J. J. - See BIELSKI, B.H. J.
- FRIEDLANDER, G. - See CHEN, K.; CHU, Y.Y.
- FRIEDMAN, L. Ion molecule reactions. *Annu. Rev. Phys. Chem.* (in press).
- FRIEDMAN, L. AND IRSA, A.P. Variation in the isotopic composition of carbon in urban atmospheric carbon dioxide. (N) *Science* **158**, 263-4 (1967).
- FRIEDMAN, L. - See also LEVENTHAL, J. J.
- GARTH, B.H. - See DENNEY, D.B.
- GEBICKI, J.M. - See BIELSKI, B.H. J.
- GODEL, J.B. AND HENDRIE, J.M. Control blades for the High Flux Beam Reactor. *Nucl. Appl.* **4**, 418-24 (1968).
- GODEL, J.B. - See also COPPENS, P.; RUDMAN, R.
- GOLD, V. The rule of the geometric mean: Its role in the treatment of thermodynamic and kinetic deuterium solvent isotope effects. *Trans. Faraday Soc.* (in press).
- GOLDFARB, T.D. - See RUDMAN, R.
- GOPINATHAN, K.P. - See RUBINSON, W.
- GROVER, J.R., LEBOWITZ, E., AND BAKER, E.W. Rapid emanation of astatine and radon. (A) Presented at Amer. Chem. Soc. Meet., San Francisco, April 1968.
- GROVER, J.R. - See also CHEN, K.; HILLMAN, M. (Nuclear Engineering).
- GUTLICH, P. AND HARBOTTLE, G. A study of ^{51}Cr retention and annealing in single crystals of K_2CrO_4 irradiated at low neutron doses. *Radiochim. Acta* **8**, 30-3 (1967).
- HAHN, R.L. - See CHU, Y.Y.
- HALEVI, E.A. - See SHINER, V. J. Jr.
- HAMILTON, W.C. Comparison of x-ray and neutron diffraction structural results: A study in methods of error analysis. Presented at Int. Meet. Accurate Determination of X-ray Intensities and Structure Factors, Cambridge, England, June 1968.
- HAMILTON, W.C. Computers, chemists and crystallography. *J. Comput. Phys.* (in press).
- HAMILTON, W.C. Diffraction studies of molecular motion. Submitted to *Mol. Cryst.*
- HAMILTON, W.C. Dynamics and structure in molecular crystals. I. Scattering methods and intermolecular forces: Models, techniques, and results. Presented at 2nd Mater. Res. Symp. Molecular Dynamics and Structure of Solids, Gaithersburg, Md., Oct. 1967.
- HAMILTON, W.C. Neutron diffraction: Applications to systems of biological interest. (A) Presented at Amer. Chem. Soc. Meet., Atlantic City, Sept. 1968.
- HAMILTON, W.C. On hydrogen in inorganic crystals: Some generalizations, some recent results, and some new techniques. In *Structural Chemistry and Molecular Biology (a volume dedicated to Linus Pauling)*, pp. 466-83, A. Rich and N. Davidson, Editors, W.H. Freeman and Co., San Francisco, 1968.
- HAMILTON, W.C. Structural chemistry in the nuclear age. *J. Chem. Educ.* **45**, 296-303 (1968).
- HAMILTON, W.C. AND ABRAHAMS, S.C. International Union of Crystallography Commission on Crystallographic Apparatus: Single crystal intensity project report. II. Least squares refinements of structural parameters. Presented at Int. Meet. Accurate Determination of X-Ray Intensities and Structure Factors, Cambridge, England, June 1968.
- HAMILTON, W.C. AND BERNAL, I. The crystal and molecular structure of the tetra-*n*-butylammonium salt of bis(maleonitriledithiolato)iron(III) - A pyramidal iron(III) dimer. *Inorg. Chem.* **6**, 2003-8 (1967).
- HAMILTON, W.C. AND LA PLACA, S. J. The crystal and molecular structure of an antileukemia drug: Methylglyoxal bisguanyldihydrazone dihydrochloride monohydrate, $\text{C}_5\text{N}_8\text{H}_{12} \cdot 2\text{HCl} \cdot \text{H}_2\text{O}$. Neutron and x-ray diffraction studies. *Acta Cryst.* (in press).
- HAMILTON, W.C. - See also ABRAHAMS, S.C.; BEDNOWITZ, A.L.; COPPENS, P.; LALANCETTE, R.A.; RICCI, J.S. JR.; RUDMAN, R.; SEQUEIRA, A.; SHEN, K.; TIPPE, A.
- HARBOTTLE, G. Some current problems in the chemical effects of nuclear transformations. Presented at 2nd Inter-Amer. Conf. Radiochemistry, Mexico City, April 1968.
- HARBOTTLE, G. AND ZAHN, U. Recoil behavior of different isotopes in metal hexacarbonyls. (N) *Radiochim. Acta* **8**, 114-6 (1967).
- HARBOTTLE, G. - See also BUTTERWORTH, J.S.; GUTLICH, P.
- HARMER, D.S. - See DAVIS, R. JR.
- HASTINGS, J.M. AND CORLISS, L.M. Magnetic structure and metamagnetism of HgCr_2S_4 . *J. Phys. Chem. Solids* **29**, 9-14 (1968).
- HASTINGS, J.M. - See also CORLISS, L.M.; KUNNMANN, W.; NORVELL, J.C.
- HAVENS, W.W. JR. - See LEUNG, P.S.
- HECHTL, E. - See CHU, Y.Y.
- HO, S.K., SIEGEL, S., AND SCHWARZ, H.A. Pulse radiolysis of polystyrene. *J. Phys. Chem.* **71**, 4527-33 (1967).
- HUDIS, J. Production of neon-24 and sodium-24 in the 1-3 GeV proton bombardment of copper, silver, gold and uranium targets. *Phys. Rev.* **171**, 1301-4 (1968).
- HUDIS, J. AND TANAKA, S. Production of ^7Be , ^{22}Na and ^{24}Na fragments from heavy elements at 3, 10 and 30 GeV. *Ibid.*, 1297-300.
- IBERS, J.A. - See COPPENS, P.
- IRSA, A.P. - See FRIEDMAN, L.
- ISHIDA, T. AND BIGELEISEN, J. A greaseless valve for use in mercury reservoirs. (N) *J. Sci. Instr.* **1**, 359-60 (1968).
- ISHIDA, T., SPINDEL, W., AND BIGELEISEN, J. Theoretical analysis of chemical isotope fractionation by orthogonal polynomial methods. Submitted to *Advan. Chem.*
- ISHIDA, T. - See also BIGELEISEN, J.
- JEEVANANDAM, M. - See BIGELEISEN, J.
- KAROL, P. J. - See CHU, Y.Y.
- KATCOFF, S. Interactions of 1.0-, 2.0-, and 3-GeV protons with Ag and Br in nuclear emulsion. II. *Phys. Rev.* **164**, 1367-9 (1967).
- KATCOFF, S., FICKEL, H.R., AND WYTENBACH, A. Distribution of radionuclides from the interaction of 3- and 29-GeV protons with silver. *Ibid.* **166**, 1147-55 (1968).
- KAZIMIR, E.O., CEFOLA, M., AND ERICKSON, N.E. The relationship between molecular geometry and the quad-

- rupole splitting in the Mössbauer spectra of certain tin compounds. (A) Presented at Amer. Chem. Soc. Meet., Atlantic City, Sept. 1968.
- KAZIMIR, E.O. - See also CEFOLA, M.
- KIBBY, C.L. AND WESTON, R.E. JR. Difference in the reactivities of trifluoromethyl and methyl radicals produced by photodissociation. (L) *J. Amer. Chem. Soc.* **90**, 1084-5 (1968).
- KIRSTEN, T., SCHAEFFER, O.A., NORTON, E., AND STOENNER, R.W. Experimental evidence for the double beta decay of Te^{130} . (L) Submitted to *Phys. Rev. Letters*.
- KROFF, R. - See BEDNOWITZ, A.L.
- KUNNMANN, W. A review of the preparation of single crystals by fused melt electrolysis and some general properties. Submitted to *Prep. Solid State Mater.*
- KUNNMANN, W., LA PLACA, S. J., CORLISS, L.M., HASTINGS, J.M., AND BANKS, E. Magnetic structures of the ordered trirutiles Cr_2WO_6 , Cr_2TeO_6 and Fe_2TeO_6 . *J. Phys. Chem. Solids* (in press).
- LALANCETTE, R.A., CEFOLA, M., HAMILTON, W.C., AND LA PLACA, S. J. Unusual dodecahedral coordination in the structure of ammonium tetrakis [4,4,4-trifluoro-1-(2-thienyl)-1,3-butanedionol]-praseodymium(III) monohydrate, $\text{NH}_4\text{Pr}(\text{C}_8\text{H}_4\text{F}_3\text{O}_2\text{S})_4 \cdot \text{H}_2\text{O}$. *Inorg. Chem.* **6**, 2127-34 (1967).
- LALANCETTE, R.A. - See also BERNAL, I.
- LA PLACA, S. J. - See HAMILTON, W.C.; KUNNMANN, W.; LALANCETTE, R.A.; SHEN, K.; VOGT, L.H. JR.
- LEBOWITZ, E. AND MILLER, J.M. The production of tritium from bombardment of He^4 by high-energy protons. Submitted to *Phys. Rev.*
- LEBOWITZ, E. - See also GROVER, J.R.
- LECHTMAN, H.N. - See SAYRE, E.V.
- LEUNG, P.S., TAYLOR, T.I., AND HAVENS, W.W. JR. Studies of phase transitions in ammonium salts and barriers to rotation of ammonium ions by neutron scattering cross sections as a function of temperature. Submitted to *J. Chem. Phys.*
- LEVENTHAL, J. J. AND FRIEDMAN, L. Charge transfer and proton transfer in polyatomic ion-molecule systems. *J. Chem. Phys.* **48**, 1559-70 (1968).
- LEVENTHAL, J. J. AND FRIEDMAN, L. Experimental determination of D_3^+ dissociation energy. *J. Chem. Phys.* (in press).
- LEVENTHAL, J.J., MORAN, T.F., AND FRIEDMAN, L. Reactions of ArD^+ and gaseous molecules. (A) *Bull. Amer. Phys. Soc.* **13**, 68 (1968).
- MARTIN, H.R. - See ERICKSON, N.E.
- MARTINOTTI, F.F., WELCH, M. J., AND WOLF, A.P. The reactivity of thermal carbon atoms in the gas phase. *Chem. Commun.* **1968**, No. 3, 115-16.
- MATHIESON, A.M. - See ABRAHAMS, S.C.
- MC EWEN, W.E., WOLF, A.P., VANDERWERF, C.A., BLADE-FONT, A., AND WOLFE, J.W. Mechanism of the thermal decomposition of the condensation product of a phosphonium ylide with an epoxide. *J. Amer. Chem. Soc.* **89**, 6685-91 (1967).
- MC EWEN, W.E. - See also SHEN, K.
- MIGITA, T., REDVANLY, C.S., AND WOLF, A.P. The gas phase photolysis of diazoisobutane: Steric control in a carbene rearrangement. (A) Presented at Amer. Chem. Soc. Meet., San Francisco, April 1968.
- MILLER, J.M. - See CHEN, K.; LEBOWITZ, E.
- MORAN, T.F. - See LEVENTHAL, J. J.
- MYLONAKIS, S.G. AND SELTZER, S. On the possibility of energy transfer through a hydrocarbon chain during thermal decomposition of an azo compound. *J. Amer. Chem. Soc.* (in press).
- MYLONAKIS, S.G. - See also SELTZER, S.
- NORTON, E. - See KIRSTEN, T.
- NORVELL, J.C., WOLF, W.P., CORLISS, L.M., HASTINGS, J.M., AND NATHANS, R. Critical magnetic scattering from dysprosium aluminum garnet (DAG). (A) *J. Appl. Phys.* **39**, 1232 (1968).
- NOVICK, S. - See RUDMAN, R.
- OAE, S., REDVANLY, C.S., AND WOLF, A.P. Recoil labeling and selective radiation labeling. A novel synthesis of propanol-2,3- $^{14}\text{C}_1$. *J. Labelled Comds.* **4**, 28-42 (1968).
- O'FARREL, C.P. - See DENNEY, D.B.
- ORHANOVIĆ, M., PO, H.N., AND SUTIN, N. The kinetics and mechanism of the oxidation of hexaquoovanadium(II) by the isothiocyanato- and thiocyanatopentaaquochromium(III) ions. *J. Amer. Chem. Soc.* **90**, 4286-90 (1968).
- ORHANOVIĆ, M. AND SUTIN, N. The kinetics of the spontaneous and mercury(II)-catalyzed aquation and isomerization of the sulfur-bonded monothiocyanate complex of chromium(III). *J. Amer. Chem. Soc.* (in press).
- ORHANOVIĆ, M. AND SUTIN, N. The mercury(II)-catalyzed isomerization of the sulfur-bonded monothiocyanate complex of chromium(III). (L) *J. Amer. Chem. Soc.* **90**, 538 (1968).
- PERLMAN, M.L. *The Atomic Electrons and Nuclear Transition: Some Interrelationships*, Brookhaven Lecture Series No. 72, Feb. 28, 1968. BNL 50100 (T-487).
- PERLMAN, M.L. - See also BOCQUET, J.-P.; ERICKSON, N.E.; PLASIL, F.; STEPHAN, C. J.
- PLASIL, F., REMSBERG, L.P., PERLMAN, M.L., AND CUMMING, J.B. Correlated energy and velocity measurements on fragment pairs from 2.9-GeV proton-induced fission of uranium. (A) Presented at Amer. Chem. Soc. Meet., San Francisco, April 1968.
- PO, H.N. AND SUTIN, N. The stability constant of the monochloro complex of iron(II). (L) *Inorg. Chem.* **7**, 621-4 (1968).
- PO, H.N. - See also ORHANOVIĆ, M.
- POSKANZER, A.M. Recent work on delayed neutron and proton emitters. (A) *Arkiv. Fysik* **36**, 469-70 (1966).
- POSKANZER, A.M., CUMMING, J.B., AND REMSBERG, L.P. The $\text{Al}^{27}(p, p\pi^+)\text{Mg}^{27}$ reaction from 0.6 to 28 GeV. *Phys. Rev.* **168**, 1331-5 (1968).
- POSKANZER, A.M. - See also CRESPO, V.P.
- POST, B. - See RUDMAN, R.
- RAO, K.N. AND ALLEN, A.O. The radiation chemistry of acetamide. *J. Phys. Chem.* **72**, 2181-5 (1968).
- RAPP, M. - See SHINER, V. J. JR.
- REDVANLY, C.S. - See MIGITA, T.; OAE, S.
- REIFF, W.M., BAKER, W.A. JR., AND ERICKSON, N.E. Studies of some binuclear, oxygen bridged complexes of iron(III). New iron(III)-2,2',2''-terpyridine complexes. Submitted to *J. Amer. Chem. Soc.*
- REMSBERG, L.P. Angular distributions of the recoil nuclei from the $\text{Cu}^{65}(p, pn)\text{Cu}^{64}$ reaction at 0.37, 1.0, and 2.8 GeV. Submitted to *Phys. Rev.*

- REMSBERG, L.P. Experience with a wired-program, multi-parameter pulse height analysis system. (A) Presented at Amer. Chem. Soc. Meet., San Francisco, April 1968.
- REMSBERG, L.P. - See also PLASIL, F.; POSKANZER, A.M.
- RIBNIKAR, S.V. AND BIEGELEISEN, J. Vapor pressures of solid isotropic isomers. (A) Presented at 5th Symp. Stable Isotopes, Leipzig, East Germany, Oct. 1967.
- RIBNIKAR, S.V. - See also BIEGELEISEN, J.
- RICCI, J.S. JR., BERNAL, I., AND HAMILTON, W.C. The crystal and molecular structure of 2,2'-biphenyldisulfide. *J. Amer. Chem. Soc.* (in press).
- ROWLAND, F.S. - See DIEHN, B.
- RUBINSON, W. AND GOPINATHAN, K.P. The conversion coefficients of the Fe^{57} 14.4-keV transition, the K -capture fraction in Co^{57} e^- capture, and the K -fluorescence yield of Fe. *Phys. Rev.* **170**, 969-78 (1968).
- RUDMAN, R. Single-crystal alignment with a Polaroid adapter for the Weissenberg goniometer. *Acta Cryst.* (in press).
- RUDMAN, R. AND GODEL, J.B. An automatic low-temperature apparatus for single crystal diffractometry. Submitted to *J. Sci. Instr.*
- RUDMAN, R., HAMILTON, W.C., NOVICK, S., AND GOLDFARB, T.D. Pentacoordinate silicon: The crystal structure of dimethylsilylamine pentamer. *J. Amer. Chem. Soc.* **89**, 5157-60 (1967).
- RUDMAN, R. AND POST, B. Polymorphism of crystalline cyclooctanone and cyclononanone. *Mol. Cryst.* **3**, 325-37 (1968).
- SAITO, E. Electron spin resonance studies of gamma-irradiated ferrocene. Submitted to *J. Chem. Phys.*
- SAYRE, E.V. Examination of fine art objects by nuclear means. (A) Presented at Nuclear Week in New York, New York, May 1968.
- SAYRE, E.V. The nuclear age and the fine arts. Presented at 1967 Youth Congr. on the Atom, Chicago, Nov. 1967.
- SAYRE, E.V. Revelation of internal structure of paintings through neutron activation autoradiography. In *Proc. 1st Int. Conf. Forensic Activation Analysis, San Diego, Calif., Sept. 1967*, pp. 119-32, V.P. Guinn, Editor, Gulf General Atomic, Inc., San Diego, 1967.
- SAYRE, E.V. Summary of the Brookhaven program of analysis of ancient glass. In *Application of Science in Examination of Works of Art (Proc. Seminar, Sept. 1965)*, pp. 145-54, Boston Museum of Fine Arts, 1967.
- SAYRE, E.V. AND CHAN, L.H. High resolution gamma ray spectroscopy applied in the analysis of ancient South Arabian and Mayan pottery. (A) Presented at Amer. Chem. Soc. Meet., Atlantic City, Sept. 1968.
- SAYRE, E.V. AND LECHTMAN, H.N. Neutron activation autoradiography of oil paintings. Submitted to *Stud. Conserv.*
- SAYRE, E.V. - See also AL KITAL, R.A.; CHAN, L.
- SCHAEFFER, O.A. - See KIRSTEN, T.
- SCHAEFFER, S.E. AND SELTZER, S. Neighboring-group effects in free radical reactions. The thermal decomposition of 1,1',2,2'-tetraphenylazoethane and 1,1',2,2'-tetraphenylazoethane-1,1'- d_2 . *J. Amer. Chem. Soc.* **90**, 358-62 (1968).
- SCHAEFFER, S.E. AND SELTZER, S. Rate studies of the thermal decomposition of 1,1',2,2'-tetraphenylazoethane and 1,1',2,2'-tetraphenylazoethane- α - α - d_2 . (A) Presented at Midwest Regional Meet. Amer. Chem. Soc., Columbia, Mo., Nov. 1967.
- SCHMIDT, W.F. AND ALLEN, A.O. Ionization of liquids by radiation: Measurement by a clearing field. (N) *Science* **160**, 301-2 (1968).
- SCHMIDT, W.F. AND ALLEN, A.O. Yield of free ions in irradiated liquids: Determination by a clearing field. (A) Presented at Symp. Radiation Chemistry and Photochemistry, Natick, Mass., April 1968.
- SCHWARZ, H.A. - See BIELSKI, B.H. J.; HO, S.K.
- SEEWALD, D. AND SUTIN, N. The formation of binuclear intermediates in the reactions of chloropentaaquoruthenium(III) with chromium(II) and the properties of ruthenium(II). (A) Presented at Amer. Chem. Soc. Meet., San Francisco, April 1968.
- SELTZER, S. The mechanism of the Diels-Alder reaction. *Advan. Alicyclic Chem.* (in press).
- SELTZER, S. AND MYLONAKIS, S.G. The correlation of secondary α -deuterium isotope effects with primary nitrogen effects in the thermolysis of azo compounds. *J. Amer. Chem. Soc.* **89**, 6584-9 (1967).
- SELTZER, S. AND MYLONAKIS, S.G. The effect of temperature on magnetically nonequivalent protons in an asymmetric azo compound. *J. Phys. Chem.* **72**, 754-6 (1968).
- SELTZER, S. AND STEVENS, K.D. A model for the enzyme-coenzyme catalyzed *cis-trans* isomerization of maleylacetoacetic acid. (A) Presented at Amer. Chem. Soc. Meet., San Francisco, April 1968.
- SELTZER, S. AND STEVENS, K.D. The preparation of *cis*- β -acetylacrylic acid. *J. Org. Chem.* **33**, 2708-11 (1968).
- SELTZER, S. AND ZAVITSAS, A.A. Correlation of isotope effects in substitution reactions with nucleophilicities. Secondary- α -deuterium isotope effect in the iodide-131 exchange of methyl- d_3 iodide. *Can. J. Chem.* **45**, 2023-31 (1967).
- SELTZER, S. - See also DENNY, D.B.; MYLONAKIS, S.G.; SCHEPPELE, S.E.; STEVENS, K.D.
- SEQUEIRA, A., BERKEBILE, C.A., AND HAMILTON, W.C. Structure and dynamics in hydrogen bonding systems. I. A neutron diffraction study of potassium hydrogen diaspirinate [bisacetylsalicylate]. *J. Mol. Struct.* **1**, 283-94 (1968).
- SEQUEIRA, A. AND BERNAL, I. A neutron diffraction study of lithium perchlorate trihydrate. (A) Presented at 2nd Mater. Res. Symp. Molecular Dynamics and Structure of Solids, Gaithersburg, Md., Oct. 1967.
- SEQUEIRA, A. AND HAMILTON, W.C. Hydrogen bonding in phosphonium iodide: A neutron-diffraction study. *J. Chem. Phys.* **47**, 1818-22 (1967).
- SEQUEIRA, A. - See also ABRAHAMS, S.C.
- SHEN, K., MCEWEN, W.E., LA PLACA, S. J., HAMILTON, W.C., AND WOLF, A.P. Crystal and molecular structures of methoxytetraphenylantimony and dimethoxytriphenylantimony. *J. Amer. Chem. Soc.* **90**, 1718-23 (1968).
- SHINER, V. J. JR., RAPP, M., HALEVI, E.A., AND WOLFSBERG, M. Solvolytic α -deuterium effects for different leaving groups. (L) Submitted to *J. Amer. Chem. Soc.*
- SIEGEL, S. - See HO, S.K.
- SNYDER, R.L., CEFOLA, M., AND COPPENS, P. A study of the triatomic polyhalide anions. I. A new preparative technique. Submitted to *J. Amer. Chem. Soc.*

- SOUTHWICK, P.L. - See BEDNOWITZ, A.L.
 SPINDEL, W. - See ISHIDA, T.
 STANFIELD, R.A. - See BEDNOWITZ, A.L.
 STEPHAN, C. J. AND PERLMAN, M.L. Fission of uranium and tantalum induced by 156-MeV protons. *Phys. Rev.* **164**, 1528-36 (1967).
 STEVENS, K.D. AND SELTZER, S. Thiocyanate-catalyzed *cis-trans* isomerization of *cis*- β -acetylacrylic acid, a model for maleylacetoacetic acid. *J. Org. Chem.* (in press).
 STEVENS, K.D. - See also SELTZER, S.
 STEWART, R.F. AND COPPENS, P. The interaction between x-ray thermal parameters and the redistribution of valence electron density in molecules. (A) Presented at Amer. Cryst. Ass. Meet., Tucson, Ariz., Feb. 1968.
 STOENNER, R.W. - See KIRSTEN, T.
 SUTIN, N. Free energies, barriers, and reactivity patterns in electron transfer reactions. *Accounts Chem. Res.* (in press).
 SUTIN, N. *The Mechanisms of Oxidation-Reduction Reactions in Solution, Brookhaven Lecture Series No. 67, June 21, 1967.* BNL 50070 (T-469).
 SUTIN, N. The mechanisms of some electron transfer reactions in solution. *Electrochim. Acta* (in press).
 SUTIN, N. - See also ARDON, M.; BAKER, B.R.; ORHANOVIĆ, M.; PO, H.N.; SEEWALD, D.
 TAFT, R.W. - See WELLS, P.R.
 TANAKA, S. - See HUDIS, J.
 TAYLOR, T.I. - See LEUNG, P.S.
 TIPPE, A. AND HAMILTON, W.C. A neutron diffraction study of decaborane. Submitted to *Inorg. Chem.*
 TSOLIS, A. - See DENNY, D.B.
 VANDERWERF, C.A. - See McEWEN, W.E.
 VOGT, L.H. JR., LAPLAGA, S. J., AND BEDNOWITZ, A.L. The crystal and molecular structure of bis(2,4,6-trichlorophenolato)-N,N',N'-tetramethylethylenediaminecopper(II). (A) Presented at Amer. Chem. Soc. Meet., San Francisco, April 1968.
 VOS, A. - See COPPENS, P.
 WELCH, M. J. AND WOLF, A.P. Reaction intermediates in the chemistry of recoil carbon atoms. *Chem. Commun.* **1968**, No. 3, 117-18.
 WELCH, M. J. - See also MARTINOTTI, F.F.
 WELCH, T. J. - See BAKER, B.R.
 WELLS, P.R., EHRENSON, S., AND TAFT, R.W. Substituent effects in the naphthalene series. An analysis of polar and pi delocalization effects. *Progr. Phys. Org. Chem.* (in press).
 WESTON, R.E. JR. Transition-state models and hydrogen-isotope effects. *Science* **158**, 332-42 (1967).
 WESTON, R.E. JR. - See also KIBBY, C.L.
 WITHNELL, R. A high voltage supply for solid state particle detectors. (L) *Nucl. Instr. Methods* **62**, 351-2 (1968).
 WOLF, A.P. Labeling of organic compounds by irradiation and other non-synthetic methods. In *Methods of Preparing and Storing Labelled Compounds (Proc. 2nd Int. Conf., Brussels, Nov. 28-Dec. 3, 1966)*, pp. 907-34, J. Sirchis, Editor, Euratom, Brussels, March 1968.
 WOLF, A.P. Mechanistic aspects of carbon atom reactions. (A) In *Proc. 18th Symp. Organic Reaction Mechanisms, Kyoto, Japan, Oct. 1967* (in press).
 WOLF, A.P. - See also ACHE, H. J.; DIEHN, B.; MARTINOTTI, F.F.; McEWEN, W.E.; MIGITA, T.; OAE, S.; SHEN, K.; WELCH, M. J.
 WOLF, W.P. - See NORVELL, J.C.
 WOLFE, J.W. - See McEWEN, W.E.
 WOLFSBERG, M. Correction to the effect of anharmonicity on isotopic exchange equilibria. Submitted to *Advan. Chem. Ser.*
 WOLFSBERG, M. Correction to the effect of anharmonicity on isotopic exchange equilibria. Application to polyatomic molecules. (N) Submitted to *J. Chem. Phys.*
 WOLFSBERG, M. Isotope effects as tools for the study of chemical reactions. (A) Presented at 5th Symp. Stable Isotopes, Leipzig, East Germany, Oct. 1967.
 WOLFSBERG, M. - See also BIGEISEN, J.; SHINER, V. J. JR.
 WYTENBACH, A. - See KATCOFF, S.
 ZAHN, U. - See HARBOTTLE, G.
 ZAVITSAS, A.A. - See SELTZER, S.

Instrumentation and Health Physics Department

- BAKER, L.A. JR. AND FERRARO, C. JR. Combustible gas detection in high energy research operations. Presented at Annu. Meet. Instr. Soc. Amer., Chicago, Sept. 1967.
 BAKER, L.A. JR. - See also TICHLER, P. (Reactor).
 BAUM, J.W., STONE, S.L., AND KUEHNER, A.V. Radial distribution of dose along heavy ion tracks, LET_r. In *Proc. Symp. Microdosimetry, Ispra, Italy, Nov. 1967*, pp. 269-94, Euratom, Brussels, Jan. 1968.
 BAUM, J.W. - See also LITTLEFIELD, P.S.
 BROWN, R.M. Hail, hail - A case history. *Weatherwise* **20**, 254-8 (1967).
 BUSCH, N.E. - See FRIZZOLA, J.A.; SINGER, I.A.
 CHAMPAGNE, R. J. - See PHILLIPS, L.F.
 CHASE, R.L. A pulse timing system for use with gamma rays on Ge(Li) detectors. *Rev. Sci. Instr.* (in press).
 CHASE, R.L. - See also CHESTER, J.; KRANER, H.W.
 CHESTER, J. AND CHASE, R.L. A compact counting system utilizing integrated circuits and a solid state detector. Submitted to *Health Phys. J.*
 COHEN, L.A. - See SMITH, M.E.
 COWAN, F.P. Interactions above 10 GeV. *Radiat. Res. Suppl.* **7**, 1-9 (1967).
 DISTENFELD, C.H. - See ADAMS, R.R. (Accelerator); LEVINE, G.S. (Accelerator).
 FERRARO, C. JR. - See BAKER, L.A. JR.
 FISCHER, J. Digitized spark chambers in high energy physics. In *Proc. Int. Conf. Electromagnetic Interactions at Low and Intermediate Energies, Dubna, USSR, Feb. 1967*, Vol. 4, pp. 179-250, Acad. Sci. USSR, Moscow, 1967.
 FISCHER, J. AND SHIBATA, S. Transmission-line type large digital spark chambers. *IEEE Trans. Nucl. Sci.* **NS-15**, No. 3, 572 (1968).
 FISCHER, J. - See also SUTTER, R. J. (Physics).
 FRIZZOLA, J.A., SINGER, I.A., AND BUSCH, N.E. A summary of recent turbulence measurements at Brookhaven National Laboratory. In *Proc. AEC Meteorol. Inform. Meet., Chalk River, Canada, Sept. 1967* (in press).
 FRIZZOLA, J.A. - See also SINGER, I.A.
 GILMARTIN, J.T. - See HULL, A.P.
 HAYES, J.V. - See OGDEN, E.C.; RAYNOR, G.S.
 HIGINBOTHAM, W.A. Effectiveness and failures of monitoring systems. In *Pediatrics* **41**, Pt. 2, 196-206 (1968).

- HULL, A.P. Ambient air sampling and analysis methods. Gross alpha analysis; Gross beta analysis. In *Manual of Methods for Ambient Air Sampling and Analysis, Section on Radioactivity*, Amer. Public Health Ass., New York (in press); in *Standard Methods, Section on Radiological Methods for Biological and Environmental Samples*, 1970 Ed., Amer. Public Health Ass., New York (in press).
- HULL, A.P. 1965 *Environmental Monitoring Radiation Levels at Brookhaven National Laboratory*. BNL 50093 (T-483), Sept. 1967.
- HULL, A.P., GILMARTIN, J.T., AND SMITH, M.E. The evaluation of fission product and activation isotopes in a reactor stack effluent and in the nearby environment. In *Proc. Health Phys. Soc. Symp. Environmental Surveillance, Augusta, Ga., Jan. 1968* (in press).
- HULL, A.P. AND SMITH, M.E. Environmental monitoring of ^{131}I as a verification of meteorological calculations of dispersion from a 100 meter stack. In *Proc. 1st Int. Congr. Radiat. Protect. Ass., Rome, Italy, Sept. 1966* (in press).
- HULL, A.P. AND STEIMERS, J. Determination of tritium oxide in air by adsorption. In *Manual of Methods for Ambient Air Sampling and Analysis, Section on Radioactivity*, Amer. Public Health Ass., New York (in press); in *Standard Methods, Section on Radiological Methods for Biological and Environmental Samples*, 1970 Ed., Amer. Public Health Ass., New York (in press).
- HULL, A.P. AND STEIMERS, J. Determination of tritium oxide in air by cooling. *Ibid.*
- HULL, A.P. - See also LITTLEFIELD, P.S.
- KARLOVAC, N. - See RADEKA, V.
- KRANER, H.W. AND CHASE, R.L. A total absorption Ge(Li) gamma ray spectrometer. *IEEE Trans. Nucl. Sci.* NS-15, No. 3, 381 (1968).
- KRANER, H.W., CHASMAN, C., AND JONES, K.W. Effects produced by fast neutron bombardment of Ge(Li) gamma ray detectors. *Nucl. Instr. Methods* 62, 173-83 (1968).
- KRANER, H.W. AND WEGNER, H.E. Gamma-ray compensated germanium detectors. (A) *Bull. Amer. Phys. Soc.* 13, 560 (1968).
- KUEHNER, A.V. - See BAUM, J.W.
- LITTLEFIELD, P.S., HULL, A.P., BAUM, J.W., AND SMITH, M.E. Continuous low level environmental measurement of ^{41}Ar and other radioactive noble gases. In *Proc. Health Phys. Soc. Symp. Environmental Surveillance, Augusta, Ga., Jan. 1968* (in press).
- OGDEN, E.C., RAYNOR, G.S., AND HAYES, J.V. Diurnal patterns of pollen emission in *Ambrosia*, *Phleum*, *Zea* and *Ricinus*. Submitted to *Amer. J. Botany*.
- OGDEN, E.C. - See also RAYNOR, G.S.
- OPHIR, D., RANKOWITZ, S., SHEPHERD, B. J., AND SPINRAD, R. J. BRAD: The Brookhaven Raster Display. *Commun. Ass. for Computing Machinery* 2, 415-16 (1968).
- OPHIR, D. AND SHEPHERD, B. J. DTN - Data terminal network computer system. *Nucl. Instr. Methods* 62, 285-94 (1968).
- OPHIR, D., SHEPHERD, B. J. AND SPINRAD, R. J. Three-dimensional computer display. Submitted to *Commun. Ass. for Computing Machinery*.
- PEARSALL, S.G. AND WILSHUSEN, W. The disposal of chemical and radioactive waste. In *Proc. 14th Nat. Conf. Campus Safety, Univ. of Nebraska, Lincoln, June 1967, Monograph No. 23*, pp. 10-25, Campus Safety Ass., 1967.
- PHILLIPS, L.F. AND CHAMPAGNE, R. J. The effect of the secondary electron population in air on the interpretation and calibration of personnel monitoring film badges. In *Dosimetry of Irradiations From External Sources (Proc. Int. Symp., Paris, Nov. 1964)*, Vol. 1, pp. 60-4, French Sect. Health Phys. Soc., Central Service, 1967.
- PHILLIPS, L.F., SCALSKY, E.D., AND CHAMPAGNE, R. J. Dose distributions as a function of LET and measurements of QF around the BNL Medical Research Reactor. *Health Phys. J.* 13, 1175-86 (1967).
- RADEKA, V. The effect of "baseline restoration" on signal-to-noise ratio in pulse amplitude measurements. *Rev. Sci. Instr.* 38, 1397-403 (1967).
- RADEKA, V. Field-effect transistor noise as a function of temperature and frequency. In *Proc. Conf. Semiconductor Radiation Detectors and Circuits, Gatlinburg, Tenn., May 1967*, Nat. Res. Council (in press).
- RADEKA, V. Optimum signal-processing for pulse-amplitude spectrometry in the presence of high-rate effects and noise. *IEEE Trans. Nucl. Sci.* NS-15, No. 3, 455 (1968).
- RADEKA, V. Signal processing for high-resolution pulse amplitude spectrometry. In *Proc. Conf. Semiconductor Radiation Detectors and Circuits, Gatlinburg, Tenn., May 1967*, Nat. Res. Council (in press).
- RADEKA, V. AND KARLOVAC, N. Time-variant filters for high-rate pulse amplitude spectrometry. *Ibid.*
- RANKOWITZ, S. - See OPHIR, D.
- RAYNOR, G.S., OGDEN, E.C., AND HAYES, J.V. Effect of a local source on ragweed pollen concentrations from background sources. *J. Allergy* 41, 217-25 (1968).
- RAYNOR, G.S. - See also OGDEN, E.C.
- ROGERS, E. J. A portable neutron dose equivalent meter. *IEEE Trans. Nucl. Sci.* NS-14, No. 5, 8-14 (1967).
- ROGERS, E. J. Semiconductor lifetime measuring apparatus. Informal Report BNL 11645.
- ROGERS, E. J. - See also TONNA, E.A. (Medical).
- SANCHEZ, J. A computer oriented system for solid state physics studies. Informal Report BNL 11743.
- SCALSKY, E.D. - See PHILLIPS, L.F.
- SHEPHERD, B. J. - See OPHIR, D.
- SHIBATA, S. - See FISCHER, J.
- SINGER, I.A. Steadiness of the wind. *J. Appl. Meteorol.* 6, 1033-8 (1967).
- SINGER, I.A., BUSCH, N.E., AND FRIZZOLA, J.A. The micro-meteorology of the turbulent flow field in the atmospheric surface boundary layer. In *Proc. Int. Res. Seminar Wind Effects on Buildings and Structures, Ottawa, Canada, Sept. 1967*, Nat. Res. Council (in press); submitted to *Acta Polytech. Scand.*
- SINGER, I.A. - See also FRIZZOLA, J.A.
- SMITH, M.E. The influence of atmospheric dispersion on the exposure of plants to airborne pollutants. Submitted to *J. Am. Phytopathol. Soc.*
- SMITH, M.E. The tall stack. *Mech. Eng.* 90, 20-2 (1968).
- SMITH, M.E. AND COHEN, L.A. An isotopic ratio tracer technique. In *Proc. AEC Meteorol. Inform. Meet., Chalk River, Ontario, Canada, Sept. 1967* (in press).
- SMITH, M.E. - See also HULL, A.P.; LITTLEFIELD, P.S.
- SPINRAD, R. J. The automated laboratory. *Trans. N.Y. Acad. Sci.* (in press).

- SPINRAD, R. J. Automation in the laboratory. *Science* **158**, 55-60 (1967).
 SPINRAD, R. J. - See also OPHIR, D.
 STEIMERS, J. - See HULL, A.P.
 STEPHANI, D. Percentage of amplitude modulation measurements. *Electron. World* **79**, 51 (1968).
 STONE, S.L. - See BAUM, J.W.
 WILSHUSEN, W. - See PEARSALL, S.G.

Medical Department

- ABE, H. - See SHREEVE, W.W.
 ARONSON, R.B. - See COTZIAS, G.C.
 ATKINS, H.L. Nuclear medicine program at Brookhaven National Laboratory. (A) Presented at AEC Meet., Div. Biol. Med., Washington, D.C. March 1968.
 ATKINS, H.L. Radionuclides for medical application. II. Endocrine. In *Handbook of Radioactive Isotopes* (in press).
 ATKINS, H.L. Scintillation scanning with technetium-99m. Submitted to *J. Inst. Radiol. Oncol., Kazakhstan*.
 ATKINS, H.L. Use of californium-252 as an interstitial source of fast neutrons. Presented at Transplutonium Program Comm. Meet., Germantown, Md., April 1968.
 ATKINS, H.L. AND FLEAY, R.F. Data blending with technetium-99m in evaluation of thyroid anatomy by scintillation scanning. *J. Nucl. Med.* **9**, 66-73 (1968).
 ATKINS, H.L., HAUSER, W., AND RICHARDS, P. A comparison of conventional and blended display technics in scintiscanning. *Radiology* **90**, 912-20 (1968).
 ATKINS, H.L., HAUSER, W., AND RICHARDS, P. Reduction of respiratory artifact in scintillation scanning. *Am. J. Roentgenol. Radiat. Ther. Nucl. Med.* (in press).
 ATKINS, H.L., HAUSER, W., RICHARDS, P., AND ROBERTSON, J.S. Analysis of the optimum conditions for data display and image perception in photoscanning. In *Proc. Symp. Medical Radioisotope Scintigraphy, Salzburg, Austria, Aug. 1968* (in press).
 ATKINS, H.L. AND RICHARDS, P. Assessment of thyroid function and anatomy with technetium-99m as per-technetate. *J. Nucl. Med.* **9**, 7-15 (1968).
 ATKINS, H.L. AND RICHARDS, P. Demonstration of bone infarct by scintillation scanning with ^{99m}Tc colloid. A case report. *Ibid.*, 163-4.
 ATKINS, H.L. - See also HAUSER, W.; COHN, S.H.; RICHARDS, P. (Nuclear Engineering); SCHIFFER, L.M.
 BATEMAN, J.L. A relation of irradiation dose-rate effects in mammals and in mammalian cells. Presented at Symp. Dose Rate in Mammalian Radiation Biology, Oak Ridge, Tenn., April 1968.
 BATEMAN, J.L., BIAVATI, B. J., AND BOND, V.P. Dose-dependence of fast neutron RBE for lens opacification in mice. Submitted to *Radiat. Res.*
 BATEMAN, J.L. AND BOND, V.P. Lens opacification in mice exposed to fast neutrons. *Radiat. Res. Suppl.* **7**, 239-49 (1967).
 BATEMAN, J.L., JOHNSON, H.A., BOND, V.P., AND ROSSI, H.H. The dependence of RBE on the energy of fast neutrons. V. Spermatogonia depletion in mice. *Radiat. Res.* **35**, 86-101 (1968).
 BERMAN, M.C. - See BISESI, G.; BROWNELL, G.L.
 BERTINCHAMPS, A. - See FORADORI, A.C.
 BIAVATI, B. J. - See BATEMAN, J.L.
 BISESI, G. AND BERMAN, M.C. Differential accumulation of glycine by avian (chicken) and mammalian (human) erythrocytes: Lack of insulin effect. *Proc. Soc. Exp. Biol. Med.* **127**, 363-4 (1968).
 BOND, V.P. *The Cellular Basis of Acute Radiation Death in the Mammal, Brookhaven Lecture Series No. 63, Feb. 8, 1967.* BNL 50064 (T-465).
 BOND, V.P. Cellular radiobiology in the mammal. In *Proc. 1st Int. Symp. Biological Interpretation of Dose From Accelerator-Produced Radiation, Berkeley, Calif., March 1967*, pp. 1-14, R. Wallace, Editor, CONF-670305, 1967.
 BOND, V.P. Lens opacification in the mouse: Implications for RBE and QF. In *Biophysical Aspects of Radiation Quality (Proc. 2nd IAEA Panel, Vienna, April 1967)*, pp. 149-60, IAEA, Vienna, 1968.
 BOND, V.P. AND ROBINSON, C.V. A mortality determinant in nonuniform exposures of the mammal. *Radiat. Res. Suppl.* **7**, 265-75 (1967).
 BOND, V.P. - See also BATEMAN, J.L.; CARSTEN, A.L.; CONARD, R.A.; JESSEPH, J.E.; ODARTCHENKO, N.; TIS-LJAR-LENTULIS, G.M.
 BORG, D.C. - See COTZIAS, G.C.; GRADY, F. J.; PAPAVASILIOU, P.S.
 BORNER, G. - See VINCENT, P.C.
 BOZZO, S.R. - See GUSMANO, E.A.
 BRONK, B.V. On radioactive labeling of proliferating cells: The graph of labeled mitosis. Submitted to *J. Theoret. Biol.*
 BRONK, B.V., DIENES, G. J., AND PASKIN, A. The stochastic theory of cell proliferation: Statistical kinematics. Submitted to *Biophys. J.*
 BRONK, B.V. - See also DIENES, G. J. (Physics); PASKIN, A. (Nuclear Engineering).
 BROWN, R.R., HANKES, L.V., SCHMAELER, M., AND LEKLEM, J. Tryptophan metabolism in cats studied with ¹⁴C-labeled intermediates. (A) *Fed. Proc.* **26**, 388 (1967).
 BROWN, R.R. - See also HANKES, L.V.
 BROWNELL, G.L., BERMAN, M., AND ROBERTSON, J.S. Nomenclature for tracer kinetics. *Int. J. Appl. Radiat. Isotopes* **19**, 249-62 (1968).
 BRYSK, M.M., CORPE, W.A., AND HANKES, L.V. Aspects of glycine metabolism in HCN producing strains of *Chromobacterium violaceum*. (A) *Bacteriol. Proc.* **1968**, 115.
 BRYSK, M.M., CORPE, W.A., AND HANKES, L.V. β -Cyanoalanine formation by *Chromobacterium violaceum*. Submitted to *Arch. Biochem. Biophys.*
 BRYSK, M.M., CORPE, W.A., AND HANKES, L.V. Formation of β -cyano-L-alanine by *Chromobacterium violaceum*. (A) *Bacteriol. Proc.* **1967**, 132.
 CARSTEN, A.L. Effects of ionizing radiation on the elasmobranch brain. (A) In *Shark Research Panel*, pp. 15-16, Amer. Inst. Biol. Sci., Washington, D.C., 1967-1968.
 CARSTEN, A.L. Pathogenesis of x-irradiation effects in the monkey cerebral cortex. II. Irradiation and functional changes. *Brain Res.* **7**, 5-27 (1968).
 CARSTEN, A.L. AND BOND, V.P. Colony forming units in the bone marrow of partial body irradiated mice. Presented at Teaching Symp. Normal and Malignant Cell Growth, Univ. of Chicago, Chicago, Ill., Feb. 1968.
 CARSTEN, A.L. AND BOND, V.P. CFU content of the x-ray-exposed and shielded mouse femur. *Exp. Hematol. (ORNL)* **No. 15**, 95-103 (1968).

- CARSTEN, A.L. AND BOND, V.P. Effect of shielding on the CFU content of the mouse leg. (A) *Radiat. Res.* (in press).
- CARSTEN, A.L. AND BOND, V.P. Viability of stored bone marrow colony forming units. *Nature* (in press).
- CARSTEN, A.L. - See also BAKER, D.G. (Biology), CAVENESS, W.F.; ROIZIN, L.
- CAVENESS, W.F., ROIZIN, L., CARSTEN, A.L., AND SCHADE, J.P. The effects of x-irradiation on the cerebral cortex of the monkey. (A) In *Proc. 92nd Annu. Meet. Amer. Neurol. Ass., Atlantic City, June 1967* (in press).
- CAVENESS, W.F. - See also ROIZIN, L.
- CHANANA, A.D., CRONKITE, E.P., GREENBERG, M.L., JOEL, D.D., SCHIFFER, L.M., SCHNAPPAUF, H., AND STRYCKMANS, P.A. Effects of extracorporeal irradiation of blood and lymph on homotransplantation. In *Lymph and the Lymphatic System (Proc. Conf., New Orleans, Dec. 1965)*, Chap. 17, pp. 363-83, H.S. Mayerson, Chairman, Thomas, Springfield, Ill., 1968.
- CHANANA, A.D., CRONKITE, E.P., GREENBERG, M.L., RAI, K.R., SCHIFFER, L.M., STRYCKMANS, P.A., AND VINCENT, P.C. Experience with arteriovenous shunts in leukemic patients. *Arch. Surg.* 97, 154-60 (1968).
- CHANANA, A.D., CRONKITE, E.P., AND JOEL, D.D. Thyrmectomy of the calf. *Amer. J. Vet. Res.* 28, 1591-5 (1967).
- CHANANA, A.D., CRONKITE, E.P., JOEL, D.D., AND SCHIFFER, L.M. Influence of extracorporeal irradiation of lymph upon immunologically committed cells in the thoracic duct lymph. Studies on skin transplantation immunity. (A) In *Proc. 12th Congr. Int. Soc. Hematol., New York, Sept. 1968* (in press).
- CHANANA, A.D., CRONKITE, E.P., JOEL, D.D., AND SCHIFFER, L.M. Skin allograft survival in lymphocyte depleted calves. (A) Presented at 2nd Int. Congr. Transplantation Soc., New York, Sept. 1968.
- CHANANA, A.D. - See also CRONKITE, E.P.; GREENBERG, M.L.; JOEL, D.D.; MOON, H.W.; RAI, K.R.; SCHIFFER, L.M.; STRYCKMANS, P.A.; VINCENT, P.C.
- COHN, S.H., BAKER, D.G., JAHN, A., AND DOMBROWSKI, C. Influence of cold exposure on skeletal metabolism in rats. *J. Appl. Physiol.* (in press).
- COHN, S.H., DOMBROWSKI, C.S., HAUSER, W., AND ATKINS, H.L. The effect of high calcium diet on the parameters of calcium metabolism in osteoporosis. *Amer. J. Clin. Nutr.* (in press).
- COHN, S.H., DOMBROWSKI, C.S., AND STRAVINO, M. J. Levels of fallout ^{137}Cs in man over the past seven years. (A) Presented at Annu. Meet. Health Phys. Soc., Denver, June 1968.
- COHN, S.H. AND GUSMANO, E.A. Kinetics of strontium and calcium skeletal metabolism in the rat. *Proc. Soc. Exp. Biol. Med.* 126, 79-83 (1967).
- COHN, S.H., GUSMANO, E.A., AND ROBERTSON, J.S. Calculation of radiation dose from Thorotrast using whole-body gamma-ray spectral data. *Ann. N.Y. Acad. Sci.* 145, 608-22 (1967).
- COHN, S.H., TERE, T.M., AND GUSMANO, E.A. The effect of varying calcium intake on the parameters of calcium metabolism in the rat. *J. Nutr.* 94, 261-8 (1968).
- COHN, S.H. - See also CONARD, R.A.; GUSMANO, E.A.; SCHIFFER, L.M.
- CONARD, R.A. Acute and delayed effects of fallout radiation on man. (A) *Radiat. Res.* (in press).
- CONARD, R.A. Late effects of radioactive fallout on the thyroid gland in a Marshallese population. Presented at AAAS Meet., New York, Dec. 1967.
- CONARD, R.A. The 1968 annual medical survey of the Rongelap people exposed to fallout in 1954. Informal Report BNL 12623.
- CONARD, R.A. Quantification of blast formation in PHA stimulated and irradiated blood cultures. (A) Presented at Annu. Meet. Tissue Culture Ass., San Juan, P.R., June 1968.
- CONARD, R.A., CRONKITE, E.P., BOND, V.P., ROBERTSON, J.S., AND COHN, S.H. Fallout radiation: Effects on Marshallese people. In *Atomic Medicine*, 5th Ed., Chap. 12, C.H. Behrens and J. Carpenter, Editors, Williams & Wilkins, Baltimore (in press).
- CONARD, R.A. - See also LISCO, H.
- CONCANNON, J.N. - See GUSMANO, E.A.
- CORPE, W.A. - See BRYSK, M.M.
- COTTIER, H. - See CUNNINGHAM, L.; HESS, M.W.; MOLLEYRES, J.; ODARTCHENKO, N.
- COTZIAS, G.C., D-L Dopa and Parkinsonism. (L) Submitted to *Brit. Med. J.*
- COTZIAS, G.C. Dopa and Parkinsonism: Query and reply. (L) Submitted to *J. Amer. Med. Ass.*
- COTZIAS, G.C. Importance of trace substances in environmental health as exemplified by manganese. Presented at 1st Annu. Conf. Trace Substances in Environmental Health, Univ. of Missouri, Columbia, July 1967.
- COTZIAS, G.C. L-Dopa for Parkinsonism. (L) *New Engl. J. Med.* 278, 630 (1968).
- COTZIAS, G.C. AND FORADORI, A.C. Trace metal metabolism. In *The Biological Bases of Medicine*, E.E. Bittar, Editor, Univ. of Cambridge, England (in press).
- COTZIAS, G.C., HORIUCHI, K., FUENZALIDA, S., AND MENA, I. Chronic manganese poisoning: Clearance of tissue manganese concentrations with persistence of the neurological picture. *Neurology* 18, 376-82 (1968).
- COTZIAS, G.C. AND PAPAVALILOU, P.S. Therapeutic studies of Parkinsonian patients: Long-term effects of D-L and L-dopa. Presented at 2nd Int. Congr. Neuro-Genetics and Neuro-Ophthalmology, Montreal, Sept. 1967.
- COTZIAS, G.C., PAPAVALILOU, P.S., AND GELLEN, R. Experimental treatment of Parkinsonism with L-dopa. (A) Presented at 20th Annu. Meet. Amer. Acad. Neurol., Chicago, April 1968.
- COTZIAS, G.C., PAPAVALILOU, P.S., GELLEN, R., AND ARONSON, R.B. Parkinsonism and dopa. *Trans. Ass. Amer. Physicians* (in press).
- COTZIAS, G.C., PAPAVALILOU, P.S., GELLEN, R., ARONSON, R.B., AND MENA, I. Long-term effects of dopa on Parkinsonism: A proposal. In *Proc. 3rd Symp. Parkinson's Disease, Edinburgh, May 1968* (in press).
- COTZIAS, G.C., PAPAVALILOU, P.S., GELLEN, R., ARONSON, R.B., AND MENA, I. Parkinsonism and dopa: A proposal. Submitted to *Brit. Med. J.*
- COTZIAS, G.C., PAPAVALILOU, P.S., HUGHES, E.R., TANG, L., AND BORG, D.C. Slow turnover of manganese in active rheumatoid arthritis accelerated by prednisone. *J. Clin. Invest.* 47, 992-1001 (1968).
- COTZIAS, G.C. - See also FORADORI, A.C.; PAPAVALILOU, P.S.; VAN WOERT, M.H.

- CRONKITE, E.P. Effects of extracorporeal irradiation of blood and lymph upon the lymphoreticular system. (A) Presented at Soc. Franc. Hématol. Conf. Lymphocyte Circulation in Man, Paris, Feb. 1968.
- CRONKITE, E.P. *Extracorporeal Irradiation of the Blood and Lymph in the Study of Normal and Leukemic Cell Proliferation*, Brookhaven Lecture Series No. 48, June 23, 1965. BNL 50088 (T-480). (Revised Dec. 1967.)
- CRONKITE, E.P. A historical account of development of knowledge about lymphocytic function. *Nouv. Rev. Hématol.* (in press).
- CRONKITE, E.P. Kinetics of granulocytopoiesis. Presented at Nat. Inst. Health, Bethesda, Md., Nov. 1967.
- CRONKITE, E.P. Kinetics of leukemic cell proliferation. In *Perspectives in Leukemia (Proc. Symp., New Orleans, Dec. 1966)*, pp. 158-86, Grune & Stratton, New York, 1968.
- CRONKITE, E.P. Kinetics of leukemic cell proliferation. *Seminars Hematol.* 4, 415-23 (1967).
- CRONKITE, E.P. Normal myelopoiesis. (A) Presented at Symp. Myeloproliferative Disorders of Animals and Man, Richland, Wash., May 1968.
- CRONKITE, E.P. Radiation-induced aplastic anemia. *Seminars Hematol.* 4, 273-7 (1967).
- CRONKITE, E.P. Radiation injury. In *Harrison's Principles of Internal Medicine*, Chap. 257, R. Adams et al., Editors, McGraw-Hill, New York (in press).
- CRONKITE, E.P. AND CHANANA, A.D. Ionizing radiation. In *Human Transplantation*, Chap. 27, pp. 423-39, F. Rapaport and J. Dausset, Editors, Grune & Stratton, New York, 1968.
- CRONKITE, E.P., CHANANA, A.D., JOEL, D.D., RAI, K.R., AND SCHIFFER, L.M. Influence of extracorporeal irradiation of the blood and lymph on lymphopoiesis and immunity. Presented at IAEA Symp. Effect of Radiation on Cellular Proliferation and Differentiation, Monaco, April 1968.
- CRONKITE, E.P. - See also CHANANA, A.D.; CONARD, R.A.; CUNNINGHAM, L.; GREENBERG, M.L.; JOEL, D.D.; MOON, H.W.; RAI, K.R.; SCHIFFER, L.M.; STRYCKMANS, P.A.; VINCENT, P.C.
- CUNNINGHAM, L., COTTIER, H., CRONKITE, E.P., JANSEN, C.R., RAI, K.R., SAFIER, S., AND WAGNER, H.P. Studies on lymphocytes. VIII. Short *in vivo* mitotic time of basophilic lymphoid cells in the thoracic duct of calves after simulated and extracorporeal irradiation of circulating blood. *Exp. Cell Res.* 47, 479-88 (1967).
- DAHL, L.K. Discussion of article, "Salt in the infant's diet." (L) *Nutr. Rev.* 26, 124-5 (1968).
- DAHL, L.K. Effects of chronic excess salt ingestion. Experimental hypertension in the rat: Correlation with human hypertension. In *Epidemiology of Hypertension (Proc. Int. Symp., Chicago, Feb. 1964)*, pp. 218-39, J. Stamler et al., Editors, Grune & Stratton, New York, 1967.
- DAHL, L.K. Salt in processed baby foods. *Amer. J. Clin. Nutr.* 219, 735 (1968).
- DAHL, L.K., KNUDSEN, K.D., AND HEINE, M. Effects of chronic excess salt ingestion. Genetic influence on the development of salt hypertension in parabiotic rats: Evidence for a humoral factor. *J. Exp. Med.* 126, 687-99 (1967).
- DAHL, L.K., KNUDSEN, K.D., HEINE, M.A., AND LEITL, G. J. Effects of chronic excess salt ingestion: Modification of experimental hypertension in the rat by variations. *Circulation Res.* 22, 11-18 (1968).
- DAHL, L.K., KNUDSEN, K.D., HEINE, M., AND LEITL, G. Hypertension and stress. *Nature* 219, 735 (1968).
- DAHL, L.K. - See also KNUDSEN, K.D.
- DELIHAS, N. Guanine and cytosine rich fragments from ribosomal RNA: Spectrophotometric and sedimentation properties. Submitted to *Biochemistry*.
- DELIHAS, N. Liver ribosomal ribonucleic acid structural studies. Characterization of fragments from partial nuclease digestion. *Biochemistry* 6, 3356-62 (1967).
- DOMBROWSKI, C. - See COHN, S.H.
- DUBOIS, B.M. - See OVERWEG, N.I.A.; WALTER, R.
- DUFFY, T.E. - See O'NEILL, J. J.
- EGGENA, P., WALTER, R., AND SCHWARTZ, I.L. Contractile response of the *in vitro* urinary bladder of the toad, *Bufo marinus*, to neurohypophyseal hormones, theophylline, and cyclic 3',5'-AMP. (A) Presented at Fed. Amer. Soc. Exp. Biol. Meet., Atlantic City, April 1968.
- EGGENA, P., WALTER, R., AND SCHWARTZ, I.L. Relationship between hydroosmotic flow and the inhibited response of the toad bladder to vasopressin. Submitted to *Life Sci.*
- EGGENA, P., SCHWARTZ, I.L., AND WALTER, R. A sensitive hydroosmotic toad bladder assay: Affinity and intrinsic activity of neurohypophyseal peptides. Submitted to *J. General Physiol.*
- EGGENA, P. - See also WALTER, R.
- FAIRCHILD, R.G. Sources of fission neutrons and their dosimetry. In *Proc. Transplutonium Program Comm. Meet., Germantown, Md., April 1968* (in press).
- FAIRCHILD, R.G., TONNA, E.A., SEIBOLD, C.T., AND STRAUB, R.F. Neutron autoradiographic determination of ^{10}B concentration and distribution in mammalian tissue. *Radiat. Res.* (in press).
- FLEAY, R.F. - See ATKINS, H.L.
- FORADORI, A.C., BERTINCHAMPS, A., GULIBON, J.M., AND COTZIAS, G.C. The discrimination between magnesium and manganese by serum proteins. *J. General Physiol.* 50, 2255-66 (1967).
- FORADORI, A.C. - See also COTZIAS, G.C.
- FUENZALIDA, S. - See COTZIAS, G.C.
- GELLINE, R. - See COTZIAS, G.C.
- GIZIS, E. AND MEYER, L.M. A DEAE-cellulose chromatographic separation of Co^{57} vitamin B_{12} binders in normal human serum. *Proc. Soc. Exp. Biol. Med.* 126, 577-9 (1967).
- GORDON, W., HAVRAN, R.T., SCHWARTZ, I.L., AND WALTER, R. Conformational differences in neurohypophyseal peptides: A countercurrent distribution and partition chromatography study. Submitted to *Proc. Nat. Acad. Sci. U.S.*
- GORDON, W. - See also WALTER, R.
- GRADY, F. J. AND BORG, D.C. Electron paramagnetic resonance studies on melanins. I. The effect of pH on spectra at Q band. *J. Amer. Chem. Soc.* 90, 2949-52 (1968).
- GRADY, F. J. AND BORG, D.C. Light-induced free radicals of retinal, retinol, and rhodopsin. *Biochemistry* 7, 675-82 (1968).
- GREENBERG, M.L., CHANANA, A.D., CRONKITE, E.P., SCHIFFER, L.M., AND STRYCKMANS, P.A. Extracorporeal irradiation of blood in man. III. Radiation resistance of circulating platelets. *Radiat. Res.* 35, 147-54 (1968).

- GREENBERG, M.L. - See also CHANANA, A.D.; SCHIFFER, L.M.; STRYCKMANS, P.A.; VINCENT, P.C.
- GULIBON, J.M. - See FORADORI, A.C.
- GUSMANO, E.A., CONCANNON, J.N., BOZZO, S.R., AND COHN, S.H. Evaluation of the parameters of strontium metabolism in the rat as a function of age. *Radiat. Res.* **33**, 540-53 (1968).
- GUSMANO, E.A. - See also COHN, S.H.
- GUT, V., RUDINGER, J., WALTER, R., HERLING, P.A., AND SCHWARTZ, I.L. Derivatives of 1-tosyl-3-amino-2-piperidone: Preparation and conversion to derivatives and peptides of ornithine. Submitted to *Tetrahedron*.
- HABICHT, G.S. - See TERRES, G.
- HAMILTON, L.D. DNA: Models and reality. *Nature* **218**, 633-7 (1968).
- HAMILTON, L.D. - See also JAMUAR, M.P.; KIM, C.W.; SAVEL, H.
- HANKES, L.V. AND BROWN, R.R. Metabolism of D- and L-kynurenine-keto- C^{14} in rats and the effects of unlabeled enantiomers. *Proc. Soc. Exp. Biol. Med.* (in press).
- HANKES, L.V., BROWN, R.R., SCHIFFER, L.M., AND SCHMAELER, M. Tryptophan metabolism in humans with various types of anemias. *Blood* (in press).
- HANKES, L.V. AND SCHMAELER, M. The effects of either isomer of tryptophan on the metabolism of the other. (A) *Fed. Proc.* **27**, 762 (1968).
- HANKES, L.V. - See also BROWN, R.R.; BRYSK, M.M.
- HARRISON, A.L. The research medical record that tells everything about everything - in confidence. *Med. Record News* **39**, 24-37 (1968).
- HAUSER, W., ATKINS, H.L., AND RICHARDS, P. Amyloidosis of the heart. Possible pitfall in the diagnosis of pericardial effusion by scintillation scanning. *J. Amer. Med. Ass.* **204**, 628-30 (1968).
- HAUSER, W. - See also ATKINS, H.L.; COHN, S.H.
- HAVRAN, R.T., SCHWARTZ, I.L., WAHRENBURG, M., AND WALTER, R. The synthesis and pharmacological properties of [4-ornithine]-oxytocin and [5-ornithine]-oxytocin. (A) Presented at Amer. Chem. Soc. Meet., Atlantic City, Sept. 1968.
- HAVRAN, R.T. - See also GORDON, W.
- HEINE, M. - See DAHL, L.K.
- HERLING, P.A. - See GUT, V.
- HESS, M.W., COTTIER, H., AND STONER, R.D. The role of the thymus in the establishment of immunological competence. In *Proc. 2nd Int. Congr. Lymphology, Miami Beach, March 1968* (in press).
- HESS, M.W. - See also MOLLEYRES, J.
- HORIUCHI, K. - See COTZIAS, G.C.
- HOSHI, M. - See SHREEVE, W.W.
- HUGHES, E.R. - See COTZIAS, G.C.; PAPAVASILIOU, P.S.
- JAMUAR, M.P., KIM, C.W., AND HAMILTON, L.D. Fine structure of lymphocytes sensitized to *Trichinella spiralis* antigen. *J. Immunol.* **100**, 329-37 (1968).
- JAMUAR, M.P., KIM, C.W., AND HAMILTON, L.D. Ultrastructure of lymphocytes sensitized to *Trichinella spiralis*. (A) *J. Cell. Biol.* **35**, 170-1A (1967).
- JAMUAR, M.P. - See also KIM, C.W.
- JANSEN, C.R. - See CUNNINGHAM, L.
- JESSEPH, J.E., MOORE, W.H., STRAUB, R.F., TISLJAR-LENTULIS, G.M., AND BOND, V.P. The RBE of 2.2-BeV protons for 30-day lethality in mice. *Radiat. Res.* (in press).
- JOEL, D.D., CHANANA, A.D., CRONKITE, E.P., AND SCHIFFER, L.M. Cytotoxic antibody response to skin allografts in calves: Effects of extracorporeal irradiation of lymph. *Proc. Soc. Exp. Biol. Med.* (in press).
- JOEL, D.D., CHANANA, A.D., CRONKITE, E.P., AND SCHIFFER, L.M. Effect of extracorporeal irradiation of lymph (ECIL) on the humoral cytotoxin response to skin allografts. (A) In *Proc. 12th Congr. Int. Soc. Hematol., New York, Sept. 1968* (in press).
- JOEL, D.D. - See also CHANANA, A.D.; CRONKITE, E.P.; MOON, H.W.; RAI, K.R.; VINCENT, P.C.
- JOHNSON, H.A. Relative hypertrophy of the mouse's right kidney. Submitted to *Growth*.
- JOHNSON, H.A. AND PAVELEC, M. The effect of small doses of ionizing radiation on peroxidase in solution. (A) Presented at Radiat. Res. Soc. Meet., Houston, Texas, April 1968.
- JOHNSON, H.A. AND VERA ROMAN, J.M. Renal epithelial hyperplasia: Failure to demonstrate a humoral control factor. *J. Cell Tissue Kinetics* **1**, 35-41 (1968).
- JOHNSON, H.A. - See also BATEMAN, J.L.; PRASAD, K.N.
- JOHNSON, S. - See KATSOYANNIS, P.C.
- JOUBERT, S.M. - See KALLIE, R.N.
- KALLIE, R.N., SHREEVE, W.W., JOUBERT, S.M., AND PATH, M.C. Studies in primary hyperuricaemia. III. The conversion of ^{14}C to breath $^{14}CO_2$ from glucose-1- ^{14}C and glucose-6- ^{14}C in hyperuricaemia and gout. *S. African Med. J.* **42**, 473-6 (1968).
- KATSOYANNIS, P.G., TOMETSKO, A.M., AND ZALUT, C. Insulin peptides. XVII. The synthesis of the A chain of human (porcine) insulin and its isolation as the S-sulfonated derivative. *J. Amer. Chem. Soc.* **89**, 4505-13 (1967).
- KATSOYANNIS, P.G., TOMETSKO, A., ZALUT, C., JOHNSON, S., AND TRAKATELLIS, A.C. Studies on the synthesis of insulin from natural and synthetic A and B chains. I. Splitting of insulin and isolation of the S-sulfonated derivatives of the A and B chains. *Biochemistry* **6**, 2635-42 (1967).
- KATSOYANNIS, P.G., ZALUT, C., AND TOMETSKO, A.M. Insulin peptides. XVI. The synthesis of a nonapeptide and dodecapeptide derivative related to the A chain of human insulin (positions 1-9 and 10-21). *J. Amer. Chem. Soc.* **89**, 4502-4 (1967).
- KIM, C.W., JAMUAR, M.P., AND HAMILTON, L.D. Antibody response in recipients after transfer of lymph node cells from sensitized donors. (A) *Fed. Proc.* **27**, 543 (1968).
- KIM, C.W., JAMUAR, M.P., AND HAMILTON, L.D. Delayed hypersensitivity to *Trichinella spiralis*. II. Antibody response in recipients after transfer of delayed hypersensitivity. *J. Immunol.* **99**, 1156-61 (1967).
- KIM, C.W., SAVEL, H., AND HAMILTON, L.D. Delayed hypersensitivity to *Trichinella spiralis*. I. Transfer of delayed hypersensitivity of lymph node cells. *Ibid.*, 1150-5.
- KIM, C.W. - See also JAMUAR, M.P.; SAVEL, H.
- KIRSTEN, C. - See VINCENT, P.C.
- KNUDSEN, K.D., DAHL, L.K., AND TASSINARI, L.M. Blood lactic acid in rats and men: Comparison of normo- and hypertensive individuals. *Proc. Soc. Exp. Biol. Med.* **128**, 476-80 (1968).
- KNUDSEN, K.D. - See also DAHL, L.K.

- LEITL, G. - See DAHL, L.K.
 LEKLEM, J. - See BROWN, R.R.
 LENHARD, J.A. Technetium-99m (^{99m}Tc): Its capabilities as a scanning agent. *J. Amer. Med. Technologists* **29**, 271-9 (1967).
 LISCO, H. AND CONARD, R.A. Chromosome studies on Marshallese people exposed to fallout radiation. *Science* **157**, 445-7 (1967).
 LIU, J.C. - See ROIZIN, L.
 LYMAN, H. Effect of red light on photoreactivation of chloroplast replication in *Euglena*. (A) In *Proc. 5th Int. Congr. Photobiol., Hanover, N.H., April 1968* (in press).
 LYMAN, H. The role of light in nalidixic-acid induced inhibition of chloroplast replication in *Euglena*. (A) Presented at Meet. Amer. Soc. Plant Physiologists, Yonkers, N.Y., May 1968.
 LYMAN, H. Specific inhibition of chloroplast replication in *Euglena gracilis* by nalidixic acid. *J. Cell Biol.* **35**, 726-30 (1967).
 LYMAN, H. - See also RUSSELL, G.K.
 MACHEK, J. - See ROIZIN, L.
 MANSPEIZER, S. AND TONNA, E.A. Skeletal cell proliferative rates, studied autoradiographically in mice with increasing doses of tritiated thymidine (H^3TDR). *Proc. Soc. Exp. Biol. Med.* **126**, 331-5 (1967).
 MENA, I. - See COTZIAS, G.C.
 MEYER, L.M. - See GIZIS, E.
 MILLER, S.T. - See PAPAVALIOU, P.S.
 MOELLER, G. - See ROBERTSON, J.S.
 MOLLEYRES, J., COTTIER, H., SCHINDLER, R., SLONECKER, C., HESS, M.W., AND STONER, R.D. Lymphoid cell migration between distant lymph nodes in mice. In *Proc. 2nd Int. Congr. Lymphology, Miami Beach, March 1968* (in press).
 MONTJAR, M. J. - See TRAKATELLIS, A.C.
 MOON, H.W., JOEL, D.D., CHANANA, A.D., CRONKITE, E.P., AND STONER, R.D. Responses of lymphocyte-depleted calves to fluid tetanus toxoid. Submitted to *Amer. J. Vet. Res.*
 NICHOLSON, A. - See VAN WOERT, M.H.
 ODARTCHENKO, N., COTTIER, H., AND BOND, V.P. Studies on "ineffective" erythropoiesis in the dog. *Brit. J. Haematol.* (in press).
 OJI, N. - See SHREEVE, W.W.
 OKUYAMA, S. - See SCHIFFER, L.M.
 O'NEILL, J. J., DUFFY, T.E., SIMON, S.H., AND SHREEVE, W.W. Influence of added pyruvate on brain metabolism: A Pasteur-like effect, reversible by electrical stimulation. *J. Biol. Chem.* **243**, 3345-50 (1968).
 OVERWEG, N.I.A., SCHWARTZ, I.L., DUBOIS, B.M., AND WALTER, R. Inhibition of the action of oxytocin on the rat uterus by acyclic oxytocin intermediates. Submitted to *J. Pharmacol. Exp. Therap.*
 PANDE, C.S., RUDICK, J., SCHWARTZ, I.L., AND WALTER, R. Synthetic, biological and specific labelling studies of a carboxyl-terminal tetrapeptide analog of gastrin. (A) Presented at Amer. Chem. Soc. Meet., Atlantic City, Sept. 1968.
 PAPAVALIOU, P.S., HUGHES, E.R., BORG, D.C., AND COTZIAS, G.C. Slow turnover of manganese in active rheumatoid arthritis accelerated by prednisone. (A) Presented at Soc. Clin. Invest. Meet., Atlantic City, May 1968.
 PAPAVALIOU, P.S., MILLER, S.T., AND COTZIAS, G.C. Functional interactions between biogenic amines, 3',5'-cyclic AMP and manganese. Submitted to *Nature*.
 PAPAVALIOU, P.S. - See also COTZIAS, G.C.
 PATH, M.C. - See KALLIE, R.N.
 PAVELEC, M. - See JOHNSON, H.A.; SEVERSON, A.R.; SMITH, R.F. (Photography and Graphic Arts).
 POTCHEN, E. J. - See SHREEVE, W.W.
 PRASAD, K.N. *Necturus maculosus* as an experimental animal to study cellular injuries of the irradiated gut *in vivo*. In *Excerpta Med. Monogr. Nucl. Med. Biol. No. 1, Gastrointestinal Radiation Injury (Proc. Symp., Richland, Wash., Sept. 1966)*, pp. 377-84.
 PRASAD, K.N. AND JOHNSON, H.A. Differential radiosensitivity of the hepatic melanocytes of *Amphiuma tridactylum*. *Radiat. Res.* **33**, 403-16 (1968).
 PRICE, D.C. - See SCHIFFER, L.M.
 QUADRIFOGLIO, F. - See URRY, D.W.; WALTER, R.
 RAI, K.R., CHANANA, A.D., CRONKITE, E.P., JOEL, D.D., SIPE, C.R., AND SCHIFFER, L.M. Depletion and recovery of blood lymphocytes following extracorporeal irradiation: Long-term bovine studies. (A) In *Proc. 12th Congr. Int. Soc. Hematol., New York, Sept. 1968* (in press).
 RAI, K.R. - See also CHANANA, A.D.; CRONKITE, E.P.; CUNNINGHAM, L.; SCHIFFER, L.M.; VINCENT, P.C.
 ROBERTSON, J.S. Basic physical mechanisms in radiobiology. In *Proc. 1st Int. Symp. Biological Interpretation of Dose From Accelerator-Produced Radiation, Berkeley, Calif., March 1967*, pp. 15-29, R. Wallace, Editor, CONF-670305, 1967.
 ROBERTSON, J.S. Computer applications in a nuclear medicine research program. In *Proc. Conf. Use of Computers in Radiology, Chicago, Oct. 1966*, pp. e95-112, Univ. of Missouri, 1968.
 ROBERTSON, J.S. Estimation of dose from internally deposited radionuclides. (A) Presented at Health Phys. Soc. Meet., Denver, June 1968.
 ROBERTSON, J.S. AND MOELLER, G. *Computation of Continuous Decompression Schedules for Deep Sea Dives*. BNL 50104 (T-490), March 1968.
 ROBERTSON, J.S. - See also ATKINS, H.L.; BROWNELL, G.L.; COHN, S.H.; CONARD, R.A.; TISLJAR-LENTULIS, G.M.
 ROBINSON, C.V. Analysis in terms of cellular parameters of interanimal variation of hemopoietic radioresistance. In *Proc. U.S.-Japan Seminar Comparative Cellular and Species Radiosensitivity in Animals, Kyoto, Japan, May 1968* (in press).
 ROBINSON, C.V. A reexamination of "transformed-cell" models of radiation-induced leukemias. (A) Presented at Radiat. Res. Soc. Meet., Houston, Texas, April 1968.
 ROBINSON, C.V. Relationship between animal and stem cell dose-survival curves. *Radiat. Res.* (in press).
 ROBINSON, C.V. - See also BOND, V.P.
 ROIZIN, L., CARSTEN, A.L., MACHEK, J., LIU, J.C., AND CAVENESS, W.F. The vasculo-circulatory factor in the central nervous system pathogenesis of the x-ray postirradiation effects. *Trans. Amer. Neurol. Ass.* **93** (in press).
 ROIZIN, L. - See also CAVENESS, W.F.
 ROSSI, H.H. - See BATEMAN, J.L.
 RUDICK, J. - See PANDE, C.S.
 RUDINGER, J. - See GUT, V.

- RUSSELL, G.K. AND LYMAN, H. Isolation of mutants of *Euglena gracilis* with impaired photosynthesis. *Plant Physiol.* (in press).
- SAFIER, S. - See CUNNINGHAM, L.
- SAVEL, H., KIM, C.W., AND HAMILTON, L.D. Synthesis of radioactive *Trichinella spiralis* larval antigen *in vitro*. Submitted to *Exp. Parasitol.*
- SAVEL, H. - See also KIM, C.W.
- SCHADE, J.P. - See CAVENESS, W.F.
- SCHIFFER, L.M. Kinetics of chronic lymphocytic leukemia. *Ser. Haematol.* (in press).
- SCHIFFER, L.M., ATKINS, H.L., CHANANA, A.D., CRONKITE, E.P., GREENBERG, M.L., AND STRYCKMANS, P.A. Extracorporeal irradiation of blood (ECIB) in man. II. Treatment of acute myelocytic leukemia. *Blood* 31, 17-32 (1968).
- SCHIFFER, L.M., CHANANA, A.D., CRONKITE, E.P., GREENBERG, M.L., OKUYAMA, S., RAI, K.R., STRYCKMANS, P.A., AND VINCENT, P.C. Treatment of chronic lymphocytic leukemia with extracorporeal irradiation of the blood (ECIB). (A) Presented at Amer. Soc. Clin. Invest. Meet., Atlantic City, May 1968.
- SCHIFFER, L.M., CHANANA, A.D., CRONKITE, E.P., OKUYAMA, S., RAI, K.R., AND VINCENT, P.C. Extracorporeal irradiation of blood (ECIB): Treatment of chronic lymphocytic leukemia. (A) In *Proc. 12th Congr. Int. Soc. Hematol., New York, Sept. 1968* (in press).
- SCHIFFER, L.M., COHN, S.H., PRICE, D.C., AND CRONKITE, E.P. Whole-body counting studies of retention and accessibility of radioactive vitamin B₁₂. *Amer. J. Clin. Nutr.* 21, 665-72 (1968).
- SCHIFFER, L.M. - See also CHANANA, A.D.; CRONKITE, E.P.; GREENBERG, M.L.; HANKES, L.V.; JOEL, D.D.; RAI, K.R.; STRYCKMANS, P.A.; VINCENT, P.C.
- SCHINDLER, R. - See MOLLEYRES, J.
- SCHMAELER, M. - See BROWN, R.R.; HANKES, L.V.
- SCHNAPPAUF, H. - See CHANANA, A.D.; STRYCKMANS, P.A.
- SCHWARTZ, I.L. AND WALTER, R. Neurohypophyseal hormone-calcium interrelationships in the toad bladder. In *Proc. Int. Symp. Protein and Polypeptide Hormone, Liege, Belgium, May 1968* (in press).
- SCHWARTZ, I.L. - See also EGGENA, P.; GORDON, W.; GUT, V.; HAVRAN, R.T.; OVERWEG, N.I.A.; PANDE, C.S.; THEODOROPoulos, D.; URRY, D.W.; WALTER, R.
- SEIBOLD, C.T. - See FAIRCHILD, R.G.
- SEVERSON, A.R., TONNA, E.A., AND PAVELEC, M. Application and evaluation of the lead-adenosine method in skeletal tissue. *Stain Technol.* 48, 221-5 (1968).
- SEVERSON, A.R., TONNA, E.A., AND PAVELEC, M. Histochemical demonstration of adenosine triphosphatase (ATPase) activity in healing fractures. (A) *J. Anat.* (in press).
- SEVERSON, A.R., TONNA, E.A., AND PAVELEC, M. Histochemical demonstration of adenosine triphosphatase in osteoclasts. *J. Histochem. Cytochem.* 15, 550-2 (1967).
- SEVERSON, A.R., TONNA, E.A., AND PAVELEC, M. Localization and distribution of adenosine triphosphatase activity in the femurs of young mice. *Anat. Record* (in press).
- SHIGETA, Y. - See SHREEVE, W.W.
- SHREEVE, W.W., HOSHI, M., OJI, N., SHIGETA, Y., AND ABE, H. Insulin and the utilization of carbohydrates in obesity. Submitted to *Amer. J. Clin. Nutr.*
- SHREEVE, W.W. AND POTCHEN, E.J. Metabolic diseases. In *Principles of Nuclear Medicine*, Chap. 8, pp. 370-403, A.W. Wagner, Jr., Editor, Saunders, Philadelphia, Jan. 1968.
- SHREEVE, W.W. - See also KALLIE, R.N.; O'NEILL, J.J.
- SIMON, S.H. - See O'NEILL, J.J.
- SIPLE, C.R. - See RAI, K.R.
- SLONECKER, C. - See MOLLEYRES, J.
- STAHL, S.S. AND TONNA, E.A. Comparison of gingival repair following chemical or surgical injury. *Periodontics* 6, 26-9 (1968).
- STAHL, S.S., TONNA, E.A., AND WEISS, R. Autoradiographic evaluation of gingival response to injury. I. Surgical trauma in young adult rats. *Arch. Oral Biol.* 13, 71-86 (1968).
- STONER, R.D. - See HESS, M.W.; MOLLEYRES, J.; MOON, H.W.; TERRES, G.
- STRAUB, R.F. - See FAIRCHILD, R.G.; JESSEPH, J.E.
- STRAVINO, M.J. - See COHN, S.H.
- STRYCKMANS, P.A., CHANANA, A.D., CRONKITE, E.P., GREENBERG, M.L., AND SCHIFFER, L.M. Studies on lymphocytes. IX. The survival of autotransfused labeled lymphocytes in chronic lymphocytic leukemia. *Eur. J. Cancer* 4, 241-6 (1968).
- STRYCKMANS, P.A., CHANANA, A.D., CRONKITE, E.P., GREENBERG, M.L., AND SCHIFFER, L.M. Studies on lymphocytes. X. Influence of extracorporeal irradiation of the blood (ECIB) on lymphocytes in chronic lymphocytic leukemia. Apparent correlation with RNA turnover. *Radiat. Res.* (in press).
- STRYCKMANS, P.A., CRONKITE, E.P., GIACOMELLI, G., SCHIFFER, L.M., AND SCHNAPPAUF, H. The maturation and fate of reticulocytes after *in vitro* labeling with tritiated acids. *Blood* 31, 33-43 (1968).
- STRYCKMANS, P.A. - See also CHANANA, A.D.; GREENBERG, M.L.; SCHIFFER, L.M.; VINCENT, P.C.
- TANG, L. - See COTZIAS, G.C.
- TASSINARI, L.M. - See KNUDSEN, K.D.
- TEREE, T.M. - See COHN, S.H.
- TERRES, G., HABICHT, G.S., AND STONER, R.D. The time course of specific immunologic responsiveness following the injection of immune complexes in mice. (A) Presented at Fed. Amer. Soc. Exp. Biol. Meet., Atlantic City, April 1968.
- THEODOROPoulos, D., SCHWARTZ, I.L., AND WALTER, R. Synthesis of selenium-containing peptides. *Biochemistry* 6, 3927-32 (1967).
- TISLJAR-LENTULIS, G.M., BOND, V.P., ROBERTSON, J.S., AND MOORE, W.H. Jr. Counter telescope measurements of a beam of negative π mesons. Submitted to *Radiat. Res.*
- TISLJAR-LENTULIS, G.M. - See also JESSEPH, J.E.
- TOMETSKO, A. - See KATSOYANNIS, P.G.
- TONNA, E.A. The source of osteoblasts in healing fractures in animals of different ages. In *The Healing of Osseous Tissue*, pp. 93-110, R.A. Robinson, Editor, Nat. Acad. Sci. - Nat. Res. Council, Washington, D.C., 1967.
- TONNA, E.A. AND ROGERS, E. J. Microscopic photodensitometry and microspectrophotometry using a fixed double-aperture optical system and an electronically controlled automatic scanning microscope stage. *J. Roy. Microscop. Soc.* 88, 71-84 (1968).

- TONNA, E.A. - See also FAIRCHILD, R.G.; MANSPEIZER, S.; SEVERSON, A.R.; STAHL, S.S.
- TRAKATELLIS, A.C. Effect of sparsomycin on protein synthesis in the mouse liver. *Proc. Nat. Acad. Sci. U.S.* 59, 854-60 (1968).
- TRAKATELLIS, A.C. AND MONTJAR, M.J. Effect of cycloheximide on ribosome formation in the mouse liver. *Life Sci.* 7, Pt. 2, 413-9 (1968).
- TRAKATELLIS, A.C. - See also KATSOYANNIS, P.G.
- URRY, D.W., QUADRIFOGLIO, F., WALTER, R., AND SCHWARTZ, I.L. Conformational studies on neurohypophyseal hormones. The disulfide bridge of oxytocin. Submitted to *Proc. Nat. Acad. Sci. U.S.*
- URRY, D.W. - See also WALTER, R.
- VAN WOERT, M.H., NICHOLSON, A., AND COTZIAS, G.C. Mitochondrial functions of polymelanosomes. *Comparative Biochem. Physiol.* 22, 477-85 (1967).
- VERA ROMAN, J.M. - See JOHNSON, H.A.
- VINCENT, P.C., BORNER, G., CHANANA, A.D., CRONKITE, E.P., JOEL, D.D., SCHIFFER, L.M., AND STRYCKMANS, P.A. Comparison of two methods of estimating DNA synthesis time in calf thoracic duct lymphocytes. (A) Presented at Amer. Soc. Clin. Invest. Meet., Atlantic City, May 1968.
- VINCENT, P.C., CRONKITE, E.P., GREENBERG, M.L., KIRSTEN, C., RAI, K.R., AND SCHIFFER, L.M. Leukocyte kinetics in chronic myeloid leukemia (CML). (A) In *Proc. 12 Congr. Int. Soc. Hematol., New York, Sept. 1968* (in press).
- VINCENT, P.C. - See also CHANANA, A.D.; SCHIFFER, L.M.
- WAGNER, H.P. - See CUNNINGHAM, L.
- WAHRENBURG, M. - See HAVRAN, R.T.; WALTER, R.
- WALTER, R., DUBOIS, B.M., AND SCHWARTZ, I.L. The biological significance of the amino acid residue in position 3 of neurohypophyseal hormones and the effect of magnesium on their uterotonic action. Submitted to *Endocrinology*.
- WALTER, R., GORDON, W., SCHWARTZ, I.L., QUADRIFOGLIO, F., AND URRY, D.W. Conformation studies on the neurohypophyseal hormone oxytocin and its analogs. In *Proc. 9th Eur. Symp. Peptides, Orsay, France, April 1968* (in press).
- WALTER, R., GORDON, W., WAHRENBURG, M., EGGENA, P., AND SCHWARTZ, I.L. Studies on the role of the disulfide bond in neurohypophyseal hormones. (A) In *Proc. 24th Int. Congr. Physiol. Sci., Washington, D.C., Aug. 1968* (in press).
- WALTER, R. AND SCHWARTZ, I.L. Comparison of the pharmacological properties of two highly potent, crystalline neurohypophyseal hormone analogs: deamino-1-seleno-oxytocin and deamino-oxytocin. In *Pharmacology of Hormonal Polypeptides and Proteins (Proc. Int. Symp., Milan, Italy, Sept. 1967)*, pp. 101-4, N. Bock, Editor, Plenum Press, New York, 1968.
- WALTER, R. AND SCHWARTZ, I.L. Correlation of conformation and hydroosmotic activity of neurohypophyseal hormones. (A) In *Proc. Symp. Biophysical Aspects of Permeability, Jerusalem, July 1968* (in press).
- WALTER, R. AND SCHWARTZ, I.L. Synthesis and biological properties of an analog of deamino-oxytocin containing alanine in place of tyrosine. *Life Sci.* 7, 545-8 (1968).
- WALTER, R. - See also EGGENA, P.; GORDON, W.; GUT, V.; HAVRAN, R.T.; OVERWEG, N.I.A.; PANDE, C.S.; SCHWARTZ, I.L.; THEODOROPOULOS, D.; URRY, D.W.
- WEISS, R. - See STAHL, S.S.
- ZALUT, C. - See KATSOYANNIS, P.G.

Nuclear Engineering Department

- ADAMS, P.D. Electrical resistivity of liquid-mercury alloys. (A) *Bull. Amer. Phys. Soc.* 13, 712 (1968).
- ADAMS, P.D. Experimental evidence that the Mott model for mercury alloy resistivities is not valid. (L) *Phys. Rev. Letters* 20, 537-8 (1968).
- ADAMS, P.D. AND ASHCROFT, N.W. The feasibility of testing the Born approximation in metals via x-ray measurements. *Advan. Phys.* 16, 597-600 (1967).
- ADAMS, P.D., DAVIES, H.A., AND EPSTEIN, S.G., Editors, *The Properties of Liquid Metals (Proc. Int. Conf., Brookhaven National Laboratory, Sept. 1966)*, Taylor & Francis, London, 1967.
- ADAMS, P.D. - See also SCHWEITZER, D.G.
- ADLER, G. AND BAYSAL, B. Some solid-state aspects of vinyl polymerization in organic crystals. Submitted to *Mol. Cryst.*
- ADLER, G. - See also FAUCITANO, A.
- AKCASU, A.Z. AND NISHINA, K. On the interpretation of neutron wave experiments. *Trans. Amer. Nucl. Soc.* 10, 203 (1967).
- AKCASU, A.Z. AND SHOTKIN, L.M. Approximate zero-power describing function valid at all frequencies. *Nucl. Sci. Eng.* 32, 271-3 (1968).
- AKCASU, A.Z. - See also CHERNICK, J.
- ALTSCHULER, S. J. Inelastic scattering effects in hydrogenous substances at 20°K. (A) In *Proc. IAEA Symp. Elastic Scattering, Copenhagen, May 1968* (in press).
- ANDERSON, E.W. - See MCKENZIE, D.R.
- ARONSON, A. - See TAKAHASHI, H.
- ARONSON, S. - Free energies of formation of thorium sulfides from solid-state EMF measurements. *J. Inorg. Nucl. Chem.* 29, 1611-17 (1967).
- ARONSON, S. AND AUSKERN, A.B. Magnetic susceptibility of thorium carbides, nitrides and carbonitrides. *J. Chem. Phys.* 48, 1760-5 (1968).
- ARONSON, S., SALZANO, F. J., AND BELLAFFIORE, D. Thermodynamic properties of the potassium-graphite lamellar compounds from solid-state EMF measurements. *J. Chem. Phys.* (in press).
- ARONSON, S. - See also AUSKERN, A.B.; SALZANO, F. J.
- ASCARELLI, P. Velocity of sound and compressibility in liquid metals. *Phys. Rev.* (in press).
- ASCARELLI, P., HARRISON, R. J., AND PASKIN, A. A relation between structure and pair potential for liquid metals. *Advan. Phys.* 16, 717-29 (1967).
- ASCARELLI, P. AND PASKIN, A. Dense-gas formulation of self-diffusion of liquid metals. *Phys. Rev.* 165, 222-4 (1968).
- ASCARELLI, P. - See also PASKIN, A.
- ASHCROFT, N.W. - See ADAMS, P.D.
- ATTARDO, M. J., DAVIDSON, J. L., GALLIGAN, J. M., AND JEANNOTTE, D. Defect studies in metals. In *Proc. Int. Conf. Strengthening Mechanisms on Metals and Alloys, Tokyo, Sept. 1967* (in press).

- ATTARDO, M.J. - See also GALLIGAN, J.M.
 AUERBACH, C. - See PRACH, T.F.
 AUSKERN, A.B. AND ARONSON, S. Electrical properties of thorium borides. *J. Chem. Phys.* (in press).
 AUSKERN, A.B. AND ARONSON, S. Electrical properties of thorium carbonitrides. Submitted to *J. Appl. Phys.*
 AUSKERN, A.B. - See also ARONSON, S.
 BALDWIN, R. Stainless steel primary piping for the High Flux Beam Reactor. To be presented at Annu. Meet. ASME, New York, Dec. 1968.
 BAYSAL, B. - See ADLER, G.
 BECKER, W. - See SUSSKIND, H.
 BELLAFFIORE, D. - See ARONSON, S.
 BELLER, M. AND STEINBERG, M. A nuclear desalting and power complex for the Salton Sea, California, Imperial Valley area. Informal Report BNL 11855.
 BELLER, M. - See also POWELL, J.; STEINBERG, M.
 BHAT, M.R., CHRIEN, R.E., WASSON, O.A., BEER, M., AND LONE, M.A. Investigation of γ rays following S- and P-wave neutron capture in tin isotopes. *Phys. Rev.* **166**, 1111-20 (1968).
 BHAT, M.R., WASSON, O.A., CHRIEN, R.E., AND GARBER, D.I. Thermal and resonance neutron capture gamma spectra in antimony. (A) *Bull. Amer. Phys. Soc.* **13**, 721 (1968).
 BHAT, M.R. - See also BEER, M. (Physics); CHRIEN, R.E. (Physics); GARBER, D.I. (Physics); LONE, M.A. (Physics); MUGHABGHAB, S.F.; WASSON, O.A. (Physics).
 BLOCH, F.W. AND MACKENZIE, D.R. Radiolysis of cyclic fluorocarbons. II. Perfluoroaromatics at elevated temperatures. Submitted to *J. Phys. Chem.*
 BRACKER, J. - See EGAN, J.J.
 BRYNER, J.S. The effects of fast neutron irradiation in iron and steel. (A) Presented at Seminar U.S.-Japan Coop. Sci. Program, San Francisco, June 1968.
 CASTLEMAN, A.W. JR. AND MUNKELWITZ, H.R. The diffusion of iodine in uranium monocarbide. (A) *Trans. Amer. Nucl. Soc.* **11**, 155-6 (1968).
 CASTLEMAN, A.W. JR. AND TANG, I.N. On the transport of fission products from sodium. *Advan. Chem. Ser.* (in press).
 CASTLEMAN, A.W. JR. AND TANG, I.N. Thermodynamics of fission-product-sodium solutions. (A) *Trans. Amer. Nucl. Soc.* **10**, 494-5 (1967).
 CASTLEMAN, A.W. JR., TANG, I.N., AND MUNKELWITZ, H. R. The chemical states of fission-product iodine emanating into a high temperature aqueous environment. *Inorg. Nucl. Chem.* **30**, 5-13 (1968).
 CASTLEMAN, A.W. JR. - See also HORN, F.L.; TANG, I.N.
 CHANDRASEKHARAIHA, M.S. - See TVEEKREM, J.O.
 CHEN, J.C. Incipient boiling superheats in liquid metals. *J. Heat Transfer* (in press).
 CHEN, J.C., KALISH, S., AND SCHOENER, G.A. A probe for detection and measurement of voids in liquid metals. *Rev. Sci. Instr.* (in press).
 CHEN, J.C. - See also YU, W.S.
 CHERNICK, J., LELLOUCHE, G.S., LEVINE, M., MICHAEL, P., SHOTKIN, L.M., AND AKCASU, A.Z. Reactor kinetics research at Brookhaven National Laboratory. In *Proc. Brookhaven Conf. Industrial Needs and Academic Research in Reactor Kinetics, April 1968*, pp. 230-54, BNL 50117 (T-497).
 CHERNICK, J. - See also WAGSCHAL, J.J.
 CHOW, J.G.Y. Effect of irradiation on mechanical properties of cobalt base alloys. Presented at ASTM Symp. Effects of Radiation on Structural Metals, San Francisco, June 1968.
 CHOW, J.G.Y. Effect of microstructure on the elevated temperature ductility of irradiated austenitic stainless steels. *Ibid.*
 CHOW, J.G.Y. AND GALLIGAN, J.M. The effect of neutron irradiation on the superplasticity of Ni-Fe-Cr alloys. (A) Presented at AIME Meet., Detroit, Oct. 1968.
 CHOW, J.G.Y. - See also FLEITMAN, A.H.; GALLIGAN, J.M.
 CLARKE, J.T. Reaction of graphite and hydrogen above 2000°K. In *Applications of Plasma to Chemical Processing*, pp. 132-56, R.F. Baddour and R. Timmons, Editors, MIT Press, Cambridge, Mass., 1967.
 CLARKE, J.T. AND FOX, B.R. Thermal efficiency of the production of acetylene from carbon and hydrogen. *Ind. Eng. Chem. Fundamentals* **7**, 197-201 (1968).
 COLLINS, C.H. - See WEISS, J.
 COLOMBO, P. - See KUKACKA, L.E.; STEINBERG, M.
 CONANT, J.F. - See PALMEDO, P.F.
 CONNOR, R.D. - See MACKENZIE, D.R.
 COURT, A., DOWNES, K.W., AND KOUTS, H.J.C. Safety analysis report, Brookhaven National Laboratory critical facility. Informal Report BNL 11636.
 DANBY, G.R. - See POWELL, J.R.
 DAVIDSON, J.L. - See ATTARDO, M.J.
 DAVIES, H.A. AND LEACH, J.S.L. On the liquidus of the gold-tin system. (N) *J. Inst. Metals* **96**, 220-1 (1968).
 DAVIES, H.A. - See also ADAMS, P.D.
 DAVIS, C.R. - See HILL, F.B.
 DICKEY, J.M. - See PASKIN, A.
 DIETZ, R.N. Gas chromatographic analysis of nitric oxide on treated molecular sieve. *Anal. Chem.* **40**, 1576-8 (1968).
 DORNING, J.J. JR. Application of the S_N -method to pulsed-neutron experiment calculations. In *A Review of the Discrete Ordinates S_N Method for Radiation Transport Calculations*, pp. 213-19, D.K. Trubey and B.F. Maske-witz, Editors, ORNL-RSIC-19, 1968.
 DORNING, J.J. JR. The effect of scattering anisotropy on the calculation of pulsed-neutron decay constants. In *Neutron Thermalization and Reactor Spectra (Proc. IAEA Symp., Ann Arbor, Mich., July 1967)*, Vol. 1, pp. 571-89, IAEA, Vienna, 1968.
 DORNING, J.J. JR. Neutron thermalization in finite media. Informal Report BNL 11707; (A) *Trans. Amer. Nucl. Soc.* **10**, 626-7 (1967).
 DORNING, J.J. JR. Size-dependent extrapolation distances for pulsed small systems. *Ibid.* **11**, 295-6 (1968).
 DORNING, J.J. JR. Thermal neutron decay in small systems. *Nucl. Sci. Eng.* **33**, 65-80 (1968).
 DORNING, J.J. JR. Time-dependent neutron thermalization in finite media. Informal Report BNL 11680.
 DORNING, J.J. JR. Time-dependent thermalization in finite light water systems. *Nucl. Sci. Eng.* **33**, 81-92 (1968).
 DORNING, J.J. JR. AND THURBER, J.K. Unstable pulsed-neutron decay states in noncrystalline moderators. (A) *Trans. Amer. Nucl. Soc.* **11**, 290-1 (1968).

- DOWNES, K.W. - See COURT, A.
- DRAGER, R.F. - See STRICKLAND, G.
- DWYER, O.E. Heat transfer. In *Liquid Metals Handbook, Sodium and NaK Suppl.*, 1968 Ed., Chap. 5 (in press).
- DWYER, O.E. Heat transfer with liquid metals. In *Encyclopaedic Dictionary of Physics, Suppl. No. 2*, pp. 114-16, 1966-67.
- DWYER, O.E. - See also KALISH, S.
- EGAN, J. J. AND BRACKER, J. Thermodynamic properties of some binary fused salt mixtures from EMF measurements. (A) Presented at Amer. Chem. Soc. Meet., San Francisco, April 1968.
- EPEL, L.G., LEVINE, M.M., NUGENT, G., AND PARSICK, R. J., Editors. *The Ordered-Bed Fast Reactor Concept [1000-MW(e) Reactor Design]*. BNL 50027 (T-444), June 1966.
- EPSTEIN, S.G. Electromigration and diffusion of cadmium and indium in liquid sodium. *Phys. Chem. Liquids* (in press).
- EPSTEIN, S.G. Electromigration of a series of solutes in liquid bismuth. *Advan. Phys.* **16**, 325-32 (1967).
- EPSTEIN, S.G. Evidence for a correlation between electromigration and electrical resistivity. *Trans. Met. Soc. AIME* (in press).
- EPSTEIN, S.G., ROMANO, A. J., AND RUTHERFORD, J.E. An apparatus for the measurement of mass transport in liquid alkali metals. Informal Report BNL 11312.
- EPSTEIN, S.G. - See also ADAMS, P.D.
- FAJER, J. Observations on iron(III) chloride in non-aqueous solvents. (N) *J. Inorg. Nucl. Chem.* (in press).
- FAJER, J. Photoisomerization of perfluoroaromatic compounds in condensed phase. (A) Presented at Amer. Chem. Soc. Meet., San Francisco, April 1968.
- FAJER, J., BIELSKI, B.H. J., AND FELTON, R.H. Electronic and electron spin resonance spectra of the perfluoro-2,1,3-benzoselenadiazole anion radical. *J. Phys. Chem.* **72**, 1281-8 (1968).
- FAJER, J. AND MACKENZIE, D.R. Radiolysis of fluorocarbons: Valence tautomerization. *Advan. Chem. Ser.* **82**, 469 (1968).
- FAUCITANO, A., PEROTTI, A., AND ADLER, G. Reaction of gases with irradiated organic solids. I. Preliminary results on propionamide, *n*-butyramide and isobutyramide. *Ric. Sci.* **37**, 1149-55 (1967).
- FELDBERG, S.W. Digital simulation: A general method for solving electrochemical diffusion-kinetic problems. *Advan. Electroanal. Chem.* **3** (in press).
- FELDER, R.M. *Classical Differential Cross Sections for Scattering From an Inverse Power Potential*. BNL 50102 (T-489), March 1968.
- FELDER, R.M. Classical differential cross sections for scattering from a repulsive inverse power potential. (L) *J. Chem. Phys.* (in press).
- FELDER, R.M. AND HILL, F.B. Mixing effects in chemical reactors. *Chem. Eng. Sci.* (in press).
- FELDER, R.M. AND HILL, F.B. Mixing effects in chemical reactors. II. Radiation-induced chain reactions in flow systems. To be presented at A.I.Ch.E. Meet., Los Angeles, Dec. 1968.
- FELTON, R.H. - See FAJER, J.
- FERRARI, L.A. On the beam disruption in a plasma betatron. Submitted to *Phys. Fluids*.
- FERRARI, L.A. AND ZUCKER, M.S. Stability of orbits in combined betatron and azimuthal magnetic fields. *Ibid.*
- FERRARI, L.A. - See also ZUCKER, M.S.
- FINE, H.L. - See STRONGIN, M. (Physics).
- FLEITMAN, A.H., HERCHENROEDER, R.B., AND CHOW, J.G.Y. Cobalt-base alloys. In *USAEC Reactor Handbook*, 3rd Ed., Vol. 1. Chap. 21 (in press).
- FLEITMAN, A.H., ROMANO, A. J., AND KLAMUT, C. J. Hg corrosion and inhibition in once-through 2¼ Cr-1 Mo steel boilers. *Nucl. Appl.* (in press).
- FLEITMAN, A.H. AND WEEKS, J.R. Mercury. In *USAEC Reactor Handbook*, 3rd Ed., Vol. 1, Chap. 46 (in press).
- FLEITMAN, A.H. - See also SADOFSKY, J.
- FOX, B.R. - See CLARKE, J.T.
- GALLIGAN, J.M. The flow stress of tungsten in the presence of a nonequilibrium concentration of kinks. (L) *Phys. Letters* **26A**, 550-1 (1968).
- GALLIGAN, J.M. AND ATTARDO, M. J. Dislocation loops and mechanical properties of neutron-irradiated tungsten. (A) *Bull. Amer. Phys. Soc.* **13**, 463 (1968).
- GALLIGAN, J.M. AND ATTARDO, M. J. Radiation hardening in platinum. *Phys. Status Solidi* (in press).
- GALLIGAN, J.M., CHOW, J.G.Y., AND INAL, O.T. On the temperature dependence of the yield stress in neutron irradiated platinum. (A) Presented at AIME Meet., Detroit, Oct. 1968.
- GALLIGAN, J.M. - See also ATTARDO, M. J.; CHOW, J.G.Y.
- GILBERT, T.W., NEWMAN, L., AND KLOTZ, P. Mixed-metal hydroxycarboxylic acid complexes. The chromium(III) inhibition of the solvent extraction of indium(III). Submitted to *Anal. Chem.*
- GOLDSTEIN, R. Intermediate resonance absorption for multi-nuclide systems. (N) *Nucl. Sci. Eng.* **30**, 304 (1967).
- GOLDSTEIN, R. Iteration and intermediate resonance absorption. (N) *Ibid.*, 146-7.
- GOLDSTEIN, R. Iterative solutions by means of trial operators. *J. Math. Phys.* (in press).
- GOODRICH, R. - See SUTHERLAND, J.W.
- GORDON, B.M. AND WEINSTOCK, E.V. The capture resonance integral of ²⁵³Cf. Submitted to *Nucl. Sci. Eng.*
- GORDON, B.M. AND WEINSTOCK, E.V. The neutron absorption resonance integral of Cf²⁵². (A) Presented at Amer. Chem. Soc. Meet., San Francisco, April 1968.
- GURINSKY, D.H. Some materials problems in fast reactors. (A) Presented at Amer. Nucl. Soc. Meet., Cincinnati, April 1968.
- HAHNE, R.M.A. - See HILLMAN, M.
- HARRISON, R. J. - See ASCARELLI, P.; PASKIN, A.
- HASSON, J. - See LIU, C.H.
- HELLENS, R.L., SEHGAL, B.R., AND MIZUTA, H. A comparative analysis of some graphite and water moderated reactor lattices. In *Proc. Conf. Physics Problems in Thermal Reactor Design, London, June 1967*, pp. 27-37, Brit. Nucl. Energy Soc., London.
- HENDRIE, J.M. - See GODEL, J.B. (Chemistry); HOFFMAN, K.C.
- HERCHENROEDER, R.B. - See FLEITMAN, A.H.
- HILL, F.B., DAVIS, C.R., MULLER, A.C., ROTHBART, M.A., AND ZAVADOSKI, R.W. Influence of the flow regime on the performance of a continuous tubular radiation chemical reactor. (A) *Trans. Amer. Nucl. Soc.* **11**, 75-6 (1968).
- HILL, F.B. AND REISS, N. Nonuniform initiation of photo-reactions. II. Diffusion of reactive intermediates. *Can. J. Chem. Eng.* **46**, 124-31 (1968).

- HILL, F.B., REISS, N., AND SHENDALMAN, L.H. Nonuniform initiation of photoreactions. III. Reactant diffusion in single-step reactions. *A.I.Ch.E. J.* (in press).
- HILL, F.B. - See also FELDER, R.M.; MULLER, A.C.; SHENDALMAN, L.H.; TICHLER, P.R. (Reactor).
- HILLMAN, M. AND GROVER, J.R. Combinatorial calculations of nuclear level densities. (A) Presented at Amer. Chem. Soc. Meet., San Francisco, April 1968.
- HILLMAN, M., KIM, C.K., SHIKATA, E., AND WEISS, A.J. Isotope effects in the Szilard-Chalmers reactions of hafnium and zirconium phthalocyanine. Submitted to *Radiochim. Acta*.
- HILLMAN, M. AND SHIKATA, E. Cross sections of some reactions of hafnium isotopes with 14.5-MeV neutrons. Submitted to *J. Inorg. Nucl. Chem.*
- HILLMAN, M. AND WEISS, A.J. Chemical effects of decay of ^{129m}Te in aqueous solution. (A) Presented at Int. Symp. Hot-Atom Chemistry, Kyoto, Japan, Oct. 1967.
- HILLMAN, M., WEISS, A.J. AND HAHNE, R.M.A. The Szilard-Chalmers reactions of hafnocene and zirconocene. (A) Presented at Amer. Chem. Soc. Meet., San Francisco, April 1968.
- HOFFMAN, K.C. AND HENDRIE, J.M., Editors. Pulsed fast research reactor project. Progress report for the period May 1, 1967, to October 31, 1967. Informal Report BNL 11968.
- HOFFMAN, K.C. AND HENDRIE, J.M., Editors. Pulsed fast research reactor project. Progress report for the period Nov. 1, 1967, to April 30, 1968. Informal report BNL 12470.
- HOFFMAN, K.C., REILLY, J.J., WISWALL, R.H., SHEEHAN, T.V., AND WINSCHER, W.E. Metal hydride energy storage systems. Submitted to *IEEE Trans. Aerospace Electron. Syst. Suppl.*
- HOFFMAN, K.C., REILLY, J.J., WISWALL, R.H., AND WINSCHER, W.E. Reversible metal hydrides as energy storage media for mobile power source applications. (A) Presented at Intersociety Energy Conversion Engineering Conf., IEEE, Denver, Aug. 1968.
- HOFFMAN, K.C. - See also DAVIS, R. JR. (Chemistry); WINSCHER, W.E.
- HORN, F.L. Some aerosol properties of vaporized fast-reactor fuels. (A) *Trans. Amer. Nucl. Soc.* **10**, 699 (1967).
- HORN, F.L. AND CASTLEMAN, A.W. JR. $\text{PuO}_2\text{-UO}_2\text{-Na}$ aerosols produced by vaporization of fast reactor core materials. (A) In *Proc. IAEA-USAEC Symp. Operating and Development Experience in the Treatment of Airborne Radioactive Wastes, United Nations, New York, Aug. 1968* (in press).
- Hsu, C. J. Analytical study of heat transfer to liquid metals flowing along a row of spheres. *Int. J. Heat Mass Transfer* **10**, 1693-708 (1967).
- Hsu, C. J. An exact mathematical solution for entrance-region laminar heat transfer with axial conduction. *Appl. Sci. Res.* **17**, 359 (1967).
- Hsu, C. J. Exact solution to entry-region laminar heat transfer with axial conduction and the boundary condition of the third kind. *Chem. Eng. Sci.* **23**, 457-68 (1968).
- Hsu, C. J. AND LINDAUER, G.C. The influence of axial conduction on the thermal entry-region heat transfer in magnetohydrodynamic channel flow. *Nucl. Sci. Eng.* **32**, 16-29 (1968).
- Hsu, C. J. - See also LINDAUER, G.C.
- HUSZAGH, D.W. Human behavior considerations in control system design. Submitted to *Instr. Control Syst.*
- HUSZAGH, D.W., KUKACKA, L.E., AND STEINBERG, M. A radiation facility for use with hazardous chemical systems. In *Proc. Conf. Remote Syst. Technol., 15th Amer. Nucl. Soc. Winter Meet., Chicago, 1967*, pp. 153-7, 1967.
- INAL, O.T. - See GALLIGAN, J.M.
- INGRAHAM, A. - See SALZANO, F.J.
- ISAACS, H.S. The gettering of oxygen in sodium by uranium. (A) Presented at AEC Corros. Inform. Meet., Columbus, Ohio, May 1968.
- ISAACS, H.S. - See also MINUSHKIN, B.
- ISLER, R. - See TICHLER, P. (Reactor).
- JAMES, S.D. The alkali metal doping of semiconductors. *Mater. Res. Bull.* **2**, 773-4 (1967).
- JAMES, S.D. The electrochemical activation of platinum electrodes. *J. Electrochem. Soc.* **114**, 1113-19 (1967).
- JAMES, S.D. The thallium(I)-(III) electrode reaction in acidic media. *Electrochim. Acta* **12**, 939-54 (1967).
- JEANNOTTE, D. - See ATTARDO, M.J.
- JEFFERSON, L.R. - See STEINBERG, M.
- KALISH, S. AND DWYER, O.E. Heat transfer to NaK flowing through unbaffled rod bundles. *Int. J. Heat Mass Transfer* **10**, 1533-58 (1967).
- KALISH, S. - See also CHEN, J.C.
- KAMMERER, O.F. - See CROW, J.E. (Physics); STRONGIN, M. (Physics).
- KATZ, H. AND SEARS, J.T. Electric field phenomena in fluidized and fixed beds. Submitted to *Can. J. Chem. Eng.*
- KIM, C.K. - See HILLMAN, M.
- KLAMUT, C.J. - See FLEITMAN, A.H.; ROMANO, A.J.
- KLOTZ, P. - See GILBERT, T.W.; NEWMAN, L.
- KOUTS, H. J.C. Repetitively pulsed fast research reactors. Informal Report BNL 12084.
- KOUTS, H. J.C. - See also COURT, A.
- KRAMER, H. - See SUTHERLAND, J.W.
- KRIEGER, T. J. Nuclear cross section fluctuations and random matrices. (A) In *Proc. Int. Nucl. Phys. Conf., Gatlinburg, Tenn., Sept. 1966*, pp. 789-91, R.L. Becker, Editor, Academic, New York, 1967.
- KRIEGER, T. J. - See also KUJAWSKI, E.
- KRIKAWA, J., LEVINE, M.M., NUGENT, G., POWELL, R.W., SHEEHAN, T.V., AND THOMPSON, D. Irradiation and steam generator facility. (Proposed conversion of BGRR to H_2O cooled, pressure tube type reactor). Informal Report BNL 11695.
- KUJAWSKI, E. AND KRIEGER, T. J. Statistical theory of polarized nuclear reactions. (L) *Phys. Letters* **27B**, 132-5 (1968).
- KUKACKA, L.E., COLOMBO, P., AND STEINBERG, M. The use of gamma radiation to initiate polymerization reactions. In *5th Pacific-Northwest Plastics Workshop, Vancouver, Wash., June 1968*, pp. 167-87, Washington State Univ., 1968.
- KUKACKA, L.E., COLOMBO, P., STEINBERG, M., AND MANOWITZ, B. The formation of concrete-polymer composites by gamma radiation and chemical initiators. (A) Presented at A.I.Ch.E. Conf. Mater. Eng. Sci., Philadelphia, April 1968.
- KUKACKA, L.E. - See also HUSZAGH, D.W.; STEINBERG, M.
- KUKK, M. - See SLATER, L.M.

- LEACH, J.S.L. - See DAVIES, H.A.
- LELLOUCHE, G.S. An application of Popov's asymptotic stability criterion. *J. Math. Phys.* **46**, 225-36 (1967).
- LELLOUCHE, G.S. - See also CHERNICK, J.
- LEVINE, M.M. Out-of-core detector response to arbitrary power shapes. (A) *Trans. Amer. Nucl. Soc.* **11**, 307-8 (1968).
- LEVINE, M.M. - See also CHERNICK, J.; EPEL, L.G.; KRIKAWA, J.; WAGSCHAL, J.J.
- LINDAUER, G.C. Heat flow between two infinitely long eccentric cylinders. (N) Submitted to *J. Heat Transfer*.
- LINDAUER, G.C. Heat transfer in packed and fluidized beds using the method of cyclic temperature variations. *A.I.Ch.E. J.* **13**, 1181-7 (1967).
- LINDAUER, G.C. AND HSU, C. J. Unsteady forced convection MHD heat transfer in a parallel plate channel. *AIChE J.* (in press).
- LINDAUER, G.C. - See also Hsu, C. J.
- LIU, C.H., NEWMAN, L., AND HASSON, J. Potentiometric studies on tetrahalonickelate(II) ions in molten dimethyl sulfone. *Inorg. Chem.* (in press).
- LUDEWIG, H. A method for analyzing exponential cores using a one-dimensional S_n code. (A) *Trans. Amer. Nucl. Soc.* **11**, 306-7 (1968).
- LUDEWIG, H. A method for treating the leakage in small exponential cores. Submitted to *Nucl. Sci. Eng.*
- MACKENZIE, D.R. AND CONNOR, R.D. The decay of ^{239}U . *Nucl. Phys.* **A108**, 81-93 (1968).
- MACKENZIE, D.R., WILSON, V.H., AND ANDERSON, E.W. Perfluoro-1,1-dimethylcyclopentane from pyrolysis of perfluorobicyclohexyl. *J. Chem. Soc.* (in press).
- MACKENZIE, D.R. - See also BLOCH, F.W.; FAJER, J.
- MAGURNO, B.A. A compilation of neutron-induced threshold reactions. In *Proc. USAEC Conf. Small Accelerators, Oak Ridge, Tenn., April 1968*, Oak Ridge Ass. Univ. (in press).
- MANOWITZ, B. Elements of gamma irradiator design. *Advan. Chem. Ser.* **65**, 109-17 (1967).
- MANOWITZ, B. *Gamma Rays for Fun and Profit, Brookhaven Lecture Series No. 56, April 20, 1966*. BNL 50084 (T-477).
- MANOWITZ, B. Review of industrial radiation chemistry in the United States. *J. Brit. Nucl. Energy Soc.* **1967**, 310-19.
- MANOWITZ, B. Status of gamma irradiator design. *Chem. Eng. Progr. Symp. Ser. 83 (Nucl. Eng. Pt. 19)* **64**, 16-30 (1968).
- MANOWITZ, B. - See also POWELL, J.; STEINBERG, M.
- McNICHOLAS, J. J. The specific conductivity of molten lead bromide. *J. Electrochem. Soc.* **115**, 936-7 (1968).
- McRICKARD, S.B. Defect saturation and radiation sensitivity in iron and steel. (A) Presented at 4th ASTM Symp. Effects of Radiation on Structural Materials, San Francisco, June 1968.
- McRICKARD, S.B. Effect of neutron irradiation on carbon and nitrogen strain aging in iron. (A) Presented at Annu. Meet. AIME, New York, Feb. 1968.
- McRICKARD, S.B. The effects of neutron irradiation on the activation parameters for slip in iron. *Acta Met.* (in press).
- McRICKARD, S.B. Saturation and exposure dependence of the yield stress of irradiated iron. Submitted to *Phil. Mag.*
- METZ, D. J. *Radiation and Organic Liquids, Brookhaven Lecture Series No. 70, Nov. 15, 1967*. BNL 50110 (T-493).
- METZ, D. J. Radiation-induced ionic polymerization. *Advan. Chem. Ser.* (in press).
- METZ, D. J. Radiation-induced polymerization of pure liquid α -methylstyrene. *Ibid.* **66**, 170-83 (1967).
- METZ, D. J. - See also TICHLER, P. (Reactor).
- MICHAEL, P. AND MOORE, M.N. The relationship between pulsed, poisoning, and wave experiments. In *Neutron Thermalization and Reactor Spectra (Proc. IAEA Symp., Ann Arbor, Mich., July 1967)*, Vol. 1, pp. 125-44, IAEA, Vienna, 1968.
- MICHAEL, P. - See also CHERNICK, J.
- MILAU, J.S. - See WAGNER, J.I.
- MINUSHKIN, B. AND ISAACS, H.S. The chemistry of oxygen in sodium. (A) Presented at AEC Corros. Inform. Meet., Columbus, Ohio, May 1968.
- MIZUTA, H. - See HELLENS, R.L.
- MOORE, M.N. - See MICHAEL, P.
- MOORE, S.O. - See AUERBACH, E.H. (Physics).
- MUGHABGHAB, S.F., BHAT, M.R., WASSON, O.A., GARBER, D.I., AND CHRIEN, R.E. Radiative transitions following P-wave neutron capture in Mo^{98} . (A) *Bull. Amer. Phys. Soc.* **13**, 721 (1968).
- MUGHABGHAB, S.F. AND CHRIEN, R.E. Neutron cross sections and resonance parameters of Yb isotopes. *Phys. Rev.* (in press).
- MUGHABGHAB, S.F. AND CHRIEN, R.E. The thermal cross sections and paramagnetic scattering cross sections of the Yb isotopes. In *Proc. 2nd Conf. Neutron Cross Sections and Technology, Washington, D.C., March 1968* (in press).
- MUGHABGHAB, S.F., CHRIEN, R.E., AND BHAT, M.R. Neutron resonance parameters of the erbium isotopes. *Phys. Rev.* **162**, 1130-9 (1967).
- MUGHABGHAB, S.F., CHRIEN, R.E., WASSON, O.A., AND BHAT, M.R. Gamma rays from resonant neutron capture in Mo^{95} and Mo^{96} . (A) *Bull. Amer. Phys. Soc.* **12**, 1199-200 (1967).
- MUGHABGHAB, S.F. - See also CHRIEN, R.E. (Physics).
- MULLER, A.C. The solar cell dose rate meter. In *Manual on Radiation Dosimetry*, N. Holm, and R. Berry, Editors, M. Dekker, New York (in press).
- MULLER, A.C. The solar cell integrating dosimeter. *Ibid.*
- MULLER, A.C. AND HILL, F.B. The radiation-sensitized quartz dosimeter. (A) *Trans. Amer. Nucl. Soc.* **11**, 74-5 (1968).
- MULLER, A.C. - See also HILL, F.B.
- MUNKELWITZ, H.R. - See CASTLEMAN, A.W. JR.
- NEWMAN, L. AND KLOTZ, P. Mixed β -diketones. In *Proc. Int. Conf. Solvent Extraction Chemistry, Gothenburg, Sweden, Aug. 27-Sept. 1, 1966*, pp. 128-34, J. Rydberg et al., Editors, North-Holland, Amsterdam, 1967.
- NEWMAN, L. - See also GILBERT, T.W.; LIU, C.H.; PRACH, T.F.
- NICOLOSI, L. J. - See SCHWEITZER, D.G.
- NISHINA, K. - See AKCASU, A.Z.
- NUGENT, G. - See EPEL, L.G.; KRIKAWA, J.
- ODETTE, R. - See SUSSKIND, H.
- PALMEDO, P.F. Anisotropic neutron slowing down in aluminum-water mixtures. I. Experiments; II. Monte Carlo calculations. *Nucl. Sci. Eng.* **32**, 302-18 (1968).
- PALMEDO, P.F. Studies of anisotropic neutron migration. In *Proc. Conf. Physics Problems in Thermal Reactor Design*,

- London, June 1967, pp. 79-80, Brit. Nucl. Energy Soc., London.
- PALMEDO, P.F., AND CONANT, J.F. Diffusion-length experiments in the continuous eigenvalue region. (A) *Trans. Amer. Nucl. Soc.* **11**, 255-6 (1968).
- PARSICK, R. J. - See EPEL, L.G.
- PASKIN, A. *The Dynamic Structure of Liquids*, Brookhaven Lecture Series No. 59, Sept. 28, 1966. BNL 50080 (T-475).
- PASKIN, A. Structure of liquid metals. *Advan. Phys.* **16**, 223-40 (1967).
- PASKIN, A., BRONK, B.V., AND DIENES, G. J. Stochastic models of cell proliferation and cell response to radiation. *Brookhaven Symp. Biol.* **20** [BNL 50058 (C-51)], 169-78 (1967).
- PASKIN, A. AND DICKEY, J.M. Diffusion in binary liquids. (A) *Bull. Amer. Phys. Soc.* **13**, 398 (1968).
- PASKIN, A., HARRISON, R. J., AND ASCARELLI, P. Application of a structure factor-potential relationship to the electrical resistivity of the liquid alkali metals. *Advan. Phys.* **16**, 263-9 (1967).
- PASKIN, A. - See also ASCARELLI, P.; BRONK, B.V. (Medical); DIENES, G. J. (Physics).
- PEARLSTEIN, S. An extended table of calculated ($n, 2n$) cross sections. *Nucl. Data, Sect. A*, **3**, 327-41 (1967).
- PEARLSTEIN, S. Recent developments in the automated compilation and publication of neutron data. In *Proc. 2nd Conf. Neutron Cross Sections and Technology, Washington, D.C., March 1968* (in press).
- PEARLSTEIN, S. - See also STEPHENSON, T.E.
- PEROTTI, A. - See FAUCITANO, A.
- PHELPS, J.P. AND WEINSTOCK, E.V. Criticality measurements on nearly homogeneous enriched uranium-graphite systems. Submitted to *Nucl. Sci. Eng.*
- POWELL, J.R. AND DANBY, G.R. A 300-MPH magnetically suspended train. *Mech. Eng.* **89**, No. 11, 30-5 (1967).
- POWELL, J.R., STEINBERG, M., BELLER, M., AND MANOWITZ, B. A study of H_2 - O_2 combustion MHD cycles using combination fossil-nuclear energy input. (A) Presented at 8th Annu. AIE-ARS Symp. Magnetohydrodynamics, Arnold Air Force Station, Tullahoma, Tenn., April 1968.
- POWELL, J.R. AND ZUCKER, M. On the application in nuclear MHD cycles of nonequilibrium ionization from metastable molecular states excited by fission fragments. Informal Report BNL 11670.
- POWELL, J.R. - See also STEINBERG, M.
- POWELL, R.W. - See KRIKAWA, J.
- PRACH, T.F., NEWMAN, L., AND AUERBACH, C. *The Determination of Oxygen in Sodium by the Amalgamation Method*. BNL 50118 (T-498), June 1968.
- PRICE, G.A. AND WINDSOR, H.H. Time-of-flight effects in pulsed-neutron measurements. (N) *Nucl. Sci. Eng.* **31**, 547-9 (1968).
- PRICE, G.A. - See also SEHGAL, B.R.
- PRINCE, A. Estimated fission properties of transradium isotopes. Submitted to *Nucl. Phys.*
- PRINCE, A. Thermal neutron cross sections and resonance integrals for transuranium isotopes. In *Proc. 2nd Conf. Neutron Cross Sections and Technology, Washington, D.C., March 1968* (in press).
- PRINCE, A. - See also STEPHENSON, T.; TU, P.S.
- PRUZANSKY, J. - See STEINBERG, M.
- RAO, H.M. - See WEISS, J.
- REILLY, J. J. AND WISWALL, R.H. The reaction of hydrogen with alloys of magnesium and copper. *Inorg. Chem.* **6**, 2220-3 (1967).
- REILLY, J. J. AND WISWALL, R.H. The reaction of hydrogen with alloys of magnesium and nickel. Submitted to *Inorg. Chem.*
- REILLY, J. J. - See also HOFFMAN, K.C.; WINSCH, W.E.
- REISS, N. - See HILL, F.B.
- RICHARDS, P. Nuclide generators. In *Radioactive Pharmaceuticals*, Chap. 10, pp. 155-63, G.A. Andrews et al., Editors, CONF-651111, CFSTI, Springfield, Va., 1966.
- RICHARDS, P. Radionuclide milking systems. In *Proc. 8th Japan Conf. Radioisotopes, Tokyo, Nov. 1967* (in press).
- RICHARDS, P. The technetium-99m generator. In *Radioactive Pharmaceuticals*, Chap. 17, pp. 323-34, G.A. Andrews et al., Editors, CONF-651111, CFSTI, Springfield, Va., 1966.
- RICHARDS, P. AND ATKINS, H.L. Technetium-99m labeled compounds. Presented at 7th Annu. Meet. Japan. Nucl. Med. Soc., Tokyo, Nov. 1967.
- RICHARDS, P. AND STANG, L.G. JR. Medical radionuclide development program at Brookhaven National Laboratory. Presented at Med. Radioisotope Rev. Meet., AEC, Washington, D.C., Jan. 1968.
- RICHARDS, P. - See also ATKINS, H.L. (Medical); HAUSER, W. (Medical).
- RIZZO, F.X. - See WEISS, J.
- ROGERS, R. - See SEARS, J.T.
- ROMANO, A. J. AND KLAMUT, C. J. Corrosion of oxygen-contaminated Nb-1 Zr and Ta-8 W-2 Hf alloys by reflux-boiling sodium at 1095°C. (A) *Trans. Amer. Nucl. Soc.* **11**, 118-20 (1968).
- ROMANO, A. J., WACHTEL, S. J., AND KLAMUT, C. J. Corrosion behavior of cobalt, iron, and molybdenum. (A) Presented at AEC Corros. Inform. Meet., Columbus, Ohio, May 1968.
- ROMANO, A. J., WACHTEL, S. J., AND KLAMUT, C. J. Corrosion behavior of cobalt, iron, and molybdenum base alloys in high-temperature sodium. (A) *Trans. Amer. Nucl. Soc.* **11**, 118 (1968).
- ROMANO, A. J. - See also EPSTEIN, S.G.; FLEITMAN, A.H.
- ROTHBART, M.A. - See HILL, F.B.
- RUTHERFORD, J.E. - See EPSTEIN, S.G.
- SADOFKY, J. AND FLEITMAN, A.H. The correlations between microstructure and mechanical properties of Co base superalloys. (A) Presented at 22nd AEC Metallurgy Meet., San Diego, Calif., June 1968.
- SALZANO, F. J. AND ARONSON, S. Experimental observations in the potassium-graphite system. *J. Chem. Phys.* **47**, 2978-81 (1967).
- SALZANO, F. J. AND ARONSON, S. The reaction between cesium and carbon blacks. *J. Inorg. Nucl. Chem.* (in press).
- SALZANO, F. J. AND ARONSON, S. Threshold pressures for the reaction of sodium and other alkali metals with graphite. *Trans. Amer. Nucl. Soc.* **10**, 493-4 (1967).
- SALZANO, F. J., ARONSON, S., AND INGRAHAM, A. A comment on phase equilibria in the lithium-carbon system. (N) *J. Amer. Ceram. Soc.* (in press).
- SALZANO, F. J. - See also ARONSON, S.
- SCHOENER, G.A. - See CHEN, J.C.

- SCHWEITZER, D.G. Hysteresis in superconductors. III. The effect of surface energies on the diamagnetic properties of hollow cylinders of type I superconductors. *Phys. Rev.* (in press); IV. The effect of surface energies in creating stable persistent currents and irreversible phase transitions between superconducting states. Submitted to *Phys. Rev.*; V. Surface phase equilibria in applied fields. *Ibid.*
- SCHWEITZER, D.G. On the size and temperature dependence of interstitials formed by low temperature irradiations of graphite. (L) *Carbon* 5, 623 (1967).
- SCHWEITZER, D.G. The origin of irreversibility from conventional equilibrium concepts. (L) *Phys. Letters* (in press).
- SCHWEITZER, D.G. AND ADAMS, P.D. The effect of surface energies on transport current distributions in type I superconductors. (L) Submitted to *Phys. Rev. Letters*.
- SCHWEITZER, D.G., ADAMS, P.D., AND NICHOLSI, L. J. The effect of surface strains on the diamagnetic and field-retaining properties of type-I hollow cylinders. (L) *Phys. Rev. Letters* 21, 220-3 (1968).
- SEARS, J.T. Abnormal bubble movement and induced "roll cell" formation in fluidized beds. Informal Report BNL 12650.
- SEARS, J.T. AND ROGERS, R. Excitation of nitrogen gas by fission fragments along the entire track. *J. Chem. Phys.* 47, 3174-9 (1967).
- SEARS, J.T. AND SUTHERLAND, J.W. Estimates of ozone yields in proposed chemonuclear reactors. (N) *Nucl. Appl.* 5, 62-3 (1968).
- SEARS, J.T. AND SUTHERLAND, J.W. Radiolytic formation and decomposition of ozone. *J. Phys. Chem.* 72, 1166-71 (1968).
- SEARS, J.T. - See also KATZ, H.
- SEHGAL, B.R. Analyses of Brookhaven ^{233}U - ^{232}Th oxide, light and heavy-water-moderated lattice experiments. (A) *Trans. Amer. Nucl. Soc.* 10, 596 (1967).
- SEHGAL, B.R. Analysis of Brookhaven ^{235}U -graphite critical experiments. Submitted to *Nucl. Sci. Eng.*
- SEHGAL, B.R. Analysis of some ^{235}U -graphite critical experiments. *Trans. Amer. Nucl. Soc.* 10, 535 (1967).
- SEHGAL, B.R., PRICE, G.A., AND WINDSOR, H.H. An investigation of ^{239}Pu alpha in the keV energy range through some lattice experiments. (A) *Ibid.* 11, 202-3 (1968).
- SEHGAL, B.R. - See also HELLENS, R.L.
- SETHI, D. - See SUTHERLAND, J.W.
- SHEEHAN, T.V. - See HOFFMAN, K.C.; KRIKAWA, J.; WINSCH, W.E.
- SHENDALMAN, L.H. AND HILL, F.B. Some limiting radical concentration profiles in a photoreactor. Submitted to *Chem. Eng. Sci.*
- SHENDALMAN, L.H. AND HILL, F.B. Thermal ignition and stability of batch reactors with nonuniformly initiated radiation-induced reactions. In *Proc. 4th Eur. Symp. Chemical Reaction Engineering, Brussels, Sept. 1968* (in press).
- SHENDALMAN, L.H. - See also HILL, F.B.
- SHER, R. The Mn^{55} resonance activation integral. In *Proc. 2nd Conf. Neutron Cross Sections and Technology, Washington, D.C., March 1968* (in press).
- SHIKATA, E. - See HILLMAN, M.
- SHOTKIN, L.M. The effect of slip ratio on the crucial boiling length in two-phase instability. In *Proc. Symp. Dynamics of Two-Phase Flow, Eindhoven, Netherlands, Sept. 1967* (in press).
- SHOTKIN, L.M. Some similarities between boiling and condensing flow. (N) Submitted to *Nucl. Sci. Eng.*
- SHOTKIN, L.M. - See also AKCASU, A.Z.; CHERNICK, J.
- SINGER, R.M. - See WEEKS, J.R.
- SLATER, L.M. Calibration of a polonium-210 alpha source. *J. Appl. Radiat. Isotopes* (in press).
- SLATER, L.M. Extraction of Cesium Polyiodides From Synthetic Waste Solutions into Nitrobenzene. BNL 50083 (T-478), Nov. 1967.
- SLATER, L.M. Extraction of potassium, rubidium, strontium, and cerous polyiodides into nitrobenzene. *J. Inorg. Nucl. Chem.* (in press).
- SLATER, L.M. AND KUKK, M. Coextraction of water and sodium polyiodides into nitrobenzene. In *Proc. Int. Conf. Solvent Extraction Chemistry, Gothenburg, Sweden, Aug. 27-Sept. 1, 1966*, pp. 588-94, J. Rydberg et al., Editors, North-Holland, Amsterdam, 1967.
- SOO, P. The deformation of iron which has been neutron irradiated to 10^{20} nvt. Submitted to *Acta Met.*
- STANG, L.G. JR. - See RICHARDS, P.
- STEINBERG, M., KUKACKA, L.E., COLOMBO, P., AND MANOWITZ, B. The radiation-induced ethylene polymerization program at Brookhaven National Laboratory. *Chem. Eng. Progr. Symp. Ser. 83 (Nucl. Eng. Pt. 19)* 64, 99-110 (1968).
- STEINBERG, M., POWELL, J.R., BELLER, M., AND MANOWITZ, B. Hybrid fossil-nuclear fueled MHD power cycles. Presented at Intersociety Energy Conversion Engineering Conf., IEEE, Denver, Aug. 1968.
- STEINBERG, M., POWELL, J.R., BELLER, M., AND MANOWITZ, B. A pollution-free hybrid fossil-nuclear fueled MHD power cycle. *IECEC '68 Record*, Paper No. 689118, pp. 861-73, IEEE, 1968.
- STEINBERG, M., PRUZANSKY, J., JEFFERSON, L.R., AND MANOWITZ, B. Radiation treatment of acid mine drainage. (A) *Trans. Amer. Nucl. Soc.* 11, 56 (1968).
- STEINBERG, M., PRUZANSKY, J., JEFFERSON, L.R., AND MANOWITZ, B. Removal of iron from mine drainage waste with the aid of high-energy radiation. Informal Report BNL 11576.
- STEINBERG, M., PRUZANSKY, J., JEFFERSON, L.R., AND MANOWITZ, B. Removal of iron from acid mine drainage waste with the aid of high energy radiation. Pt. II and III. Presented at Meet. Coal Ind. Advisory Comm. to Ohio River Valley Water Sanit. Comm., Pittsburgh, May 1968.
- STEINBERG, M. - See also BELLER, M.; HUSZAGH, D.W.; KUKACKA, L.E.; POWELL, J.R.
- STEPHENSON, T.E. The neutron cross section and resonance integrals of holmium. In *Proc. 2nd Conf. Neutron Cross Sections and Technology, Washington, D.C., March 1968* (in press).
- STEPHENSON, T.E. AND PEARLSTEIN, S. Parametric fit of the total neutron cross section of manganese from 0.01 eV to 50 keV. *Nucl. Sci. Eng.* 32, 377-84 (1968).
- STEPHENSON, T.E., PRINCE, A., AND PEARLSTEIN, S. Cross Section Evaluation Center. Evaluation of the Neutron Cross Section of Manganese for the ENDF/B Library. BNL 50060 (T-463), June 1967.

- STRICKLAND, G., TUTHILL, E. J., AND DRAGER, R.F. Phosphate glass process: Evaporator studies with simulated Purex wastes. In *Proc. Symp. Solidification and Long-Term Storage of Highly Radioactive Wastes, Richland, Wash., Feb. 1966*, pp. 280-99, W.H. Reagan, Editor, CONF-660208, Nov. 1966.
- STRICKLAND, G. - See also TUTHILL, E. J.
- SUSSKIND, H. AND BECKER, W. Pressure drop in geometrically ordered packed beds of spheres. *A.I.Ch.E. J.* **13**, 1155-9 (1967).
- SUSSKIND, H., ODETTE, R., AND BECKER, W. Controlled removal of spheres from a geometrically ordered packed bed by surface fluidization. Presented at A.I.Ch.E. Symp. Fluidization, Los Angeles, Calif., Dec. 1968.
- SUSSKIND, H., ODETTE, R., AND BECKER, W. Modified jet pumping of solid spheres. *Ind. Eng. Chem. Process Design Develop.* (in press).
- SUTHERLAND, J.W. AND GOODRICH, R. Radiolysis of nitrous oxide in the adsorbed state. (L) *J. Amer. Chem. Soc.* **89**, 6779-80 (1967).
- SUTHERLAND, J.W. AND KRAMER, H. Radiolytic products of liquid ammonia. *J. Phys. Chem.* **71**, 4161-2 (1967).
- SUTHERLAND, J.W., SETHI, D., AND GOODRICH, R. Radiolysis of carbon dioxide in the adsorbed state. *Ibid.*, 4422-9.
- SUTHERLAND, J.W. - See also SEARS, J.T.
- TAKAHASHI, H. Analysis of electron-phonon interaction by two-time Green's function method. (A) *Bull. Amer. Phys. Soc.* **12**, 1040 (1967).
- TAKAHASHI, H. Coherent one-phonon neutron scattering from polycrystalline graphite. (A) *Trans. Amer. Nucl. Soc.* **10**, 565-6 (1967).
- TAKAHASHI, H. Screening and electron correlation effects on the electron-phonon interaction in monovalent metals. *Phys. Rev.* (in press).
- TAKAHASHI, H. AND ARONSON, A. Survey calculations for the pulsed fast reactor: The neutron lifetime and critical volume. Informal Report BNL 11873.
- TANG, I.N. AND CASTLEMAN, A.W. JR. On the transport of fission-product iodine from molten uranium. (A) *Trans. Amer. Nucl. Soc.* **10**, 720-1 (1967).
- TANG, I.N. AND CASTLEMAN, A.W. JR. Radiation-induced decomposition of methyl iodide in air. (A) *Ibid.* **11**, 76 (1968).
- TANG, I.N. - See also CASTLEMAN, A.W. JR.
- THOMPSON, D. - See KRIKAWA, J.
- TU, P.S. AND PRINCE, A. Correlation of most probable kinetic energy of fission fragments and $\bar{\nu}_p$. Submitted to *J. Nucl. Energy*.
- TUNNEY, W. J. - See WINDSOR, H.H.
- TUTHILL, E. J., STRICKLAND, G., AND WETH, G.G. Platinum for high-temperature crucibles used in processing radioactive wastes. *Ind. Eng. Chem. Process Design Develop.* (in press).
- TUTHILL, E. J. - See also STRICKLAND, G.
- TVEKKREM, J.O. Pyrometry error on high temperature graphite from soot formation. (L) *J. Chem. Phys.* (in press).
- TVEKKREM, J.O. AND CHANDRASEKHARAIAH, M.S. The standard free energy of formation of UI_3 from EFM measurements on a solid electrolyte galvanic cell. *J. Electrochem. Soc.* (in press).
- WACHTEL, S. J. - See ROMANO, A. J.
- WAGNER, J.I. AND MILAU, J.S. *Failure of Cobalt-60 Radiation Sources*. BNL 50099 (T-486), Feb. 1968.
- WAGSCHAL, J. J. An improvement of the S_N calculation method for slab geometry. *Nucl. Sci. Eng.* **30**, 305-7 (1967).
- WAGSCHAL, J. J., LEVINE, M.M., AND CHERNICK, J. The importance of the correct treatment of the scattering integral in the Boltzmann equation in deep penetration calculations in iron. Presented at Israel Phys. Soc. Meet., Jerusalem, April 1968.
- WAGSCHAL, J. J., LEVINE, M.M., AND CHERNICK, J. Penetration of neutrons in iron. (A) *Trans. Amer. Nucl. Soc.* **10**, 621-2 (1967).
- WAIDE, C.H. - See WINSCHKE, W.E.
- WEEKS, J.R. Bi, Pb, Sn, and their alloys. In *USAEC Reactor Handbook*, 3rd Ed., Vol. 1, Chap. 47 (in press).
- WEEKS, J.R. The BNL program on corrosion by liquid sodium. Submitted to *Libby-Cockcroft Newsletter*.
- WEEKS, J.R. Materials behavior in Na-cooled reactors. Presented at 9th INCO Power Conf., Wrightsville Beach, N.C., May 1968.
- WEEKS, J.R. AND SINGER, R.M. On the solubilities of Cu, Ni, and Fe in liquid sodium. (A) Presented at AEC Corros. Inform. Meet., Columbus, Ohio, May 1968; presented at Int. Conf. Sodium Technology and Fast Reactors, ANL, Nov. 1968.
- WEEKS, J.R. - See also FLEITMAN, A.H.
- WEINSTOCK, E.V. - See GORDON, B.M.; PHELPS, J.P.
- WEISS, A. J. - See HILLMAN, M.
- WEISS, J. AND COLLINS, C.H. Radiolysis of aromatic compounds: Deuterated toluene. *Radiat. Res.* **33**, 274-81 (1968).
- WEISS, J. AND RAO, H.M. The gamma radiolysis of ethyl toluene. *Ibid.* **32**, 309-13 (1967).
- WEISS, J. AND RIZZO, F.X. Cobalt-60 dosimetry in radiation research and processing. In *Manual on Radiation Dosimetry*, Chap. 9, N. Holm and R. Berry, Editors, M. Dekker, Inc., New York (in press).
- WETH, G.G. - See TUTHILL, E. J.
- WILSON, V.H. - See MACKENZIE, D.R.
- WINDSOR, H.H. An interpretation of reflector savings measured in water moderated and reflected exponential experiments. (N) *Nucl. Sci. Eng.* **33**, 139-41 (1968).
- WINDSOR, H.H. AND TUNNEY, W. J. Reactor physics parameters of $^{233}UO_2$ - ThO_2 lattices in D_2O . (A) *Trans. Amer. Nucl. Soc.* **10**, 595-6 (1967).
- WINDSOR, H.H. - See also PRICE, G.A.; SEHGAL, B.R.
- WINSCHKE, W.E., WISWALL, R.H., REILLY, J. J., SHEEHAN, T.V., WAIDE, C.H., AND HOFFMAN, K.C. Metal hydrides as a source of fuel for vehicular propulsion. Submitted to *Environ. Sci. Tech.*
- WINSCHKE, W.E. - See also HOFFMAN, K.C.
- WISWALL, R.H. - See HOFFMAN, K.C.; REILLY, J. J.; WINSCHKE, W.E.
- YU, W.S. AND CHEN, J.C. Slug flow heat transfer with mass injection and linearly varying wall temperature. *A.I.Ch.E. J.* **13**, 1127-31 (1967).
- ZAVADOSKI, R.W. - See HILL, F.B.
- ZUCKER, M.S. AND FERRARI, L.A. A microwave cavity method of studying recombination following pulse radiolysis. Presented at Int. Conf. Radiation Chemistry, ANL, Aug. 1968.
- ZUCKER, M.S. - See also FERRARI, L.A.; POWELL, J.R.

Photography and Graphic Arts Division

- CZELADA, G. Density and density measurements. Submitted to *Phot. Appl. Sci. Technol.*
- SMITH, R.F. Behind the lens spot metering. The complete 35mm photographic system. *Phot. Appl. Sci. Technol.* 2, No. 7, 37-40 (Summer 1968).
- SMITH, R.F. Micro replication. *Ibid.*, No. 5, 24-7 (Winter 1967/68).
- SMITH, R.F. AND PAVELEC, M. The preparation of contact microradiographs. *Visual Med.* 3, 15-20 (1968).

Physics Department

- ABRAMS, R.J., COOL, R.L., GIACOMELLI, G., KYCIA, T.F., LEONTIC, B.A., LI, K.K., AND MICHAEL, D.N. Measurement of p - p and p - d total cross sections at 3.0 GeV/c. (L) Submitted to *Phys. Rev. Letters*.
- ABRAMS, R.J., COOL, R.L., GIACOMELLI, G., KYCIA, T.F., LEONTIC, B.A., LI, K.K., AND MICHAEL, D.N. New structures in the K - p and K - d total cross sections between 2.4 and 3.3 GeV/c. (L) *Phys. Rev. Letters* 19, 678-80 (1967).
- ALBURGER, D.E. The double Emperor Tandem Van de Graaff accelerator. (A) Presented at Colloq. Experimental Methods in Nuclear Physics and Particle Physics, Strasbourg, France, Dec. 1968.
- ALBURGER, D.E. Gamma-ray spectroscopy in Van de Graaff research. In *Nuclear Structure (Proc. Int. Conf., Dacca, East Pakistan, Jan. 1967)*, pp. 299-320, North-Holland, Amsterdam, 1967.
- ALBURGER, D.E. Problems using two-dimensional pulse height analysis. *Ibid.*, pp. 321-42.
- ALBURGER, D.E. - See also GALLMANN, A.; LOWE, J.; WARBURTON, E.K.; WILKINSON, D.H.
- ALITTI, J., FLAMINIO, V., METZGER, W.J., RADOJICIC, D., RAU, R.R., RICHARDSON, C.R., SAMIOS, N.P., SKILLICORN, I.O., BASSANO, D., GOLDBERG, M., AND LEITNER, J. Evidence for Ξ^* resonance with mass 1930 MeV. (L) Submitted to *Phys. Rev. Letters*.
- ALITTI, J., FLAMINIO, V., METZGER, W.J., RADOJICIC, D., RAU, R.R., SAMIOS, N.P., SKILLICORN, I.O., BASSANO, D., GOLDBERG, M., AND LEITNER, J. Evidence for Ξ resonances. (A) In *Proc. 14th Int. Conf. High Energy Physics, Vienna, Aug. 1968* (in press).
- ALITTI, J., FLAMINIO, V., METZGER, W.J., RAU, R.R., SAMIOS, N.P., SKILLICORN, I.O., BASSANO, D., AND GOLDBERG, M. Production of Ξ^- in K - p interactions at 3.9, 4.6, and 5.0 GeV/c. (A) *Bull. Amer. Phys. Soc.* 13, 705 (1968).
- ALPERIN, H.A. - See MENZINGER, F.; PICKART, S.J.
- ALVAREZ-RIVAS, J. L. AND LEVY, P.W. X-ray-induced first-stage coloring of NaCl. *Phys. Rev.* 162, 816-23 (1967).
- ANDERSON, E.W., BLESER, E.J., BLIEDEN, H.R., COLLINS, G.B., GARELICK, D., MENES, J., TURKOT, F., BIRNBAUM, D., EDELSTEIN, R.M., HIEN, N.C., MCMAHON, T.J., MUCCI, J., AND RUSS, J. π - p Elastic scattering near 180° at 8 and 16 GeV/c. (L) *Phys. Rev. Letters* 20, 1529-32 (1968).
- ANDRUS, W.S., MUETHER, H.R., AND PALEVSKY, H. Inelastic scattering of cold neutrons from liquid argon at elevated temperatures. (L) *Phys. Letters* 26A, 152-3 (1968).
- ANDRUS, W.S., MUETHER, H.R., AND PALEVSKY, H. Temperature dependence of quasi-elastic scattering of cold neutrons from liquid argon. In *Proc. IAEA Symp. Inelastic Scattering of Neutrons From Liquid Argon, Copenhagen, May 1968* (in press).
- ARNDT, R.A. - See BLUM, H.; RINGEL, H.; WHITTEN, W.B.
- ASHMORE, A., DAMERELL, C.J.S., FRISKEN, W.R., RUBINSTEIN, R., OREAR, J., OWEN, D.P., PETERSON, F.C., READ, A.L., RYAN, D.G., AND WHITE, D.H. High-energy π^- - p , K^- - p and $\bar{p}$ - p elastic scattering. (L) *Phys. Rev. Letters* 21, 387-9 (1968).
- AUERBACH, E.H., FLEMING, D.M., AND STERNHEIM, M.M. Optical-model analysis of pion-nucleus scattering. *Phys. Rev.* 162, 1683-94 (1967); II. Pion form factor. *Ibid.* 171, 1781-5 (1968).
- AUERBACH, E.H. AND MOORE, S.O. Calculations of inelastic scattering of neutrons by nuclei. II. *Phys. Rev.* 163, 1124-34 (1967).
- AUERBACH, E.H., QURESHI, H.M., AND STERNHEIM, M.M. Pion scattering and the neutron halo in lead. (L) *Phys. Rev. Letters* 21, 162 (1968).
- BACHMAN, A.H. - See BELL, R.B.
- BAGUS, P. - See WATSON, R.E.
- BARNES, V.E., DORNAN, P., CHUNG, S., LUERS, D., SAMIOS, N.P., SKILLICORN, I.O., GOLDBERG, M., JAEGER, K., LEITNER, J., MEADOWS, B., AND PRIMER, M. Meson enhancements in K - $p \rightarrow V^0 + n$ prongs at 4.6 GeV/c. (A) *Bull. Amer. Phys. Soc.* 13, 705 (1968).
- BARNES, V.E., DORNAN, P.J., KALBFLEISCH, G.R., LONDON, G., PALMER, R., RAU, R.R., SAMIOS, N.P., SKILLICORN, I.O., GOLDBERG, M., JAEGER, K., CHANG, C.Y., AND LEITNER, J. Properties of the f^* meson. (L) *Phys. Rev. Letters* 19, 964-7 (1967).
- BARNES, V.E., DORNAN, P.J., KALBFLEISCH, G.R., SKILLICORN, I.O., GOLDBERG, M., LEITNER, J., MEADOWS, B., AND PRIMER, M. Quasi two- and three-body final states in K - p interactions at 4.6 and 5.0 GeV/c. (A) *Bull. Amer. Phys. Soc.* 13, 492 (1968).
- BARNES, V.E., FLAMINIO, V., GUIDONI, P., METZGER, W.J., RAU, R.R., SAMIOS, N.P., SKILLICORN, I.O., GOLDBERG, M., JAEGER, K., AND MEADOWS, B. Evidence for a negative meson-like enhancement near 970 MeV. (A) In *Proc. 14th Int. Conf. High Energy Physics, Vienna, Aug. 1968* (in press).
- BARNES, V.E. - See also BASSANO, D.; PRIMER, M.
- BARTRAM, R.H. - See KEMMEY, P.J.
- BASSANO, D., GOLDBERG, M., GOZ, B., PERTILE, G., BARNES, V.E., DORNAN, P.J., KALBFLEISCH, R.G., SAMIOS, N.P., SKILLICORN, I.O., AND LEITNER, J. Decay rates of $K^*(1420)$ and the 2^+ nonet. (L) *Phys. Rev. Letters* 19, 968-72 (1967).
- BASSANO, D. - See also ALITTI, J.
- BASSEL, R.H. AND WILKIN, C. High energy proton scattering and the structure of light nuclei. *Phys. Rev.* (in press).
- BAUMEL, P. - See BELL, R.B.; CRENNELL, D.J.
- BEER, M., CHRIEN, R.E., BHAT, M.R., LONE, M.A., AND MUETHER, H.R. Correlation effects of partial widths in resonance neutron capture in heavy nuclei. (A) *Bull. Amer. Phys. Soc.* 12, 1187 (1967).

- BEER, M., CHRIEN, R.E., WASSON, O.A., BHAT, M.R., AND LONE, M.A. Gamma rays from resonance capture in Er^{166} and Er^{167} . (A) *Ibid.* 13, 64 (1968).
- BEER, M., LONE, M.A., CHRIEN, R.E., WASSON, O.A., BHAT, M.R., AND MUETHER, H.R. Correlations in partial widths of neutron-induced reactions. (L) *Phys. Rev. Letters* 20, 340-3 (1968).
- BEER, M. - See also BHAT, M.R. (Nuclear Engineering); CHRIEN, R.E.; LONE, M.A.; WASSON, O.A.
- BELL, R.B., CRENNELL, D. J., HOUGH, P.V.C., KARSHON, U., LAI, K.W., SCARR, J.M., SCHUMANN, T.G., SKILLICORN, I.O., STRAND, R.C., BACHMAN, A.H., BAUMEL, P., LEA, R.M., AND MONTWILL, A. Evidence for the $I = \frac{1}{2} N^*(1400)$ resonance production in $\pi^\pm p$ interactions at 6 GeV/c. (L) *Phys. Rev. Letters* 20, 164-7 (1968).
- BENJAMIN, J.A. - See LARSON, J.D.
- BENNETT, G.W. - See FRIEDES, J.L.; IGO, G.J.; SIMPSON, W.D.; SUTTER, R.J.
- BENNETT, L.H., MEBS, R.W., AND WATSON, R.E. Solute Knight shifts in noble metal alloys. (A) *Bull. Amer. Phys. Soc.* 13, 690 (1968).
- BENNETT, L.H., MEBS, R.W., AND WATSON, R.E. Solute Knight shifts in noble metals. *Phys. Rev.* 171, 611-26 (1968).
- BENNETT, L.H., SWARTZENDRUBER, L. J., AND WATSON, R.E. Hyperfine fields and electronic structure of CsCl-type ternary alloys of the first transition series. *Phys. Rev.* 165, 500-5 (1968).
- BENNETT, L.H. - See also WATSON, R.E.
- BERGER, E.L., ELLIS, W.E., MILLER, D. J., MORRIS, T.W., AND PANVINI, R.S. Investigation of low multiplicity final states from pp interactions at 28.5 BeV/c. (A) In *Proc. 14th Int. Conf. High Energy Physics, Vienna, Aug. 1968* (in press).
- BERTMAN, B. AND KITCHENS, T.A. Heat transport in superfluid filled capillaries. *Cryogenics* 8, 36-41 (1968).
- BIRNBAUM, D. - See ANDERSON, E.W.
- BLESER, E. J. - See ANDERSON, E.W.
- BLIEDEN, H.R. - See ANDERSON, E.W.
- BLOOD, F.A. JR. Relativistic and causal theories with four-fermion interaction Hamiltonians. *J. Math. Phys.* 8, 1633-41 (1967).
- BLOOM, S.D. - See WARBURTON, E.K.
- BLUM, A., DIENES, G. J., HATCHER, R.D., AND WILSON, W.D. Positive and negative ion vacancies in KCl and LiH. (A) *Bull. Amer. Phys. Soc.* 13, 500 (1968).
- BLUM, H., MATTERN, P.L., ARNDT, R.A., AND DAMASK, A.C. γ -Radiation induced color centers in anthracene. *Mol. Cryst.* 3, 269-80 (1967).
- BLUM, H. - See also MATTERN, P.L.
- BLUME, M. Hyperfine structure in a fluctuating environment. In *Hyperfine Structure and Nuclear Radiations (Proc. Int. Conf., Pacific Grove, Calif., Aug. 1967)*, pp. 911-27, E. Matthias and D.A. Shirley, Editors, North-Holland, Amsterdam, 1968.
- BLUME, M. Stochastic theory of line shape: Generalization of the Kubo-Anderson model. *Phys. Rev.* (in press).
- BLUME, M. AND KISTNER, O.C. Resonant absorption in the presence of Faraday rotation. *Phys. Rev.* 171, 417-25 (1968).
- BLUME, M. AND TJON, J.A. Mössbauer spectra in a fluctuating environment. *Phys. Rev.* 165, 446-56 (1968).
- BLUME, M. - See also SCHERMER, R.I.; STERNHEIMER, R.M.; TJON, J.A.; VINEYARD, G.H.; WATSON, R.E.; WILSON, W.D.
- BRAYSHAW, D. AND PEIERLS, R.F. Connection between bound states or resonances of two-particle and three-particle systems. Submitted to *Phys. Rev.*
- BRODSKY, S. J. AND DE RAFAEL, E. Suggested boson-lepton pair couplings and the anomalous magnetic moment of the muon. (L) *Phys. Rev.* 168, 1620-2 (1968).
- BRUNHART, G. Hyperfine interaction in rare earth metals and compounds. (A) In *Proc. 6th Conf. Rare Earth Research, Gatlinburg, Tenn., May 1967*, pp. 495-505, CFSTI, Springfield, Va., 1967.
- BRUNHART, G. - See also SCHERMER, R.I.
- BUCK, B. - See ZUKER, A.P.
- BUDNICK, J.I. - See CRAIG, P.P.
- BUBBLE CHAMBER GROUP. The 14-foot cryogenic bubble chamber research and development program. The 7-foot test facility. Informal Report BNL 11810.
- BUBBLE CHAMBER GROUP. Scaling studies of large cryogenic bubble chambers. Informal Report BNL 12336.
- BUGG, W.M. - See CNOPS, A.M.
- BURKE, E.A. - See GENTER, R.F.; STAUBER, M.C.
- BURRIS, R.W. - See RAY, A.K.
- BUTTERWORTH, J.S., EASER, P., AND LEVY, P.W. Effect of thallium impurity on the production of color centers in KCl by gamma radiation at room temperature. (A) *Bull. Amer. Phys. Soc.* 13, 392-3 (1968).
- BUTTERWORTH, J.S. - See also ESSER, P.
- CAGLIOTI, G. - See MENZINGER, F.
- CANTER, J. - See HILL, D.G.
- CHAN, L.H. Lagrangian field theory for chiral symmetry $U(n) \times U(n)$. (A) *Bull. Amer. Phys. Soc.* 13, 122 (1968).
- CHAN, Y.W., COHEN, V.W., AND SILSBEE, H.B. The nuclear spin of Pt^{197} (20 h). (A) *Ibid.*, 895.
- CHANG, C.Y. - See BARNES, V.E.
- CHASE, L.F. JR., McDONALD, R.E., TRUE, W.W., AND WARBURTON, E.K. Spin assignments of the B^{12} 0.95-, 1.67-, and 2.62-MeV levels. *Phys. Rev.* 166, 997-1003 (1968).
- CHASMAN, C., JONES, K.W., AND RISTINEN, R.A. Gamma rays from the $\text{Sc}^{45}(p, p'\gamma)$ reaction. *Phys. Rev.* (in press).
- CHASMAN, C., JONES, K.W., AND RISTINEN, R.A. Study of gamma rays from the $\text{Ca}^{43}(p, p'\gamma)\text{Ca}^{43}$ reaction and the decay of K^{43} and Sc^{43} . *Phys. Rev.* 169, 911-16 (1968).
- CHASMAN, C. - See also FOSSAN, D.B.; KRANER, H.W. (Instr. and Health Physics).
- CHENG, D. - See EMERY, V. J.
- CHO, Y. - See HILL, D.G.
- CHRIEN, R.E. Radiative capture of epithermal neutrons. (A) In *Proc. 2nd Conf. Neutron Cross Sections and Technology, Washington, D.C., March 1968* (in press).
- CHRIEN, R.E. Radiative capture of neutrons in and between resonances. (A) *Bull. Amer. Phys. Soc.* 12, 1167 (1967).
- CHRIEN, R.E., PRICE, D.L., WASSON, O.A., BHAT, M.R., LONE, M.A. AND BEER, M. Direct neutron capture in $^{238}\text{U}(n, \gamma)^{239}\text{U}$. (L) *Phys. Letters* 25B, 195-7 (1967).
- CHRIEN, R.E., WASSON, O.A., BHAT, M.R., MUGHABGHAB, S.F., GARBER, D.I., BEER, M., AND LONE, M.A. Resonant and non-resonant neutron capture experiments at the high flux beam reactor. In *Proc. IUPAP-IAEA*

- Int. Symp. Nuclear Structure, Dubna, USSR, July 1968* (in press).
- CHRIEN, R.E., WASSON, O.A., AND GARBER, D.I. Radiative capture of epithermal neutrons in iron. (A) *Bull. Amer. Phys. Soc.* **13**, 720 (1968).
- CHRIEN, R.E. - See also BEER, M.; BHAT, M.R. (Nuclear Engineering); GARBER, D.I.; LONE, M.A.; MUGHABGHAB, S.F. (Nuclear Engineering); RIMAWI, K.; WASSON, O.A.
- CHUNG, S.U. Spin-parity analysis for boson resonances. *Phys. Rev.* **169**, 1342-52 (1968).
- CHUNG, S.U. - See also BARNES, V.E.
- CHURCH, E.L. AND WENESER, J. High-energy internal-conversion coefficients. (A) *Bull. Amer. Phys. Soc.* **13**, 893-4 (1968).
- CHURCH, E.L. AND WENESER, J. Nuclear-atomic polarization effects. Presented at Int. Conf. Hyperfine Interactions Detected by Nuclear Radiation, Pacific Grove, Calif., Aug. 1967.
- CNOPS, A.M., HOUGH, P.V.C., HUSON, F.R., KENYON, I.R., SCARR, J.M., SKILLICORN, I.O., COHN, H.O., MCCULLOCH, R.D., BUGG, W.M., CONDO, G.T., AND NUSSBAUM, M.M. Coherent production of $\pi^+\pi^-\pi^+$ in deuterium by 8 GeV/c π^+ . (A) In *Proc. 14th Int. Conf. High Energy Physics, Vienna, Aug. 1968* (in press).
- CNOPS, A.M., HOUGH, P.V.C., HUSON, F.R., KENYON, I.R., SCARR, J.M., SKILLICORN, I.O., COHN, H.O., MCCULLOCH, R.D., BUGG, W.M., CONDO, G.T., AND NUSSBAUM, M.M. Enhancements in the 2- and 3-pion mass spectra near 1.7 GeV observed in the reactions of 8 GeV/c π^+ mesons with deuterium. (A) *Ibid.*
- COHEN, V.W. Nuclear magnetic and electric moments. In *Proc. 32nd Session Deutsche Physikalische Gesellschaft, Berlin, Oct. 1967*, p. 153, B.G. Teubner, Stuttgart, 1967.
- COHEN, V.W. Radio frequency measurements of electric and magnetic moments of nuclei. Presented at 15th A.M.P.E.R.E. Conf., IUPAP, Grenoble, France, Sept. 1968.
- COHEN, V.W., NATHANS, R., SILSBEE, H., LIPWORTH, E., AND RAMSEY, N. The electric dipole moment of the neutron. (A) *Bull. Amer. Phys. Soc.* **13**, 872 (1968).
- COHEN, V.W. - See also CHAN, Y.W.
- COHN, H.O. - See CNOPS, A.M.
- COLLINS, G.B. - See ANDERSON, E.W.
- COLLINS, M.F., NATHANS, R., PASSELL, L., AND SHIRANE, G. Critical behavior of iron above its Curie temperature. (L) *Phys. Rev. Letters* **21**, 99-102 (1968).
- COLLINS, M.F., NATHANS, R., PASSELL, L., AND SHIRANE, G. Critical scattering from iron. (A) *Bull. Amer. Phys. Soc.* **13**, 616 (1968).
- COLLINS, M.F., NATHANS, R., PASSELL, L., AND SHIRANE, G. High resolution studies of the critical scattering of neutrons from iron. (A) In *Proc. Int. Conf. Statistical Mechanics, Kyoto, Japan, Sept. 1968* (in press).
- CONDO, G.T. - See CNOPS, A.M.
- CONNOLLY, P.L., ELLIS, W.E., HOUGH, P.V.C., MILLER, D.J., MORRIS, T.W., OUANNES, C., PANVINI, R.S., AND THORNDIKE, A.M. Study of pp interactions at 28.5 BeV/c in two- and four-prong final states. In *Proc. 3rd Topical Conf. Resonant Particles, Athens, Ohio, Nov. 1967* (in press).
- CONNOLLY, P.L., ELLIS, W.E., HOUGH, P.V.C., MILLER, D.J., MORRIS, T.W., AND PANVINI, R.S. Cross sections for two- and four-prong processes in 28.5-GeV/c proton-proton collisions. (A) *Bull. Amer. Phys. Soc.* **12**, 1134-5 (1967).
- CONNOLLY, P.L., KENYON, I.R., MORRIS, T.W., AND THORNDIKE, A.M. The study of 28.6 GeV/c p - p interactions with 6 charged particles in the final states. In *Proc. Topical Conf. High Energy Collisions of Hadrons, Geneva, Jan. 1968*, CERN 68-7, Vol. 2, pp. 208-25, CERN, Geneva, Feb. 1968.
- CONNOLLY, P.L. - See also ELLIS, W.E.; PANVINI, R.D.
- COOL, R.L. - See ABRAMS, R.J.
- COOPER, M. J. AND NATHANS, R. The resolution function in neutron diffractometry. I. The resolution function of a neutron diffractometer and its application to phonon measurements. *Acta Cryst.* **23**, 357-67 (1967); II. The resolution function of a conventional two-crystal neutron diffractometer for elastic scattering. *Ibid.* (in press).
- CORLEY, D.M. - See FRIEDES, J.L.; IGO, G.J.; SIMPSON, W.D.; SUTTER, R.J.
- COX, D.E. AND FRAZER, B.C. A neutron diffraction study of NpO_2 . *J. Phys. Chem. Solids* **28**, 1649-50 (1967).
- COX, D.E. AND WILLIAMS, T. A neutron diffraction study of β - CrPO_4 . (A) In *Proc. Int. Conf. Magnetic Oxides, Bucharest, Sept. 1968* (in press).
- COX, D.E. - See also MIKSIC, M.G.; SKALYO, J. JR.; UMEBAYASHI, H.; WANG, F.F.Y.; WILL, G.
- COX, G.W. - See SABINE, T.M.
- CRAIG, P.P., GOLDBURG, W.I., KITCHENS, T.A., AND BUDNICK, J.I. Transport properties at critical points: The resistivity of nickel. (L) *Phys. Rev. Letters* **19**, 1334-7 (1967).
- CRAIG, P.P. - See also GOLDBURG, W.; TAYLOR, R.D.; TRIFTSHAUSER, W.; TROUSDALE, W.L.
- CRAVEN, B.M. - See SABINE, T.M.
- CRENNELL, D. J., DELANEY, W.C., FLAMINIO, V., KARSHON, U., LAI, K.W., METZGER, W. J., O'NEALL, J.S., SCARR, J.M., SCHUMANN, T.G., AND THORNDIKE, A.M. $S = -2$ baryon resonances produced in K^-n interactions at 3.6 and 3.9 GeV/c. (A) In *Proc. 14th Int. Conf. High Energy Physics, Vienna, Aug. 1968* (in press).
- CRENNELL, D. J., DELANEY, W. C., FLAMINIO, V., KARSHON, U., LAI, K.W., METZGER, W. J., O'NEALL, J.S., SCARR, J.M., THORNDIKE, A.M., BAUMEL, P., LEA, R.M., MONTWILL, A., AND SCHUMANN, T.G. Evidence for a new isospin one $\gamma_1^*(1600)$ resonance in K^-n interactions at 3.9 GeV/c. (A) *Ibid.*
- CRENNELL, D. J., FLAMINIO, V., KARSHON, U., LAI, K.W., METZGER, W. J., O'NEALL, J.S., SCARR, J.M., AND SCHUMANN, T.G. K^-n interactions at 3.6 and 3.9 GeV/c. (A) *Bull. Amer. Phys. Soc.* **13**, 704 (1968).
- CRENNELL, D. J., KARSHON, U., LAI, K.W., SCARR, J.M., AND SKILLICORN, I.O. Properties of the $g_1(1640)$ meson. (A) In *Proc. 14th Int. Conf. High Energy Physics, Vienna, Aug. 1968* (in press).
- CRENNELL, D. J., KARSHON, U., LAI, K.W., SCARR, J.M., AND SKILLICORN, I.O. Study of structure in the " $A_2(1300)$ " region in π^-p interactions at 6 GeV/c. (L) *Phys. Rev. Letters* **20**, 1318-21 (1968).
- CRENNELL, D. J., LAI, K.W., SCARR, J.M., AND SCHUMANN, T.G. ΔK enhancement at 1.7 GeV produced in $\pi p \rightarrow \Delta K \pi$ interactions at 6 GeV/c (L) *Ibid.* **19**, 1212-15 (1967).

- CRENNELL, D. J. - See also BELL, R.B.
- CROW, J.E., KAMMERER, O.F., AND STRONGIN, M. Proximity effect between superconducting and ferromagnetic layers. (A) *Bull. Amer. Phys. Soc.* **13**, 108 (1968).
- CROW, J.E. - See also STRONGIN, M.
- CUTHILL, J.R., McALISTER, A. J., WILLIAMS, M.L., AND WATSON, R.E. Density of states of Ni: Soft x-ray spectrum and comparison with photoemission and ion neutralization studies. *Phys. Rev.* **164**, 1006-17 (1967).
- DAMASK, A.C. - See BLUM, H.; KATZ, L.E.; RINGEL, H.; WHITTEN, W.B.
- DAMERELL, C. J.S. - See ASHMORE, A.
- DANIELS, W.B., SHIRANE, G., FRAZER, B.C., LEAKE, J.A., SKALYO, J., AND YAMADA, Y. Temperature dependence of phonon energies in a single crystal of neon. (A) *Bull. Amer. Phys. Soc.* **12**, 1063 (1967).
- DANIELS, W.B. - See also UMEBAYASHI, H.
- DATZ, S., ERGINSOY, C., LEIBFRIED, G., AND LUTZ, H.O. Motion of energetic particles in crystals. *Annu. Rev. Nucl. Sci.* **17**, 129 (1967).
- DELANEY, W.C. - See CRENNELL, D. J.
- DE RAFAEL, E. AND GOLDBERGER, M. Decay rates of $\Delta S = -\Delta Q$ transitions and possible $\Delta S = 2$ leptonic decays. (L) *Phys. Rev. Letters* **20**, 522-5 (1968).
- DE RAFAEL, E. - See also BRODSKY, S. J.; LAUTRUP, B.E.; MARTIN, B.R.
- DER MATEOSIAN, E. - See SCHULT, O.W.B.
- DiCARLO, J.A., SNEAD, C.L. JR., AND GOLAND, A.N. Interstitials in electron-irradiated tungsten observed by combined internal friction and resistivity. (A) *Bull. Amer. Phys. Soc.* **13**, 381 (1968).
- DIENES, G. J. "Off-center" ions in the alkali halides. (N) Submitted to *Solid State Comments*.
- DIENES, G. J. On the fluorescence decay curve of anthracene. (L) *Mol. Cryst.* **3**, 293-6 (1967).
- DIENES, G.J., BRONK, B.V., AND PASKIN, A. The stochastic theory of cell proliferation. (A) Presented at Radiat. Res. Soc. Meet., Houston, Texas, April 1968.
- DIENES, G. J. - See also BLUM, A.; BRONK, B.V. (Medical); NOWICK, A.S.; PASKIN, A. (Nuclear Engineering).
- DIMMOCK, J.O. - See WATSON, R.E.
- DORAIN, P.B. - See MINKIEWICZ, V. J.
- DORNAN, P. J. - See BARNES, V.E.; BASSANO, D.; PRIMER, M.
- DRALLE, A. - See HILL, D.G.
- EDELSTEIN, R.M. - See ANDERSON, E.W.
- ELLIS, W.E., CONNOLLY, P.L., MILLER, D. J., MORRIS, T.W., AND PANVINI, R.S. Production of the $\Delta(1236)$ isobar in proton-proton interactions at 28.5 GeV/c. (A) *Bull. Amer. Phys. Soc.* **13**, 682 (1968).
- ELLIS, W.E. - See also BERGER, E.L.; CONNOLLY, P.L.; PANVINI, R.S.
- EMERY, G.T. - See BOCQUET, J.-P. (Chemistry).
- EMERY, V. J. Low temperature expansion of the transport coefficients and specific heat of Fermi liquids. *Phys. Rev.* **170**, 205-12 (1968).
- EMERY, V. J. Properties of dilute mixtures of He³ in liquid He⁴ at low temperatures. (A) Presented at Spring School on Helium, Beirut, Lebanon, April 1968.
- EMERY, V. J. AND CHENG, D. Transport coefficients in degenerate Fermi systems. (L) *Phys. Rev. Letters* **21**, 533-9 (1968).
- ERGINSOY, C. Energy loss to electrons in crystal lattices. In *Proc. Int. Conf. Solid State Physics Research With Accelerators, Brookhaven National Laboratory, Sept. 1967*, pp. 30-42, A.N. Goland, Editor, BNL 50083 (C-52).
- ERGINSOY, C. - See also DATZ, S.
- ESSER, P., BUTTERWORTH, J.S., AND LEVY, P.W. Thermal annealing of color centers produced in KCl and KCl:Ti by gamma-ray irradiation at room temperature. (A) *Bull. Amer. Phys. Soc.* **13**, 393 (1968).
- ESSER, P. - See also BUTTERWORTH, J.S.
- FISCHER, C.R. He-Li⁺ interaction energy at small internuclear distances. *J. Chem. Phys.* **48**, 215-7 (1968).
- FISCHER, C.R., HARRISON, S.W., HATCHER, R.D., AND WILSON, W.D. A diatomic LCAO calculation of LiH crystal properties. (A) *Bull. Amer. Phys. Soc.* **13**, 500 (1968).
- FISK, H.E. - See HILL, D.G.; RAY, A.K.
- FLAMINIO, V. - See ALITTI, J.; BARNES, V.E.; CRENNELL, D. J.
- FLEMING, D.M. - See AUERBACH, E.H.
- FOLEY, K. J., JONES, R.S., LINDENBAUM, S. J., LOVE, W.A., OZAKI, S., PLATNER, E.D., QUARLES, C.A., AND WILLEN, E.H. High-energy, small-angle, p - p and $\bar{p}$ - p scattering, and p - p total cross sections. (L) *Phys. Rev. Letters* **19**, 857-60 (1967).
- FOLEY, K. J., JONES, R.S., LINDENBAUM, S. J., LOVE, W.A., OZAKI, S., PLATNER, E.D., QUARLES, C.A., AND WILLEN, E.H. High-precision $\pi^{\pm}$ - p total cross sections from 8 to 29 BeV/c. (L) *Ibid.*, 330-2.
- FOLEY, K. J., JONES, R.S., LINDENBAUM, S. J., LOVE, W.A., OZAKI, S., PLATNER, E.D., QUARLES, C.A., AND WILLEN, E.H. N^* production in $\pi^{\pm}$ - p and p - p interactions. (L) *Ibid.*, 397-9.
- FOSSAN, D.B., CHASMAN, C., AND JONES, K.W. Transition probabilities for low-lying states in Sc⁴⁶. *Phys. Rev.* **168**, 1200-4 (1968).
- FOSSAN, D.B. AND POLETTI, A.R. Analogous $\frac{3}{2}^-$ levels in ⁴³Ca and ⁴¹Ar. (L) *Phys. Letters* **24B**, 38 (1967).
- FOSSAN, D.B. AND POLETTI, A.R. Magnetic moment of the $d_{3/2}$ hole state in Sc⁴⁷. In *Hyperfine Structure and Nuclear Radiations (Proc. Int. Conf., Pacific Grove, Calif., Aug. 1967)*, pp. 116-23, E. Matthias and D.A. Shirley, Editors, North-Holland, Amsterdam, 1968.
- FRAZER, B.C. - See COX, D.E.; DANIELS, W.B.; MINKIEWICZ, V. J.; SKALYO, J. JR.; UMEBAYASHI, H.
- FREEMAN, A. J. - See WATSON, R.E.
- FRICK, G. - See GALLMANN, A.
- FRIEDES, J.L. Proton-nuclei reactions at 1-BeV incident energy. (A) *Bull. Amer. Phys. Soc.* **12**, 1171 (1967).
- FRIEDES, J.L., PALEVSKY, H., SUTTER, R. J., BENNETT, G.W., IGO, G. J., SIMPSON, W.D., AND CORLEY, D.M. Inelastic 1-GeV proton scattering from carbon and oxygen. *Nucl. Phys.* **A104**, 294-300 (1967).
- FRIEDES, J.L., SUTTER, R., PALEVSKY, H., BENNETT, G.W., IGO, G. J., SIMPSON, W.D., PHILLIPS, G.C., CORLEY, D.M., WALL, N.S., AND STEARNS, R.L. Production of high momentum deuterons from nuclei bombarded by 1 BeV protons. Presented at Int. Conf. Nuclear Structure, Tokyo, Sept. 1967.
- FRIEDES, J.L., SUTTER, R., PALEVSKY, H., BENNETT, G.W., IGO, G., SIMPSON, W.D., STEARNS, R.L., AND CORLEY, D.M. High resolution nuclear structure studies using 1-BeV protons. *Nucl. Instr. Methods* **54**, 1-12 (1967).
- FRIEDES, J.L. - See also IGO, G. J.; SIMPSON, W.D.; SUTTER, R. J.

- FRISKEN, W.R. - See ASHMORE, A.
- GALBRAITH, W., JENKINS, E.W., KYCIA, T.F., LEONTIC, B.A., PHILLIPS, R.H., READ, A.L., AND RUBINSTEIN, R. Absorption cross sections for high energy protons, anti-protons and π and K mesons on nuclei. Informal Report BNL 11598.
- GALLMANN, A., FRICK, G., WARBURTON, E.K., ALBURGER, D.E., AND HECHTL, S. Positron decay of Mg^{22} . *Phys. Rev.* **163**, 1190-7 (1967).
- GARBER, D.I., PARKS, D., WASSON, A.O., BHAT, M.R., AND CHRIEN, R.E. Gamma rays from the thermal and resonance capture of neutrons in hafnium. (A) *Bull. Amer. Phys. Soc.* **13**, 64 (1968).
- GARBER, D.I. - See also BHAT, M.R. (Nuclear Engineering); CHRIEN, R.E.; MUGHABGHAB, S.F. (Nuclear Engineering).
- GARELICK, D. - See ANDERSON, E.W.
- GARG, J.B. - See RIMAWI, K.; WASSON, O.A.
- GEIGER, J.S. - See GELLETLY, W.
- GELLETLY, W. AND GEIGER, J.S. Satellite bands in the internal conversion spectrum from ^{227}Th . (A) *Bull. Amer. Phys. Soc.* **13**, 78 (1968).
- GELLETLY, W. - See also MARISCOTTI, M.A. J.
- GENTER, R.F. AND BURKE, E.A. Atomic wave functions in Hylleraas coordinates: The beryllium atom. Submitted to *Phys. Rev.*
- GIACOMELLI, G., KYCIA, T.F., LI, K.K., AND TEIGER, J. Design and performance of a K^+ detector. *Rev. Sci. Instr.* **38**, 1408-11 (1967).
- GIACOMELLI, G. - See also ABRAMS, R. J.; STRYCKMANS, P.A. (Medical).
- GINOCCHIO, J.N. AND WENESER, J. Isospin invariance and the pairing-force problem. *Phys. Rev.* **170**, 859-79 (1968).
- GOLAND, A.N. The physics of tract registration in solids. (A) Presented at 26th Annu. Meet. Electron Microscopy Soc. Amer., New Orleans, Sept. 1968.
- GOLAND, A.N., Editor, *Proc. Int. Conf. Solid State Physics With Accelerators, Brookhaven National Laboratory, Sept. 1967*. BNL 50083 (C-52).
- GOLAND, A.N. AND KEATING, D.T. Diffuse x-ray scattering from doublet defects in martensite and ferrite. *J. Phys. Chem. Solids* **29**, 785-97 (1968).
- GOLAND, A.N. AND KEATING, D.T. The influence of interstitial carbon in iron on the scattering of x-rays. (A) Presented at Int. Conf. Vacancies and Interstitials in Metals, Julich, West Germany, Sept. 1968.
- GOLAND, A.N. - See also DiCARLO, J.A.; KEATING, D.T.
- GOLDBERG, M. - See ALITTI, J.; BARNES, V.E.; BASSANO, D.; PRIMER, M.
- GOLDBURG, W.I. AND CRAIG, P.P. Fluctuation scattering contribution to the resistivity of nickel. (A) *Bull. Amer. Phys. Soc.* **12**, 1037 (1967).
- GOLDBURG, W.I. - See also CRAIG, P.P.
- GOLDHABER, M. - See DE RAFAEL, E.
- GORDON, D., KALBFLEISCH, G., KOEHLER, J., PRODELL, A., AND VANDERBURG, V. Preliminary report on the optics and magnetic field of the BNL 31-inch bubble chamber. Informal Report BNL 11641.
- GOTTSCHALK, B. - See SIMPSON, W.D.
- GOZ, B. - See BASSANO, D.
- GUIDONI, P. - See BARNES, V.E.
- HARA, Y. Parity-violating nonleptonic decays of hyperons. *Phys. Rev.* **164**, 1844-7 (1967).
- HARRIS, W.R. - See WARBURTON, E.K.
- HARRISON, S.W. - See FISCHER, C.R.
- HATCHER, R.D. - See BLUM, A.; FISCHER, C.R.
- HAUSSER, O. - See ROSE, H. J.
- HECHTL, S. - See GALLMANN, A.; POLETTI, A.R.
- HERLEY, P. J. AND LEVY, P.W. Effects of x- and γ -ray radiation on the thermal decomposition of solid orthorhombic ammonium perchlorate. I. Experimental and results; II. Kinetics and discussion. *J. Chem. Phys.* (in press).
- HERLEY, P. J. AND LEVY, P.W. Photochemical decomposition of sodium chlorate. (A) In *Proc. 6th Int. Symp. Reactivity of Solids, Schenectady, N.Y., Aug. 1968* (in press).
- HERLEY, P. J. - See also LEVY, P.W.
- HERMAN, H. - See KATZ, L.E.
- HERTZBACH, S.S. - See KALBFLEISCH, G.R.
- HIEN, N.C. - See ANDERSON, E.W.
- HILL, D.G., ROBINSON, D.K., SAKITT, M., SKJEGGESTAD, O., CANTER, J., CHO, Y., DRALLE, A., ENGLER, A., FISK, H.E., KRAEMER, R.W., AND MELTZER, C.M. Measurement of the lifetime of the short-lived neutral K meson. *Phys. Rev.* **171**, 1418-20 (1968).
- HILL, D.G., ROBINSON, D.K., SAKITT, M., SKJEGGESTAD, O., CANTER, J., CHO, Y., DRALLE, A., FISK, H.E., ENGLER, A., KRAEMER, R.W., AND MELTZER, C.M. Measurement of the $K^0 - K^+$ mass difference. *Ibid.* **168**, 1534-6.
- HILL, D.G., SAKITT, M., SKJEGGESTAD, O., CANTER, J., DRALLE, A., ENGLER, A., FISK, H.E., KRAEMER, R.W., MELTZER, C.M., KIKUCHI, T., ROBINSON, D.K., AND TILGER, C.A. Test of the $\Delta S = \Delta Q$ rule in leptonic decays of neutral K mesons. (A) In *Proc. 14th Int. Conf. High Energy Physics, Vienna, Aug. 1968* (in press).
- HILL, D.G. - See also RAY, A.K.
- HORNOSTEL, J. - See WANG, L.C.
- HOUGH, P.V.C. - See BELL, R.B.; CNOPS, A.M.; CONNOLLY, P.L.; KALBFLEISCH, G.R.; PANVINI, R.S.
- HUSON, F.R. Coherent production of $K^-\pi^+\pi^-$ on neon. (A) *Bull. Amer. Phys. Soc.* **13**, 683 (1968).
- HUSON, F.R., MILLER, D. J., AND O'NEALL, J.S. Coherent production on $N^*(1238)^{++}\pi^-$ by 28-GeV protons in a neon-hydrogen bubble chamber. (A) In *Proc. 14th Int. Conf. High Energy Physics, Vienna, Aug. 1968* (in press).
- HUSON, F.R. - See also CNOPS, A.M.; MILLER, D. J.
- IGO, G. J., FRIEDES, J.L., PALEVSKY, H., SUTTER, R. J., BENNETT, G.W., SIMPSON, W.D., CORLEY, D.M., AND STEARNS, R.L. One-BeV proton total and scattering cross section measurements on H, He, 6Li , C, O, and Pb targets. *Nucl. Phys.* **B3**, 181 (1967).
- IGO, G. J. - See also FRIEDES, J.L.; SIMPSON, W.D.; SUTTER, R. J.
- JAEGER, K. - See BARNES, V.E.; PRIMER, M.
- JENKINS, E.W. - See GALBRAITH, W.
- JOHNSON, R.A. Calculations for the stability of voids, stacking-fault tetrahedra, and dislocation loops in nickel. *Phil. Mag.* **16**, 553-64 (1967).
- JOHNSON, R.A. Computer studies of vacancy annealing in metals. (A) *Bull. Amer. Phys. Soc.* **13**, 419 (1968).
- JOHNSON, R.A. Kinetic study of vacancy clustering and annealing in metals. *Phys. Rev.* (in press).

- JONES, K.W. - See CHASMAN, C.; FOSSAN, D.B.; KRANER, H.W. (Instr. and Health Physics); McDONALD, W. J.
- JONES, R.S. - See FOLEY, K. J.
- KALBFLEISCH, G.R., HERTZBACH, S.S., HOUGH, P.V.C., STRAND, R.C., THORNDIKE, A.M., AND VANDERBURG, V. Topological cross-sections for 1.12-1.51-BeV/c pp interactions. (A) *Bull. Amer. Phys. Soc.* **12**, 1134 (1967).
- KALBFLEISCH, G.R. - See also BARNES, V.E.; BASSANO, D.; GORDON, D.
- KANE, W.R. AND MARISCOTTI, M.A. J. An empirical method for determining the relative efficiency of a Ge(Li) gamma-ray detector. *Nucl. Instr. Methods* **56**, 189-96 (1967).
- KANE, W.R. - See also MARISCOTTI, M.A. J.; SCHULT, O.W.B.
- KARSHON, U. - See BELL, R.B.; CRENNELL, D. J.
- KASSNER, D.A. 14-Foot bubble chamber research and development program: Mechanical design of magnet coils. In *Proc. Int. Colloq. Bubble Chambers, Heidelberg, West Germany, April 1967*, CERN-67-26, Vol. 2, pp. 435-56, H. Leutz, Editor, CERN, Geneva, Aug. 1967.
- KATZ, L.E., HERMAN, H., AND DAMASK, A.C. Precipitation in neutron-irradiated Al-base Cu. *Acta Met.* **16**, 939-45 (1968).
- KEATING, D.T. Scattering of x-rays by structures containing a random distribution of defects. *J. Phys. Chem. Solids* **29**, 771-84 (1968).
- KEATING, D.T. Theory and measurement of the x-ray satellite reflections in holmium due to the aspherical 4-f charge density. Submitted to *Phys. Rev.*
- KEATING, D.T. AND GOLAND, A.N. Atomic displacements around dislocation loops. (A) Presented at Int. Conf. Vacancies and Interstitials in Metals, Julich, West Germany, Sept. 1968.
- KEATING, D.T. AND GOLAND, A.N. Atomic displacements in iron martensite. *Acta Met.* **15**, 1805-14 (1967).
- KEATING, D.T. AND GOLAND, A.N. Diffuse scattering of x-rays from Fe-C martensite and from ferrite. (A) *Bull. Amer. Phys. Soc.* **13**, 491 (1968).
- KEATING, D.T. - See also GOLAND, A.N.; MOZER, B.
- KEMMEY, P. J., MATTERN, P.L., AND BARTRAM, R.H. Ground-state wavefunctions for the N_3^- ion. (A) *Bull. Amer. Phys. Soc.* **13**, 373 (1968).
- KENYON, I.R. Impulse-model calculations of the Σ -hyperon conversion process in light nuclei. *Nuovo Cimento* **55B**, 371-403 (1968).
- KENYON, I.R. - See also CNOPS, A.M.; CONNOLLY, P.L.; MILLER, D. J.
- KESTIGIAN, M. - See WANG, F.F.Y.
- KIKUCHI, T. - See HILL, D.G.
- KISTNER, O.C. Mössbauer effect in Ru^{99} . In *Mössbauer Effect Methodology (Proc. 3rd Annu. Symp., New York, Jan. 1967)*, Vol. 3, pp. 217-30, I. J. Gruverman, Editor, Plenum Press, New York, 1967.
- KISTNER, O.C. Symmetry tests with the Mössbauer effect. In *Hyperfine Structure and Nuclear Radiations (Proc. Int. Conf., Pacific Grove, Calif., Aug. 1967)*, pp. 295-313, E. Matthias and D.A. Shirley, Editors, North-Holland, Amsterdam, 1968.
- KISTNER, O.C. Test for time-reversal invariance of the electromagnetic interaction using the Mössbauer effect in Ru^{99} . (L) *Phys. Rev. Letters* **19**, 872-7 (1967).
- KISTNER, O.C. - See also BLUME, M.
- KITCHENS, T.A. Molecular field calculation. Informal Report BNL 12468.
- KITCHENS, T.A. Properties of magnetically dilute alloys. In *Digest of Magnetic Materials*, 1968 edition (in press).
- KITCHENS, T.A., MINKIEWICZ, V. J., LIPSCHULTZ, F.P., SHIRANE, G., AND NATHANS, R. The phonon dispersion relation for hcp He^4 with a molar volume of 21.1 cm³. In *Proc. 11th Int. Conf. Low Temperature Physics, St. Andrews, Scotland, Aug. 1968* (in press).
- KITCHENS, T.A. AND TROUSDALE, W.L. Dependence of position of resistivity minimum in FeCu alloys on sample size. (A) *Bull. Amer. Phys. Soc.* **13**, 124 (1968).
- KITCHENS, T.A. AND TROUSDALE, W.L. Magnetization distribution in diluted systems. (A) *J. Appl. Phys.* **39**, 1321 (1968).
- KITCHENS, T.A. AND TROUSDALE, W.L. Magnetization distribution in magnetically diluted systems with application to iron-palladium. Submitted to *Phys. Rev.*
- KITCHENS, T.A. - See also BERTMAN, B.; CRAIG, P.P.; LIPSCHULTZ, F.P.; MINKIEWICZ, V. J.
- KOEHLER, J. - See GORDON, D.; MAYNARD, J. (Accelerator).
- KRAEMER, R.W. - See HILL, D.G.; RAY, A.K.
- KYCIA, T.F. - See ABRAMS, R. J.; GALBRAITH, W.; GIACOMELLI, G.
- LAI, K.W. Experimental review of meson resonances decaying into $(K\bar{K})$ states. In *Proc. Informal Meet. Experimental Meson Spectroscopy, Philadelphia, April 1968* (in press).
- LAI, K.W. - See also BELL, R.B.; CRENNELL, D. J.
- LARSON, J.D. AND BENJAMIN, J.A. Ungridded electrostatic mirror. (N) *Rev. Sci. Instr.* **39**, 272-3 (1968).
- LAUTRUP, B.E. AND DE RAFAEL, E. Calculation of the 6th-order contribution from the 4th-order vacuum polarization to the difference of the anomalous magnetic moment of muon and electron. Submitted to *Phys. Rev.*
- LEA, A.T., MARTIN, B.R., AND OADES, G.C. K^+p phase-shift analysis below 1500 MeV/c. *Phys. Rev.* **165**, 1770-86 (1968).
- LEA, R.M. - See BELL, R.B.; CRENNELL, D. J.
- LEAKE, J.A., SHIRANE, G., AND REMEIK, J.P. The magnetic structure of thulium orthoferrite, $TmFeO_3$. *Solid State Commun.* **6**, 15-17 (1968).
- LEAKE, J.A. - See also DANIELS, W.B.
- LEE, H. J. Effects of the charge density fluctuations on the state for electrons in a metal in a uniform magnetic field. (A) *Bull. Amer. Phys. Soc.* **13**, 91-2 (1968).
- LEE, L.L. JR., OLNESS, J.W., AND SIEMSEN, R.H. Excitation functions for the reactions $B^{11}(d,p_0)B^{12}$ and $B^{11}(d,n\gamma)C^{12}_{15.1}$. (A) *Ibid.* **12**, 1197 (1967).
- LEIBFRIED, G. - See DATZ, S.
- LEITNER, J. - See ALITTI, J.; BARNES, V.E.; BASSANO, D.; PALMER, R.B.; PRIMER, M.
- LEMONS, A.M. - See STAUBER, M.C.
- LEONTIC, B.A. A corrected optical system for wide-angle Cerenkov light. *Nucl. Instr. Methods* **56**, 32-44 (1967).
- LEONTIC, B.A. - See also ABRAMS, R. J.; GALBRAITH, W.
- LEVY, P.W. A brief survey of radiation effects applicable to geology problems. In *Proc. Conf. USAF-NATO Conf. Applications of Thermoluminescence to Geological Problems, Spoleto, Italy, Sept. 1966*, p. 25, A. J. McDougall, Editor, Academic, London, 1968.

- LEVY, P.W. Physical properties of irradiated ceramic materials. In *Proc. Symp. Radiation Effects in Ceramic Materials, Washington, D.C., May 1966, Nat. Bur. Std. U.S. Misc. Publ. 285*, pp. 21-32.
- LEVY, P.W. AND HERLEY, P. J. Electronic mechanisms in solid state photolysis. In *Proc. Int. Symp. Kinetics of Reactions in Ionic Systems, Alfred, N.Y., June 1967* (in press).
- LEVY, P.W. AND HERLEY, P. J. A solid-state approach to photolytic decomposition. (A) In *Proc. 6th Int. Symp. Reactivity of Solids, Schenectady, N.Y., Aug. 1968* (in press).
- LEVY, P.W. - See also ALVAREZ-RIVAS, J.L.; BUTTERWORTH, J.S.; ESSER, P.; HERLEY, P. J.
- LI, K.K. - See ABRAMS, R.J.; GIACOMELLI, G.
- LINDENBAUM, S. J. Forward dispersion relations. Their validity and predictions. In *Proc. Conf. πN Scattering, Irvine, Calif., Dec. 1967, Wiley, New York* (in press).
- LINDENBAUM, S. J. Some new detector systems. In *Proc. Informal Meet. Meson Spectroscopy, Philadelphia, April 1968* (in press).
- LINDENBAUM, S. J. - See also FOLEY, K. J.
- LINZ, A. - See YAMADA, Y.
- LIPSCHULTZ, F.P., MINKIEWICZ, V. J., KITCHENS, T.A., SHIRANE, G., AND NATHANS, R. Phonon dispersion measurements on a hcp He^4 single crystal at 27 atm. (L) *Phys. Rev. Letters* **19**, 1307-9 (1967).
- LIPSCHULTZ, F.P. - See also KITCHENS, T.A.; MINKIEWICZ, V. J.
- LIPWORTH, E. - See COHEN, V.W.
- LONDON, G. - See BARNES, V.E.
- LONE, M.A., CHRIEN, R.E., WASSON, O.A., BEER, M., BHAT, M.R., AND MUETHER, H.R. Resonant and non-resonant capture of slow neutrons in $\text{Tm}^{169}(n,\gamma)\text{Tm}^{170}$. *Phys. Rev.* (in press).
- LONE, M.A., CHRIEN, R.E., WASSON, O.A., BHAT, M.R., MUETHER, H.R., AND BEER, M. Resonant and non-resonant neutron capture in $\text{Tm}^{169}(n,\gamma)\text{Tm}^{170}$. (A) *Bull. Amer. Phys. Soc.* **12**, 1200 (1967).
- LONE, M.A. - See also BEER, M.; BHAT, M.R. (Nuclear Engineering); CHRIEN, R.E.; WASSON, O.A.
- LOUTTIT, R.I. 14-Foot bubble chamber research and development program: Overall plan and optics details. In *Proc. Int. Colloq. Bubble Chambers, Heidelberg, West Germany, April 1967, CERN 67-26, Vol. 1*, pp. 167-80, H. Leutz, Editor, CERN, Geneva, Aug. 1967.
- LOVE, W.A. - See FOLEY, K. J.
- LOWE, J., ALBURGER, D.E., AND WILKINSON, D.H. Branching-ratio measurements on the 6.92- and 7.12-MeV states in O^{16} . *Phys. Rev.* **163**, 1060-5 (1967).
- LOWE, J. - See also WILKINSON, D.H.
- LUERS, D. - See BARNES, V.E.
- LUTZ, H.O. - See DATZ, S.
- MARISCOTTI, M.A. J. PULCAL: A computer program to obtain peak energies from channel numbers when a precision pulser has been employed to correct for non-linearity. Informal Report BNL 12622.
- MARISCOTTI, M.A. J., GELLETLY, W., MORAGUES, J.A., AND KANE, W.R. The $\text{Ba}^{137}(n,\gamma)$ reaction and level structure of Ba^{138} . *Phys. Rev.* (in press).
- MARISCOTTI, M.A. J., GELLETLY, W., MORAGUES, J.A., AND KANE, W.R. Level structure of ^{138}Ba from the $^{137}\text{Ba}(n,\gamma)$ reaction. (A) *Bull. Amer. Phys. Soc.* **13**, 721 (1968).
- MARISCOTTI, M.A. J. - See also KANE, W.R.; SCHULT, O.W.B.
- MARTIN, A. Analytic properties of scattering amplitudes from field theory and unitarity. Presented at Rochester High Energy Conf., Rochester, N.Y., Aug. 1967.
- MARTIN, B.R. Basic statistics for physicists. Informal Report BNL 12602.
- MARTIN, B.R. Semiphenomenological calculation of low-energy s -wave πN scattering. *Phys. Rev.* **162**, 1448-53 (1967).
- MARTIN, B.R. s -Wave K^+p dynamics. Submitted to *Phys. Rev.*
- MARTIN, B.R. AND DE RAFAEL, E. Phenomenological analysis of $K \rightarrow \pi\pi(I=2)$ amplitudes and violation of CP invariance. *Phys. Rev.* **162**, 1453-62 (1967).
- MARTIN, B.R. AND DE RAFAEL, E. Phenomenological description of $K_S \rightarrow 2\gamma$ and $K_L \rightarrow 2\gamma$ decays. Submitted to *Nucl. Phys.*
- MARTIN, B.R. - See also LEA, A.T.
- MATTERN, P.L. AND BLUM, H. Temperature dependence of the EPR line width of CO_2^- molecules in calcite. (A) *Bull. Amer. Phys. Soc.* **13**, 459 (1968).
- MATTERN, P.L. - See also BLUM, H.; KEMMEY, P. J.
- MAXWELL, E., STRONGIN, M., AND REED, T.B. Isotope effect in superconducting rhenium. *Phys. Rev.* **166**, 457-8 (1968).
- MCALISTER, A. J. - See CUTHILL, J.R.
- MCCULLOCH, R.D. - See CNOPS, A.M.
- MCDONALD, R.E. - See CHASE, L.F. JR.
- MCDONALD, W. J., SAMPLE, J.T., SHEPPARD, D.M., STINSON, G.M., AND JONES, K.W. Energy levels of ^{48}Sc . *Phys. Rev.* **171**, 1254-7 (1968).
- MCGRORY, J.B. - See ZUKER, A.P.
- MCKEOWN, M. - See SCHRODER, I.G.; SUNYAR, A.W.
- MCMAHON, T. J. - See ANDERSON, E.W.
- MEADOWS, B. - See BARNES, V.E.
- MEBS, R.W. - See BENNETT, L.H.
- MEISTER, H. Special arrangements of rotating crystal spectrometers for large energy gain and quasi-elastic neutron scattering experiments. (A) *Bull. Amer. Phys. Soc.* **13**, 127 (1968).
- MELTZER, C.M. - See HILL, D.G.
- MENES, J. - See ANDERSON, E.W.
- MENZINGER, F., CAGLIOTI, G., SHIRANE, G., NATHANS, R., PICKART, S. J., AND ALPERIN, H.A. Spin-wave dispersion relation in Fe-Ni alloys. *J. Appl. Phys.* **39**, 455-7 (1968).
- MENZINGER, F. - See also NATHANS, R.
- METZGER, W. J. - See ALITTI, J.; BARNES, V.E.; CRENNELL, D. J.
- MICHAEL, D.N. - See ABRAMS, R. J.
- MIKSIC, M.G., MILLER, M.D., AND COX, D.E. A neutron diffraction study of the system $\text{Fe}_2\text{TiO}_5 - \text{FeTi}_2\text{O}_5$. (A) In *Proc. Int. Conf. Magnetic Oxides, Bucharest, Sept. 1968* (in press).
- MILLER, D. J., HUSON, F.R., KENYON, I.R., AND O'NEALL, J.S. Coherent excitation of 28-GeV/c protons in collision with neon nuclei. (A) *Bull. Amer. Phys. Soc.* **13**, 683 (1968).
- MILLER, D. J. - See also BERGER, E.L.; CONNOLLY, P.L.; ELLIS, W.E.; HUSON, F.R.; PANVINI, R.D.
- MILLER, M.D. - See MIKSIC, M.G.

- MINKIEWICZ, V.J., KITCHENS, T.A., LIPSCHULTZ, F.P., NATHANS, R., AND SHIRANE, G. Phonon dispersion measurements on hcp He⁴. (A) *Bull. Amer. Phys. Soc.* **13**, 506 (1968).
- MINKIEWICZ, V.J., KITCHENS, T.A., LIPSCHULTZ, F.P., NATHANS, R., AND SHIRANE, G. The phonon spectrum of hcp He⁴. *Phys. Rev.* (in press).
- MINKIEWICZ, V.J., SHIRANE, G., FRAZER, B.C., WHEELER, R.G., AND DORAIN, P.B. Neutron diffraction study of magnetic ordering in K₂IrCl₆, K₂ReBr₆ and K₂ReCl₆. *J. Phys. Chem. Solids* **29**, 881-4 (1968).
- MINKIEWICZ, V.J., SHIRANE, G., AND NATHANS, R. Phonon dispersion relation for iron. *Phys. Rev.* **162**, 528-31 (1967).
- MINKIEWICZ, V.J. - See also KITCHENS, T.A.; LIPSCHULTZ, F.P.; SHIRANE, G.
- MONTWILL, A.W. - See BELL, R.B.; CRENNELL, D.J.
- MORAGUES, J.A. - See MARISCOTTI, M.A.J.; THIEBERGER, P.
- MORRIS, T.W. - See BERGER, E.L.; CONNOLLY, P.L.; ELLIS, W.E.; PANVINI, R.D.
- MORRISON, D.R.O. Pomeranchukon exchange in inelastic two-body reactions. *Phys. Rev.* **165**, 1699-702 (1968).
- MOSS, S.C. - See MOZER, B.
- MOZER, B. Impurity modes of vibration in vanadium based alloys. (A) In *Localized Excitations in Solids (Proc. Int. Conf., Irvine, Calif., Sept. 1967)*, pp. 737-44, Plenum Press, New York, 1968.
- MOZER, B., KEATING, D.T., AND MOSS, S.C. Neutron measurement of clustering in the alloy CuNi. Submitted to *Phys. Rev.*; (A) *Bull. Amer. Phys. Soc.* **13**, 468 (1968).
- MUCCI, J. - See ANDERSON, E.W.
- MUELLER, A.H. 0(4), Off-shell $N\bar{N}$ scattering, and massless pions. *Phys. Rev.* (in press).
- MUETHER, H.R. - See ANDRUS, W.S.; BEER, M.; LONE, M.A.
- NATHANS, R. Spin densities. In *Proc. Amer. Cryst. Ass. Meet., Atlanta, Jan. 1967*, Vol. 3, pp. 96-109, 1967.
- NATHANS, R., MENZINGER, F., AND PICKART, S.J. Inelastic magnetic scattering from RbMnF₃ in the neighborhood of its Néel point. *J. Appl. Phys.* **39**, 1237-8 (1968).
- NATHANS, R. - See also COHEN, V.W.; COLLINS, M.F.; COOPER, M.J.; KITCHENS, T.A.; LIPSCHULTZ, F.P.; MENZINGER, F.; MINKIEWICZ, V.J.; NORVELL, J.C. (Chemistry); SHIRANE, G.; SHULL, C.G.
- NOWICK, A.S. AND DIENES, G. J. On the inherent curvature of the Arrhenius plot in diffusion experiments. *Phys. Status Solidi* **24**, 461-7 (1967).
- NUSSBAUM, M.M. - See CNOPS, A.M.
- OADES, G.C. - See LEA, A.T.
- OEHME, R. Superconvergent dispersion relations. *Ann. Phys. N.Y.* **46**, 347 (1968).
- OLNESS, J.W. Gamma-ray spectroscopy in light nuclei: Na²², an example. In *Proc. 3rd Int. Symp. Structure of Low-Medium Mass Nuclei, Lawrence, Kans., April 1968* (in press).
- OLNESS, J.W. AND WARBURTON, E.K. Gamma-ray decay of the bound levels of B¹². *Phys. Rev.* **166**, 1004-11 (1968).
- OLNESS, J.W. - See also LEE, L.L. JR.; PAUL, P.; POLETTI, A.R.; WARBURTON, E.K.
- OMNES, R. A scattering approach to the N -body problem. *Phys. Rev.* **165**, 1265 (1968).
- O'NEALL, J.S. - See CRENNELL, D.J.; HUSON, F.R.; MILLER, D.J.
- OOSTENS, J., PRUNSTER, S., WANG, C.L., AND YUAN, L.C.L. Transition radiation from relativistic charged particles and its energy dependence. (L) *Phys. Rev. Letters* **19**, 541-3 (1967).
- OREAR, J. - See ASHMORE, A.
- OUANNES, C. - See CONNOLLY, P.L.
- OWEN, D.P. - See ASHMORE, A.
- OZAKI, S. - See FOLEY, K.J.
- PAIS, A. Low-energy theorems for spin $S \geq 1$. (L) *Phys. Rev. Letters* **19**, 544-6 (1967).
- PALEVSKY, H. Experimental work using protons. In *Proc. Symp. Use of NIMROD for Nuclear Structure Physics, Rutherford High Energy Laboratory, Chilton, England, March 1968* (in press).
- PALEVSKY, H. Nuclear structure results derived from interactions of protons in the GeV region. In *High Energy Physics and Nuclear Structure*, pp. 151-70, G. Alexander, Editor, North-Holland, Amsterdam, 1967.
- PALEVSKY, H. - See also ANDRUS, W.S.; FRIEDES, J.L.; IGO, G. J.; SIMPSON, W.D.; SUTTER, R. J.
- PALMER, R.B., RADOJICIC, D., RAU, R.R., RICHARDSON, C.R., SAMIOS, N.P., SKILLICORN, I.O., AND LEITNER, J. Precision measurement of the Ω^- and Ξ^0 masses. (L) *Phys. Letters* **26B**, 323-6 (1968).
- PALMER, R.B. - See also BARNES, V.E.
- PANVINI, R.S., MORRIS, T.W., MILLER, D.J., HOUGH, P.V.C., ELLIS, W.E., AND CONNOLLY, P.L. Isobar production in peripheral p - p interactions at 28.5 GeV/c. (A) *Bull. Amer. Phys. Soc.* **12**, 1135 (1967).
- PANVINI, R.S. - See also BERGER, E.L.; CONNOLLY, P.L.; ELLIS, W.E.
- PARKS, D. - See GARBER, D.I.
- PASSELL, L. - See COLLINS, M.F.; SCHERMER, R.I.
- PAUL, P., OLNESS, J.W., AND WARBURTON, E.K. Nuclear structure of Na²². V. Doppler shift attenuation measurements. *Phys. Rev.* (in press).
- PEIERLS, R.F. - See BRAYSHAW, D.; STERNHEIMER, R.M.
- PERSSON, R. - See SUTTER, R. J.
- PERTILE, G. - See BASSANO, D.
- PETERSON, F.C. - See ASHMORE, A.
- PHILLIPS, G.C. - See FRIEDES, J.L.; SIMPSON, W.D.; SUTTER, R. J.
- PHILLIPS, R.H. - See GALBRAITH, W.
- PICKART, S.J. Spiral magnetic structure in dysprosium hydride. (A) *Bull. Amer. Phys. Soc.* **13**, 573 (1968).
- PICKART, S.J. AND ALPERIN, H.A. Magnetic structure of EuSe. *J. Phys. Chem. Solids* **29**, 414-6 (1968).
- PICKART, S.J. AND ALPERIN, H.A. Magnetic structure of RbNiF₃. (A) *J. Appl. Phys.* **39**, 1332 (1968).
- PICKART, S.J. - See also MENZINGER, F.; NATHANS, R.
- PIETENPOL, J.L. A simple soluble model for the decay of an unstable state. *Phys. Rev.* **162**, 1301-5 (1967).
- PLATNER, E.D. - See FOLEY, K.J.
- POLETTI, A.R., WARBURTON, E.K., AND OLNESS, J.W. Nuclear structure of Na²². III. Spins and parities from the linear polarization of gamma rays. *Phys. Rev.* **164**, 1479-84 (1967).
- POLETTI, A.R., WARBURTON, E.K., OLNESS, J.W., AND HECHTL, S. Nuclear structure of Na²². II. Some gamma-ray Doppler-shift and correlation measurements. *Phys. Rev.* **162**, 1040-7 (1967).

- POLETTI, A.R. - See also FOSSAN, D.B.; WARBURTON, E.K.
 PRICE, D.L. - See CHRIEN, R.E.
 PRIMER, M., GOLDBERG, M., JAEGER, K., BARNES, V.E.,
 DORNAN, P.J., SKILLICORN, I.O., AND LEITNER, J.
 Study of $\gamma_1^*(1660)$ and $\gamma_1^*(1695)$ production in K^-p
 interactions. (L) *Phys. Rev. Letters* **20**, 610-14 (1968).
 PRIMER, M. - See also BARNES, V.E.
 PRODELL, A. - See GORDON, D.
 PRUNSTER, S. - See OOSTENS, J.
 QUARLES, C.A. - See FOLEY, K.J.
 QURESHI, H.M. - See AUERBACH, E.H.
 RADOJICIC, D. - See ALITTI, J.; PALMER, R.B.
 RAHM, D.C. - See YAMAMOTO, S.S.
 RAMSEY, N. - See COHEN, V.W.
 RAU, R.R. - See ALITTI, J.; BARNES, V.E.; PALMER, R.B.
 RAWITSCHER, G.H. Effect of stripping channels upon the
 elastic scattering of deuterons for the nucleus of cal-
 cium. *Phys. Rev.* **163**, 1223-38 (1967).
 RAY, A.K., BURRIS, R.W., FISK, H.E., KRAEMER, R.W.,
 HILL, D.G., AND SAKITT, M. Resolution of the Fermi-
 Yang ambiguity in K^+ nucleon scattering. Informal
 Report BNL 12462.
 READ, A.L. - See ASHMORE, A.; GALBRAITH, W.
 REED, T.B. - See MAXWELL, E.
 REMEIK, J.P. - See LEAKE, J.A.
 REYNOLDS, C.A. - See SCHERMER, R.I.
 RICHARDSON, C.R. - See ALITTI, J.; PALMER, R.B.
 RIMAWI, K., GARG, J.B., AND CHRIEN, R.E. States in
 Rh^{104} from resonance neutron capture in Rh^{103} . (A)
Bull. Amer. Phys. Soc. **13**, 120 (1968).
 RINGEL, H., DAMASK, A.C., AND ARNDT, R.A. The heat
 capacity anomaly in phenanthrene; Effects of deuter-
 ation, purification and dissolution. *Mol. Cryst.* **3**, 145-7
 (1967).
 RISTINEN, R.A. - See CHASMAN, C.
 ROBINSON, D.K. - See HILL, D.G.
 ROGERS, P.C. The data acquisition and analysis complex
 for the BNL low-energy accelerator facility. (A) Pre-
 sented at 15th Symp. Nuclear Science, Montreal, Oct.
 1968.
 ROGERS, P.C. Inexpensive three-color computer display
 based on a standard TV tube. (A) *Bull. Amer. Phys. Soc.*
13, 701 (1968).
 ROGERS, P.C. - See also SCHWENDER, G.E.; WEGNER, H.E.
 RORER, D.C. - See SCHERMER, R.I.
 ROSE, H.J., HAUSSE, O., AND WARBURTON, E.K. Evi-
 dence for a nuclear tensor force from mass 14 beta and
 gamma ray data. *Rev. Mod. Phys.* (in press).
 RUBINSTEIN, R. - See ASHMORE, A.; GALBRAITH, W.
 RUSS, J. - See ANDERSON, E.W.
 RYAN, D.G. - See ASHMORE, A.
 SABINE, T.M., COX, G.W., AND CRAVEN, B.M. A neutron
 diffraction study of α -oxalic acid dihydrate. Submitted
 to *Acta Cryst.*
 SABINE, T.M. - See also COPPENS, P. (Chemistry).
 SAILOR, V.L. Neutron spectrometry. In *McGraw-Hill En-
 cyclopedia of Science and Technology*, McGraw-Hill, New
 York (in press).
 SAILOR, V.L. - See also SCHERMER, R.I.
 SAKITT, M. - See HILL, D.G.; RAY, A.K.
 SAMIOS, N.P. - See ALITTI, J.; BARNES, V.E.; BASSANO,
 D.; PALMER, R.B.
 SAMPLE, J.T. - See McDONALD, W.J.
 SCARR, J.M. - See BELL, R.B.; CNOPS, A.M.; CRENNELL,
 D.J.
 SCHARFF-GOLDHABER, G. Properties of nuclei in the tran-
 sition region. In *Proc. Int. Conf. Nuclear Structure, Tokyo,
 Sept. 1967*, *J. Phys. Soc. Japan* **24**, Suppl., pp. 150-9
 (1968).
 SCHARFF-GOLDHABER, G. - See also SCHROEDER, I.G.;
 SUNYAR, A.W.
 SCHERMER, R.I. AND BLUME, M. Polarization effects in
 slow-neutron scattering. III. Nuclear polarization. *Phys.
 Rev.* **166**, 554-61 (1968).
 SCHERMER, R.I., PASSELL, L., BRUNHART, G., REYNOLDS,
 C.A., SAILOR, V.L., AND SHORE, F.J. The spin depen-
 dence of the U^{235} low-energy neutron cross section. *Ibid.*
167, 1121-30.
 SCHERMER, R.I., PASSELL, L., AND RORER, D.C. Phase
 separation in $\text{He}^3\text{-He}^4$ mixtures observed with slow
 neutrons. *Ibid.* (in press).
 SCHROEDER, I.G., McKEOWN, M., AND SCHARFF-GOLD-
 HABER, G. Mass difference of K^{40} and Ar^{40} . *Ibid.* **165**,
 1184-9 (1968).
 SCHULT, O.W.B., KANE, W.R., AND DER MATEOSIAN, E.
 The decay of Au^{200} (48 min). *Ibid.* **170**, 1055-8.
 SCHULT, O.W.B., KANE, W.R., MARISCOTTI, M.A.J., AND
 SIMIC, J.M. Gamma rays from the $\text{Hg}^{199}(n,\gamma)\text{Hg}^{200}$
 reaction and energy levels in Hg^{200} . *Ibid.* **164**, 1548-58
 (1967).
 SCHUMANN, T.G. - See BELL, R.B.; CRENNELL, D.J.
 SCHWARTZSCHILD, A.Z. AND WARBURTON, E.K. The mea-
 surement of short nuclear lifetimes. In *Annu. Rev. Nucl.
 Sci.* (in press).
 SCHWENDER, G.E. AND ROGERS, P.C. The data collection
 interface used by the BNL data acquisition and anal-
 ysis complex. (A) Presented at 15th Symp. Nuclear Sci-
 ence, Montreal, Oct. 1968.
 SHEPPARD, D.M. - See McDONALD, W.J.
 SHIRANE, G., MINKIEWICZ, V.J., AND NATHANS, R. Spin
 waves in 3d metals. *J. Appl. Phys.* **39**, 383-90 (1968).
 SHIRANE, G. - See also COLLINS, M.F.; DANIELS, W.B.;
 KITCHENS, T.A.; LEAKE, J.A.; LIPSCHULTZ, F.P.;
 MENZINGER, F.; MINKIEWICZ, V.J.; UMEBAYASHI, H.;
 YAMADA, Y.
 SHORE, F.J. - See SCHERMER, R.I.
 SHULL, C.G. AND NATHANS, R. Search for a neutron elec-
 tric dipole moment by a scattering experiment. (L)
Phys. Rev. Letters **19**, 384-6 (1967).
 SIEMSEN, R.H. - See LEE, L.L. JR.
 SILSBEE, H.B. - See CHAN, Y.W.; COHEN, V.W.
 SIMIC, J.M. - See SCHULT, O.W.B.
 SIMPSON, W.D. Proton-nucleus scattering. Presented at
 Amer. Phys. Soc. Meet., Chicago, Jan. 1968.
 SIMPSON, W.D., PALVESKY, H., FRIEDES, J.L., BENNETT,
 G.W., SUTTER, R.J., GOTTSCHALK, B., IGO, G.J., PHIL-
 LIPS, G.C., CORLEY, D.M., WALL, N.S., AND STEARNS,
 R.L. ($p,2p$) Reactions at 1.0 GeV. (A) *Bull. Amer. Phys.
 Soc.* **13**, 632 (1968).
 SIMPSON, W.D. - See also FRIEDES, J.L.; IGO, G.J.;
 SUTTER, R.J.
 SKALYO, J. JR., COX, D.E., AND FRAZER, B.C. The mag-
 netic structure of $\text{CuCl}_2 \cdot 2\text{D}_2\text{O}$ above the critical field.
 (A) *Bull. Amer. Phys. Soc.* **13**, 461 (1968).

- SKALYO, J. JR. - See also DANIELS, W.B.
- SKILLICORN, I.O. The measurement of 6000 two-prong + V^0 events on the Mark II FSD. Informal Report BNL 11644.
- SKILLICORN, I.O. - See also ALITTI, J.; BARNES, V.E.; BASANO, D.; BELL, R.B.; CNOOPS, A.M.; CRENNELL, D.J.; PALMER, R.B.; PRIMER, M.
- SKJEGGESTAD, O. - See HILL, D.G.
- SMITH, R.C. - See WANG, L.C.
- SNEAD, C.L. JR. - See DiCARLO, J.A.
- SOKOLOFF, J.B. Polar spin waves in metals. (A) *Bull. Amer. Phys. Soc.* **13**, 385 (1968).
- SOKOLOFF, J.B. Polar spin waves in ferromagnetic metals. *Phys. Rev.* (in press).
- STAUBER, M.C., LEMOS, A.M., AND BURKE, E.A. Oscillator strength calculations for Tl^+ in KCl, KBr and NaCl. Submitted to *Phys. Rev.*
- STEARNS, R.L. - See FRIEDES, J.L.; IGO, G.J.; SIMPSON, W.D.; SUTTER, R.J.
- STERNHEIM, M.M. - See AUERBACH, E.H.
- STERNHEIMER, R.M. Density effect for the ionization loss of charged particles. II. *Phys. Rev.* **164**, 349-51 (1967).
- STERNHEIMER, R.M. Empirical mass relations for the hadronic particles. *Ibid.* **170**, 1267-71 (1968).
- STERNHEIMER, R.M. Quadrupole antishielding factors for ions and atomic states. *Int. J. Quantum Chem.* **1S**, 67-80 (1967).
- STERNHEIMER, R.M. Quadrupole shielding and antishielding factors for atomic states. *Phys. Rev.* **164**, 10-20 (1967).
- STERNHEIMER, R.M. Shielding and antishielding effects for the nuclear quadrupole moments of the copper isotopes. (A) Presented at Int. Conf. Atomic Physics, New York, June 1968.
- STERNHEIMER, R.M. Shielding of crystal fields at rare-earth ions. (A) *Bull. Amer. Phys. Soc.* **13**, 81 (1968).
- STERNHEIMER, R.M. Wave functions for crystal field calculations. Submitted to Amer. Doc. Inst. Auxiliary Publ. Proj., Library of Congress, Washington, D.C.; *Phys. Rev.* (in press).
- STERNHEIMER, R.M. Wave functions for quadrupole antishielding factors. Amer. Doc. Inst. Auxiliary Publ. Proj. Rpt. 9592, Library of Congress, Washington, D.C.
- STERNHEIMER, R.M. Wave functions for the electronic polarizabilities of the alkali atoms. Submitted to Amer. Doc. Inst. Auxiliary Publ. Proj., Library of Congress, Washington, D.C.; *Phys. Rev.* (in press).
- STERNHEIMER, R.M., BLUME, M., AND PEIERLS, R.F. Shielding of crystal fields at rare-earth ions. *Phys. Rev.* (in press).
- STINSON, G.M. - See McDONALD, W.J.
- STRAND, R.C. Computer-controlled precision digitizers for optical image data extraction. (A) Presented at NASA Conf. Photographic Astrometric Technique, Tampa, March 1968.
- STRAND, R.C. Man-machine cooperation in digital pattern recognition of bubble chamber tracks. In *Proc. Conf. Data Extraction and Processing of Optical Images in the Medical and Biological Sciences, New York, June 1967*, N.Y. Acad. Sci. (in press).
- STRAND, R.C. - See also BELL, R.B.; KALBFLEISCH, G.R.
- STRONGIN, M. AND KAMMERER, O.F. Superconductive phenomena in ultrathin films. *J. Appl. Phys.* **39**, 2509-14 (1968).
- STRONGIN, M., KAMMERER, O.F., AND CROW, J.E. Effect of monolayer coatings on the T_c of superconducting films. (A) *Bull. Amer. Phys. Soc.* **13**, 426 (1968).
- STRONGIN, M., KAMMERER, O.F., CROW, J.E., AND FINE, H.L. "Curie-Weiss" behavior and fluctuation phenomena in the relativistic transitions of dirty superconductors. (L) *Phys. Rev. Letters* **20**, 922-5 (1968).
- STRONGIN, M., KAMMERER, O.F., DOUGLASS, D.H. JR., MARCELJA, S., AND PARKS, R.D. Superconductive phenomena in ultrathin films prepared on cryogenic substrates. (A) *Bull. Amer. Phys. Soc.* **13**, 108 (1968).
- STRONGIN, M. - See also CROW, J.E.; MAXWELL, E.
- SUNYAR, A.W., SCHARFF-GOLDHABER, G., AND McKEOWN, M. High-speed isomer Ir^{194m_2} produced by triple neutron capture. (L) *Phys. Rev. Letters* **21**, 237-40 (1968).
- SUNYAR, A.W., SCHARFF-GOLDHABER, G., AND McKEOWN, M. Long-lived isomer of Ir^{194} . (A) *Bull. Amer. Phys. Soc.* **13**, 653 (1968).
- SUNYAR, A.W. - See also THIEBERGER, P.
- SUTTER, R.J., BENNETT, G., FISCHER, J., FRIEDES, J.L., PALEVSKY, H., PERSSON, R., IGO, G.J., AND SIMPSON, W.D. Low pressure spark chambers. High resolution spectrometer for 1-GeV protons. *Nucl. Instr. Methods* **54**, 71-6 (1967).
- SUTTER, R.J., FRIEDES, J.L., PALEVSKY, H., BENNETT, G. W., IGO, G.J., SIMPSON, W.D., PHILLIPS, G.C., CORLEY, D.M., WALL, N.S., AND STEARNS, R.L. Production of high-momentum deuterons from nuclei bombarded by 1-BeV protons. (L) *Phys. Rev. Letters* **19**, 1189-91 (1967).
- SUTTER, R.J. - See also FRIEDES, J.L.; IGO, G.J.; SIMPSON, W.D.
- SWARTZENDRUBER, L.J. - See BENNETT, L.H.
- TADIC, D. On the weak parity nonconserving potentials. Submitted to *Phys. Rev.*
- TAYLOR, R.D. AND CRAIG, P.P. Use of Mössbauer techniques to directly determine the zero point velocity of impurities: Calibration of the second-order Doppler shift. (A) To be presented at 5th Annu. Symp. Mössbauer Methodology, New York, Jan. 1969.
- TEIGER, J. - See GIACOMELLI, G.
- THIEBERGER, P., MORAGUES, J.A., AND SUNYAR, A.W. Time dependence of Mössbauer scattered radiation. *Phys. Rev.* **171**, 425-35 (1968).
- THORNDIKE, A.M. - See CONNOLLY, P.L.; CRENNELL, D.J.; KALBFLEISCH, G.R.
- TILGER, C.A. - See HILL, D.G.
- TJON, J.A. AND BLUME, M. Mössbauer spectra in a fluctuating environment. II. Randomly varying electric field gradients. *Phys. Rev.* **165**, 456-61 (1968).
- TJON, J.A. - See also BLUME, M.
- TOWNSEND, P.D. Measurements of charge trapping centers in geological specimens. In *Proc. USAF/NATO Conf. Application of Thermoluminescence to Geological Problems, Spoleto, Italy, Sept. 1966*, p. 51, O.J. McDougall, Editor, Academic, London, 1968.
- TRIFTSHAUSER, W. AND CRAIG, P.P. Time dependence of recoil-free resonance following electron capture in Co^{57} . *Phys. Rev.* **162**, 274-85 (1967).
- TROUSDALE, W.L. AND CRAIG, P.P. Limitation on relaxation rates of Fe^{57} in CoO . (L) *Phys. Letters* (in press).
- TROUSDALE, W.L. - See also KITCHENS, T.A.
- TRUE, W.W. - See CHASE, L.F. JR.

- TRUEMAN, T.L. Kinematic singularities and constraints of helicity amplitudes. *Phys. Rev.* (in press).
- TURKOT, F. Particle production in high energy proton-proton collisions. In *Proc. Topical Conf. High Energy Collisions of Hadrons, Geneva, Jan. 1968*, CERN 68-7, Vol. 1, pp. 316-44, CERN, Geneva, Feb. 1968.
- TURKOT, F. - See also ANDERSON, E.W.
- UMEBAYASHI, H., FRAZER, B.C., COX, D.E., AND SHIRANE, G. Spin-density distribution in $\text{CuCl}_2 \cdot 2\text{D}_2\text{O}$. *Phys. Rev.* **167**, 519-24 (1968).
- UMEBAYASHI, H., SHIRANE, G., FRAZER, B.C., AND DANIELS, W.B. Neutron diffraction study of Cr under high pressure. *J. Phys. Soc. Japan* **24**, 368-72 (1968).
- UMEBAYASHI, H., SHIRANE, G., FRAZER, B.C., AND DANIELS, W.B. Neutron diffraction study of Tb and Ho under high pressure. *Phys. Rev.* **165**, 688-92 (1968).
- VANDEBURG, V. - See GORDON, D.; KALBFLEISCH, G.R.
- VINEYARD, G.H., WATSON, R.E., AND BLUME, M. Computer calculations for the classical Heisenberg model: Magnetization and pair correlation functions. (A) *J. Appl. Phys.* **39**, 969 (1968).
- VINEYARD, G.H. - See also WATSON, R.E.
- WALL, N.S. - See FRIEDES, J.L.; SIMPSON, W.D.; SUTTER, R.J.
- WANG, C.L. - See OOSTENS, J.
- WANG, F.F.Y., COX, D.E., AND KESTIGIAN, M. Neutron diffraction study of RbFeF_3 . (A) *Bull. Amer. Phys. Soc.* **13**, 468 (1968).
- WANG, L.C., SMITH, R.C., WHATLEY, M.C., ZORN, G.T., AND HORNOSTEL, J. Wide gap spark chamber study of $K_L^0 \rightarrow \pi + e + \nu$. (A) *Ibid.* 871-2.
- WARBURTON, E.K. Electromagnetic lifetimes. In *Nuclear Research With Low-Energy Accelerators (Proc. Symp., College Park, Md., June 1967)*, pp. 43-74, Academic, New York, 1968.
- WARBURTON, E.K. Spin assignment for the F^{18} 1.131-MeV level. *Phys. Rev.* **163**, 1032-4 (1967).
- WARBURTON, E.K., HARRIS, W.R., AND ALBURGER, D.E. Beta decay of N^{16} to the 6.05-MeV state of O^{16} . Submitted to *Phys. Rev.*
- WARBURTON, E.K., OLNESS, J.W., BLOOM, S.D., AND POLETTI, A.R. E2 and M1 matrix elements in B^{10} . *Phys. Rev.* **171**, 1178-87 (1968).
- WARBURTON, E.K., POLETTI, A.R., AND OLNESS, J.W. Nuclear structure of Na^{22} . IV. Gamma-ray correlation measurements. *Ibid.* **168**, 1232-43.
- WARBURTON, E.K. - See also CHASE, L.F. Jr.; GALLMANN, A.; OLNESS, J.W.; PAUL, P.; POLETTI, A.R.; ROSE, H.J.; SCHWARZSCHILD, A.Z.
- WASSON, O.A., BHAT, M.R., CHRIEN, R.E., LONE, M.A., AND BEER, M. Low-energy neutron capture in gold. (A) *Bull. Amer. Phys. Soc.* **12**, 1199 (1967).
- WASSON, O.A., CHRIEN, R.E., BHAT, M.R., LONE, M.A., AND BEER, M. The $\text{Au}^{197}(n, \gamma)\text{Au}^{198}$ reaction mechanism. *Phys. Rev.* (in press).
- WASSON, O.A., GARG, J.B., CHRIEN, R.E., AND BHAT, M.R. Gamma rays following neutron capture in iron, sodium, and thorium. In *Proc. 2nd Conf. Neutron Cross Sections and Technology, Washington, D.C., March 1968* (in press).
- WASSON, O.A. - See also BEER, M.; BHAT, M.R. (Nuclear Engineering); CHRIEN, R.E.; GARBER, D.I.; LONE, M.A.; MUGHABGHAB, S.F. (Nuclear Engineering).
- WATSON, R.E., BAGUS, P., AND FREEMAN, A. J. Core polarization contributions to the magnetic hyperfine fields of rare-earth ions. (A) *Bull. Amer. Phys. Soc.* **13**, 482 (1968).
- WATSON, R.E., BENNETT, L.H., AND FREEMAN, A. J. Origin of solvent Knight shifts in alloys. (L) *Phys. Rev. Letters* **20**, 653-6 (1968).
- WATSON, R.E. AND BLUME, M. Crystal field splittings and first-order magnetic phase transitions. (A) *Int. J. Quantum Chem.* **1S**, 645 (1967).
- WATSON, R.E., BLUME, M., AND VINEYARD, G.H. Ordering in two-dimensional classical spin arrays. (A) In *Proc. 1967 Int. Congr. Magnetism, Boston, Sept. 1967* (in press).
- WATSON, R.E. AND FREEMAN, A. J. Local-moment-conduction-electron exchange coupling and $RKKY$ spin densities in metals. (A) *J. Appl. Phys.* **39**, 1100 (1968).
- WATSON, R.E., FREEMAN, A. J., AND DIMMOCK, J.O. Magnetic ordering and the electronic properties of the heavy rare-earth metals. *Phys. Rev.* **167**, 497-503 (1968).
- WATSON, R.E. - See also BENNETT, L.H.; CUTHILL, J.R.; VINEYARD, G.H.
- WEGNER, H.E. AND ROGERS, P.C. Inexpensive three-color computer display based on a standard TV tube. (A) Presented at 15th Symp. Nuclear Science, Montreal, Oct. 1968.
- WEGNER, H.E. - See also KRANER, H.W. (Instr. and Health Physics).
- WENESER, J. - See CHURCH, E.L.; GINOCCHIO, J.N.
- WHATLEY, M.C. - See WANG, L.C.
- WHEELER, R.G. - See MINKIEWICZ, V. J.
- WHITE, D.H. - See ASHMORE, A.
- WHITTEN, W.B., ARNDT, R.A., AND DAMASK, A.C. Triplet exciton decay in phenanthrene single crystals. Submitted to *Mol. Cryst.*
- WILKIN, C. High energy scattering from nuclei. Informal Report BNL 11722.
- WILKIN, C. - See also BASSEL, R.H.
- WILKINSON, D.H., ALBURGER, D.E., AND LOWE, J. Gamma-ray decay of the 6.92-, 7.12-, 8.88-, and 13.10-MeV states in O^{16} . *Phys. Rev.* (in press).
- WILKINSON, D.H. - See also LOWE, J.
- WILL, G. AND COX, D.E. An x-ray and neutron diffraction study of LaCrO_3 , LaFeO_3 , and LaMnO_3 . *Acta Cryst.* (in press).
- WILLEN, E.H. - See FOLEY, K. J.
- WILLIAMS, M.L. - See CUTHILL, J.R.
- WILLIAMS, T. - See COX, D.E.
- WILSON, W.D. Quadrupole coupling constants for Na^+ and Cl^- nuclei surrounding a Ag^+ substitutional defect in NaCl . (A) *Bull. Amer. Phys. Soc.* **13**, 500 (1968).
- WILSON, W.D. AND BLUME, M. Nuclear quadrupole resonance shifts of off-center ions in KCl . *J. Phys. Chem. Solids* (in press).
- WILSON, W.D. - See also BLUM, A.; FISCHER, C.R.
- YAMADA, Y., SHIRANE, G., AND LINZ, A. Critical fluctuations in BaTiO_3 . Submitted to *Phys. Rev.*; (A) *Bull. Amer. Phys. Soc.* **13**, 617 (1968).
- YAMADA, Y. - See also DANIELS, W.B.
- YAMAMOTO, S.S. AND RAHM, D.C. Two prong interactions by $\pi^+ + p$ collisions at 2.77 BeV/c. *Phys. Rev.* (in press).

YUAN, L.C.L. - See OOSTENS, J.

ZAMICK, L. $M1$ transitions in ^{43}Ca and ^{41}Ar . Informal Report BNL 11551.

ZORN, G.T. - See WANG, L.C.

ZUKER, A.P., BUCK, B., AND MCGRORY, J.B. Structure of O^{16} . (L) *Phys. Rev. Letters* **21**, 39-43 (1968).

Plant Engineering and Planning Division

AHLERS, G.K. AND WICHMAN, S.H. Nuclear reactor's cooling water is conserved by recharging at 15 mgd/acre. Submitted to *Water Works and Waste Eng.*

HENNESSY, J.J. Iron deposition and well fouling at Brookhaven National Laboratory. Presented at Winter Annu. Meet., ASME, New York, Dec. 1968.

WICHMAN, S.H. - See AHLERS, G.K.

Reactor Division

KINNE, G.C. AND TICHLER, P.R. Heat-exchanger tube vibration and repair in the High Flux Beam Reactor. *Trans. Amer. Nucl. Soc. Suppl.* **10**, 8-9 (1967).

POWELL, R.W. *Reactor Operations Monthly Reports* (For Internal Use Only):

July 1967	BNL 50067 (T-468)
Aug. 1967	BNL 50072 (T-470)
Sept. 1967	BNL 50076 (T-473)
Oct. 1967	BNL 50081 (T-476)
Nov. 1967	BNL 50086 (T-479)
Dec. 1967	BNL 50091 (T-481)
Jan. 1968	BNL 50095 (T-484)
Feb. 1968	BNL 50098 (T-485)
Mar. 1968	BNL 50105 (T-491)
Apr. 1968	BNL 50109 (T-492)
May 1968	BNL 50113 (T-495)
June 1968	BNL 50122 (T-500)

PROTTER, S.R. Water quality control in the HFBR. Informal Report BNL 11561.

TICHLER, P.R., BAKER, L., ISLER, R., AND METZ, D. Investigating committee report of the nitrate resin bed accident at the Brookhaven High Flux Beam Reactor. Informal Report BNL 12460.

TICHLER, P.R. - See also HILL, F.B. (Nuclear Engineering); KINNE, G.C.

Appendix B

OFFICERS AND SCIENTIFIC AND PROFESSIONAL STAFF

Maurice Goldhaber, *Director*
 George H. Vineyard, *Deputy Director*
 Victor P. Bond, *Associate Director*
 Rodney L. Cool, *Associate Director*
 R. Christian Anderson, *Assistant Director*
 William J. Catacosinos, *Assistant Director*
 G. Norris Glasoe, *Assistant Director*
 (retired December 31, 1967)
 Samuel M. Tucker, *Assistant Director*

G. Kenneth Green, *Chairman*, Accelerator Department
 Yoshio Shimamoto, *Chairman*, Applied Mathematics Department
 C.H.W. Hirs, *Chairman*, Biology Department
 Richard W. Dodson, *Chairman*, Chemistry Department
 Horner Kuper, *Chairman*, Instrumentation and Health Physics Department
 Eugene P. Cronkite, *Chairman*, Medical Department
 Warren E. Winsche, *Chairman*, Nuclear Engineering Department
 R. Ronald Rau, *Chairman*, Physics Department
 Irving J. Polk, *Head*, Mechanical Engineering Division
 Robert W. Powell, *Head*, Reactor Division

Vincent R. O'Leary, *Budget Officer*
 Lewis R. Burchill, *Controller*
 Dennis Puleston, *Information Officer*
 Charles F. Dunbar, *Legal Counsel*
 N. Peter Rathvon, Jr., *Associate Counsel*
 Joseph S. Washburne, *Personnel Manager*
 Maxwell M. Small, *Manager*, Plant Engineering and Planning
 Norbert J. Dernbach, *Public Relations Officer*
 Edward J. Burke, *Security Officer*

Accelerator Department

G. Kenneth Green, *Chairman*
 Roger R. Adams
 Christopher Agnitellis
 John C. Alderman*
 Theodore Alper
 Charles Ankenbrandt
 (postdoctoral appointment)
 David A. Barge
 Mark Q. Barton
 Kenneth Batchelor
 Gerald W. Bennett
 (on leave to
 Deutsches Elektronen-Synchrotron,
 Hamburg, West Germany)
 Arnold Benton

David Berley
 Richard A. Beth
 John W. Bittner
 John P. Blewett
 Leroy N. Blumberg
 Richard B. Britton
 Hugh N. Brown
 Theodore Carides
 Alberto G. Carlucci*
 Charles A. Casey
 Richard L. Cassel*
 Renate W. Chasman
 Peter J. Clarke
 Johannes Claus
 Jack A. Cockrill
 George W. Cornish, Jr.
 James G. Cottingham
 Joseph A. Curtiss
 Per Fridtjof Dahl

Gordon T. Danby
 Donald A. Davis
 Edward W. Dexter
 Emory G. Egler
 Arnold V. Feltman
 Norman M. Fewell
 Horst W. J. Foelsche
 Eric B. Forsyth
 John D. Fox
 Robert S. Frankel
 Martin Fruitman
 Sheldon Fuchs*
 John J. Gabusi
 Bernard D. Garfinkel
 William Gefers
 Salvatore T. Giordano
 Joseph W. Glenn, III
 Eileen C. Gran
 David L. Greenberg

*Terminated before July 1, 1968.

Harald Hahn
 Henry J. Halama
 Joseph P. Hannwacker
 William E. Harrison, Jr.
 John C. Herrera
 Charles J. Hoch*
 Garrett A. Hughes
 Robert S. Hulliger
 John W. Jackson
 David D. Jacobus
 Kurt Jellett
 Tohru Kamei*
(on leave from Univ. of Tokyo, Japan)

Henry Kasha
 Ralph R. Kassner
 John T. Keane
 Vincent J. Kovarik
 John H. Lancaster
 Ronald F. Lankshear
 Robert A. Larson
 Martin J. Lee
 Lawrence B. Leipuner
 Robert J. Lenuzza
 Gerald S. Levine
 Su Tang Lin
 Isador J. Livant
 Walter Livant
 Robert E. Lockey
 Vincent S. Lo Grasso
 Robert A. Loper
 Edward A. MacDougall
 Alfred W. Maschke*
 Harvey McChesney, Jr.
 Austin J. McGeary
 Alfred D. McInturff
 Lowell McLean
 Andrew J. McNerney
 Walter W. Merkle
 Melvin Month
 William H. Moore, Jr.
 Gerry H. Morgan
 Peter A. Montemurro
 Ronald J. Nawrocky
 Albert C. Nerenberg*
(retired September 29, 1967)
 Barbara Ann Norman*
 Leslie W. Oleksiuk
 Jean M. Oostens
 Arthur N. Otis, Jr.
 George Parzen
 Robert L. Pease*
 Jens C. Pettersen
 Martin Plotkin
 Sepp J. Prunster
*(on leave from Physikalisches Staatsinstitut,
 Institut für Experimentalphysik,
 Hamburg, West Germany)*
 Eugene C. Raka
 George Rakowsky
 George J. Reichenbacher

Raymond H. Rheaume
 Everett J. Rutan
 William B. Sampson
 Ralph T. Sanders
 James R. Sanford
 Albert J. Schoenemann
 Joseph F. Sheehan, Jr.
 Theodorus J.M. Sluyters
 Lyle W. Smith
 Anastasios Soukas
 Joel W. Spinner
 Julius Spiro
 Raymond J. Stefanski
(graduate student from Yale Univ.)
 Colin D. Stewart
 Robert C. Talsma
 Timonthy E. Toohig
 Arthur Tranis
 Clarence M. Turner
 Arie van Steenberg
*(on leave to
 National Accelerator Laboratory)*
 Uriel Vogel
 Peter J. Wanderer, Jr.
(graduate student from Yale Univ.)
 Ching Lin Wang
 Robert J. Warkentien
 Arnold R. Watts
 Irwin Weitman
 George W. Wheeler
 Richard L. Witkover
 Samuel P. Yamin
(postdoctoral appointment)

Applied Mathematics Department

Yoshio Shimamoto, *Chairman*
 Barry S. Arheit
 George A. Baker, Jr.
 Roger R. Baldwin*
 Lydia Bargiuk
 Steven Bender
 Carmen M. Benkowitz
 Harold C. Berry
 Kenneth J. Brightman
 Graham H. Campbell
 Hong-bo Chiang
 John E. Denes
 Karl P. Duerre
*(on leave from Technische Hochschule,
 Hanover, West Germany)*
 Kenneth R. Fannin*
 Jerry M. Friedman
 Kurt Fuchel
 Michael D. Goldfarb
 Charles I. Goldstein
 Frederick J. Hamilton
 Arthur D.S. Harris
 Janet I. Head*
 Heinrich Heesch
*(on leave from Technische Hochschule,
 Hanover, West Germany)*
 Sidney Heller

Margaret F. Hind
 Sin Hitotumatu*
*(on leave from
 St. Paul's Univ., Tokyo, Japan)*
 Richard S. Horwitz
 Richard D. Jenks*
 Joseph Kahane
 Anatoly Kandiew
 Minato Kawaguti
 Burton S. Kleinman
 Joshua K. Kopp
 Leslie L. Lawrence
 Raymond E. Lawrence
 Alvin A. Legerlotz
 Marc Leopold
 Irwin Lewis
 Dale W. Lick
(on leave from Univ. of Tennessee)
 Robert B. Marr
 Bruce A. Martin
 Gerald M. Nonte
 Stanley J. Osher
 Larry S. Padwa
 Ilse H. Perlman
 Arnold M. Peskin
 Joel D. Pincus
 Clarence C. Pittenger
 Marc Platt*
 Dysart A. Ravenhall
 Stuart S. Rideout
 Robert N. Salerno
 Alan M. Saltzman
 Carole J. Saurino*
 Niels F. Schumburg
 Arthur B. Scott
 Susan M. Sevia
 Morris Skibinsky
 Sharon Spark
 Morris M. Strongson
 Melvin Tainiter
 James K. Thurber
 Ralph A. Trondle
 Carol A. Wawrzusin

Biology Department

C.H.W. Hirs, *Chairman*
 Joseph J. Abata
(postdoctoral appointment)
 Nicholas Alonzo
 Ira H. Ames
(postdoctoral appointment)
 Karl P. Baetcke*
 Shabtai T. Bauer
(postdoctoral appointment)
 Donald G. Baker*
 Diana C. Bartelt
 Arnold M. Becker
 Clara A. Bjerknes
 Guy Blaudeau*
 Peter Bodlaender
(postdoctoral appointment)
 Robert W. Briggs

*Terminated before July 1, 1968.

Alice J. Burton
 Kathryn E. Carlson*
 Roger W. Carlson*
 Joseph J. Cascone*
 Rose Ann Cattolico*
 Yu-Hua Chang
 David J. Chapman*
(postdoctoral appointment)
 Theodore Chase, Jr.
(postdoctoral appointment)
 Vivien A. Chen
 William J. Cole*
(postdoctoral appointment)
 Nicholas C. Combatti
 William J. Crotty
(on leave from New York Univ.)
 Howard J. Curtis
 Richard G. Cutler
(postdoctoral appointment)
 Carol A. Czernick*
 Rosemarie Dearing
 Jeannette J. DiCarlo*
 Florence T. Dunne
 Daniel Dupourque
(postdoctoral appointment)
 Frieda M. Englberger
 Joseph A. Ernst*
 Murray J. Ettinger*
(postdoctoral appointment)
 Gad Feinstein*
(postdoctoral appointment)
 L. Raymond Fox
(postdoctoral appointment)
 Aurelie M. France*
(graduate student from Tulane Univ.)
 Walter J. Geisbusch
 Joseph S. Giordano, Jr.
 George I. Glover
(National Inst. of Health Fellow)
 Bill Greenberg
 Lewis J. Greene
 Eleanor Grist
 Kenneth L. Grist
 D. Elizabeth Hamill
 Robert L. Heath
(postdoctoral appointment)
 Susan S. Heath
 William S. Hillman
 Alden D. Hinckley
*(on leave from
 Coconut Rhinoceros Beetle Project,
 Apia, West Samoa)*
 Geoffrey Hind
 Yoshihiko Hirono*
(postdoctoral appointment)
 Richard A. Houghton, III
 Adam S. Inglis
*(assigned from Commonwealth Scientific
 and Industrial Research Organization,
 Melbourne, Australia)*

Ikuo Ino*
 Richard L. Jackson
(postdoctoral appointment)
 Alexandra H. Jahn
 Elsy K. Jonsson
 Helen J. Kelly
 Julie Klee
 J. Raymond Klein
 Donald Koenig
 Willard L. Koukkari*
(postdoctoral appointment)
 Jadwiga H. Kycia
 Sanford A. Lacks
 H. George Latham, Jr.
 Myron C. Ledbetter
 Teh-Yung Liu
 Robert A. Love, Jr.
 Gareth A. Mair
(postdoctoral appointment)
 Kodumudi M. Marimuthu
(on leave from Univ. of Michigan)
 James O. Martin*
(postdoctoral appointment)
 Dorothy M. McFadyen
 W. Arthur McKee
 Barbara McMillan
 Bonnie J. Medley
 Barbara C. Michelsen
 Rosario R. Modesto*
 David L. Mulcahy
(on leave from Univ. of Georgia)
 Herbert Y. Nakatani
 Anne F. Nauman
 Charles H. Nauman
 Marta Nawrocky
 Leslie F. Nims
 Noboru Nomura
(postdoctoral appointment)
 Regina Ann Nordstrom*
 John M. Olson
 Theresa F. Petty
 James J. Phelan
(postdoctoral appointment)
 Thomas S. Platt
 Josephine M. Po*
 Virginia Pond
 LeAnne Puglielli
 Vernon N. Reinhold*
(postdoctoral appointment)
 Meir Rigbi*
*(on leave from
 Hebrew Univ. of Jerusalem, Israel)*
 Nancy L. Roettinger*
 Marjorie L. Rudert
 Richard N. Ruffing
 John J. Ruscica
 Lloyd A. Schairer
 Benno P. Schoenborn
 Peter D. Schopfer*
(Volkswagen Foundation Fellow)
 Susan S. Schwemmer
 Roslyn Shapanka

Elizabeth K. Shaw
 Elliott N. Shaw
 Frederick G. Sherman
(on leave from Syracuse Univ.)
 Harold W. Siegelman
 Harold H. Smith
 Robert L. Smith*
(postdoctoral appointment)
 Arnold H. Sparrow
 Rhoda C. Sparrow
 Sylvia S. Springhorn
 Carol A. Staley*
 Robert Steele
 William J. Stegeman
 F. William Studier
 Haven C. Sweet
(postdoctoral appointment)
 Keith H. Thompson
 J. Philip Thornber
(postdoctoral appointment)
 John J. Tilley, Jr.
 Arlene L. Ulrich*
(postdoctoral appointment)
 Alan G. Underbrink
 Jack Van't Hof
 Chih-Cheng Wang
(postdoctoral appointment)
 Elizabeth A. Weaver
 Peter L. Webster
(postdoctoral appointment)
 Robert G. Woodley
 George M. Woodwell
 Ruth V. Wright
 Shizuko Yagi
 Joseph D. Yourno

Chemistry Department

Richard W. Dodson, *Chairman*
 Lloyd Abrams
(postdoctoral appointment)
 Augustine O. Allen
 Michael Ardon*
*(on leave from
 Hebrew Univ. of Jerusalem, Israel)*
 Elizabeth W. Baker
 Raymond C. Barile*
(postdoctoral appointment)
 Allan L. Bednowitz*
(postdoctoral appointment)
 Ivan Bernal
 Benon H. Bielski
 Jacob Bigeleisen
 Christos S. Capellos
 Lui-Heung Chan
(postdoctoral appointment)
 David R. Christman
 Yung Yee Chu
 Philip Coppens
 Lester M. Corliss
 James B. Cumming
 Raymond Davis, Jr.

*Terminated before July 1, 1968.

Mario DePas
(*postdoctoral appointment*)
 Stanton Ehrenson
 Horst Elias*
(*on leave from Technische Hochschule,
Darmstadt, West Germany*)
 Norman Elliott
 Bruce R. Erdal
(*postdoctoral appointment*)
 Nils E. Erickson
 Fausta R. Faucitano*
(*on leave from Univ. of Pavia, Italy*)
 Juan M. Figuera
(*postdoctoral appointment*)
 Eena-Mai Franz
 Gerhart Friedlander
 Lewis Friedman
 Salomon Fuks
(*postdoctoral appointment*)
 Alessandro Gandini
(*postdoctoral appointment*)
 Kodasseri P. Gopinathan
(*postdoctoral appointment*)
 James R. Grover
 Angelo Guarino*
(*on leave from
National Research Council, Rome, Italy*)
 Walter C. Hamilton
 Garman Harbottle
 Julius M. Hastings
 Erich O. Hechtl*
(*postdoctoral appointment*)
 Jerome Hudis
 Adolph P. Irsa
 Per-Gunnar Jönsson
(*on leave from
Univ. of Uppsala, Sweden*)
 Miltiades Karayannis
(*assigned from
Institute of Fine Arts, New York Univ.*)
 Paul J. Karol
(*postdoctoral appointment*)
 Seymour Katcoff
 Edward O. Kazimir
(*graduate student from Fordham Univ.*)
 John D. Kelley*
 Charles L. Kibby*
(*postdoctoral appointment*)
 Siegfried R. Krutzik
(*postdoctoral appointment*)
 Walter Kunnmann
 Georg K. Kunz
(*deceased September 28, 1967*)
 Roger A. Lalancette*
(*postdoctoral appointment*)
 Ernest Y.Y. Lam
(*postdoctoral appointment*)
 Sam J. LaPlaca
 Hon-Yen Lau
(*postdoctoral appointment*)

*Terminated before July 1, 1968.

Elliot Lebowitz
(*postdoctoral appointment*)
 Jacob B. Leventhal
 Ljubica Manojlovic-Muir
(*postdoctoral appointment*)
 Harold R. Martin
(*postdoctoral appointment*)
 Louis J. Massa
(*postdoctoral appointment*)
 Francis J. Menes
(*assigned from
Commissariat à l'Énergie Atomique,
Saclay, France*)
 Toshihiko Migita*
(*on leave from
Gumma Univ., Tenjin-Cho Kiryu, Japan*)
 Stamatios G. Mylonakis
 Beverly J. Nine
 Elinor F. Norton
 Johann Oesterreicher*
(*postdoctoral appointment*)
 Mato Orhanovic*
(*postdoctoral appointment*)
 Catherine T. Paul
 Morris L. Perlman
 Henry N. Po
(*postdoctoral appointment*)
 Carol S. Redvanly
 Louis P. Remsberg, Jr.
 Slobodan V. Ribnikar*
(*on leave from
Boris Kidrich Inst. of Nuclear Science,
Belgrade, Yugoslavia*)
 J. Keith Rowley
 William Rubinson
 Reuben M. Rudman*
(*postdoctoral appointment*)
 Cielo Maria Santiago
 Edward V. Sayre
 Werner F. Schmidt
(*postdoctoral appointment*)
 Harold A. Schwarz
 David Seewald
(*postdoctoral appointment*)
 Stanley Seltzer
 Jacob S. Shapiro
(*postdoctoral appointment*)
 Kelvin K.-W. Shen
(*graduate student from
Univ. of Massachusetts*)
 Shih-Ping Shen
(*assigned from Univ. of Pennsylvania*)
 Philip B. Shevlin
(*postdoctoral appointment*)
 Frederick J. Silkworth, Jr.
 Kenneth W. Stevens*
(*postdoctoral appointment*)
 Raymond W. Stoenner
 Norman Sutin
 Shlomo Szapiro*
(*postdoctoral appointment*)
 Sydney O. Thompson

Armin K. Tippe
(*assigned from
Fritz Haber Institut der Max Planck
Gesellschaft, Berlin, West Germany*)
 Kay O. Watkins
(*on leave from Adams State College*)
 Michael J. Welch*
(*postdoctoral appointment*)
 Theresa J. Welch*
 Ralph E. Weston, Jr.
 Hans Michael Widmer
(*postdoctoral appointment*)
 Ronald Withnell
 Alfred P. Wolf
 Max Wolfsberg
 Huei-Ying Yao*
(*postdoctoral appointment*)
 Patricia K. Zimmerman*

Instrumentation and Health Physics Department

Horner Kuper, *Chairman*
 John W. Baum
 William H. Bishop, Jr.
 Robert M. Brown
 Michael J. Butler
 Miodrag S. Carapic*
(*on leave from Inst. of Nuclear Studies,
Belgrade, Yugoslavia*)
 Robert L. Chase
 Lester A. Cohen
 Robert D. Colvett
 Frederick P. Cowan
 John B. Deitz
 D. Gerd Dimmler
 Carl H. Distenfeld
 Joan F. Felberbaum
 Joachim Fischer
 Charles W. Flood, Jr.
 Charles F. Foelix
 John A. Frizzola
 Lee Gemmell
 Norwood E. Greenlaw
 William J. Hartin
 William A. Higinbotham
 Andrew P. Hull
 John F. Jacobs
 Marco A. Jamini*
 Mary Anne Kelley
 John J. Kelsch
 Kazuo Kemmochi
(*on leave from Japan Defense Agency,
Tokyo*)
 Hobart W. Kraner
 Alan V. Kuehner
 Robert O. McClintock*
 Charles B. Meinhold
 William Michaelson
 Constance M. Nagle
 Anthony Nappi
 Casimir Z. Nawrocki
 Michael J. O'Brien

David Ophir
 James P. Palmer
 Smith G. Pearsall
 Leigh F. Phillips
 David W. Potter
 Veljko Radeka
 Seymour Rankowitz
 Gilbert S. Raynor
 Edwin J. Rogers
 Martin J. Rosenblum
 Jesús I. Sánchez
*(on leave from Junta de Energía Nuclear,
 Madrid, Spain)*
 George E. Schwender
 Barry J. Shepherd*
 Shinkicki Shibata
(on leave from Univ. of Tokyo, Japan)
 Stanley I. Silverman
 Irving A. Singer
 Maynard E. Smith
 Robert J. Spinrad*
 John P. Stohr*
 Raymond W. Stong
 Sanford E. Wagner
 Gaylord N. Wall
 Catharine L. Wingate
 Stanley Wood
 Robert W. Young

Mechanical Engineering Division

Irving J. Polk, *Head*
 John R. Aggus
 Richard W. Aichroth
 Richard C. Albert
 Joseph E. Allinger
 Richard C. Amari
 Frank H. Atkinson
 Robert D. Baldwin, Jr.
 Joseph A. Bamberger
 Alden J. Bansleben
 Alfred A. Bertsche
 Paul Bezler
 Thomas J. Blair
 Donald P. Brown
 Thomas W. Brown
 Robert H. Browne
 Vernon J. Buchanan
 Ronald W. Burgess
 Leonard N. Chimienti
 Thomas M. Coyle
 Rudolph Damm
 Jack E. Detweiler
 Basil DeVito
 Arthur C. Dick
 Carmine DiLullo
 Santo J. DiNaro, Jr.
 Bernard J. Durman
 Carlo Ferraro, Jr.
 Carl R. Flatau

*Terminated before July 1, 1968.

Edward H. Foster
 John J. Fuhrmann
 Donald W. Gardner
 Robert J. Gibbs
 Jules B. Godel
 Carl L. Goodzeit
 Charles L. Gould
 Pierre Grand
 Melvin E. Griffing
 John J. Grisoli
 Eugene E. Halik
 Charles R. Hedberg*
 Rudolph S. Hodor
 Kenneth C. Hoffman
 Daniel Hooper
 John N. Hopping, Jr.
 Hank C.H. Hsieh
 Donald W. Huszagh
 Eugene Jablonski
 Jack E. Jensen
 Marshall G. Jones
 David A. Kassner
 Andrew Kevey
 John T. Koehler
 Calman Lasky
 Paul LeDoux
 Nathan Levenson
 Boris M. Lomonosoff
 Joseph Lypecky
 Stanley J. Majeski
 Paul Mandel*
 John G. Marinuzzi
 Robert J. McCracken*
 Raven B. McKenzie-Wilson
 Thomas F. McKinley
 Hugh T. McTeague
 Anthony P. Meade
 Kurt F. Minati
 Mordechai Montag
 William J. Museler
 George Nugent*
 Adolph Oltmann
 Frederick O. Pallas
 Nicholas J. Parrinello
 Francis C. Pechar
 Paul A. Pion
 Carl J. Pozgay
 Arno Raag
 Clive E. Reed
 Morris Reich
 Louis E. Repeta
 Wesley G. Ripperger
 Eugene W. Rogers
 Albert P. Schlafke, Jr.
 William J. Schneider
 Joseph C. Schuchman
 Anthony Semplicino
 Stewart Senator
 Gerard E. Tanguay
 Charles O. Theisen
 Harvey J. Thomas
 Reese D. Thomas

Helmuth Thorwarth
 Dietrich Trocha
 Vincent Troisi, Jr.
 Stanley L. Ulc
 John C. Walker
 William G. Walker
 Irving J. Winters, Jr.
 Donald H. Wright
 Arieh Zahavi

Medical Department

Eugene P. Cronkite, *Chairman*
 Emil R. Adamik
 Klaus-Dieter Albrecht*
*(assigned from Mount Sinai Medical and
 Graduate Schools, New York)*
 Robert B. Aronson
 Harold L. Atkins
 John L. Bateman
 Gunnar L. Bengtsson
(assigned from Columbia Univ.)
 Donald C. Borg
 Harold Burlington
*(on leave from
 Univ. of Cincinnati College of Medicine)*
 Arland L. Carsten
 Arjun Dev Chanana
 Celia C. Chiu
*(assigned from Mount Sinai Medical and
 Graduate Schools, New York)*
 Stanton H. Cohn
 Spencer L. Commerford
 Robert A. Conard, Jr.
 George C. Cotzias
 Lewis K. Dahl
 Nicholas Delihias
 Charles F. Demoise
*(AUI Postdoctoral Fellow,
 National Institutes of Health Fellowship)*
 Ruth M. Drew
 Patrick Eggena
*(assigned from Mount Sinai Medical and
 Graduate Schools, New York)*
 Ralph G. Fairchild
 Rosemary A. Gellene
 James Z. Ginos*
 Frank W. Gonzalez
(assigned from Columbia Univ.)
 Leon J. Goodman
(assigned from Columbia Univ.)
 Wolfgang P. Gordon*
*(assigned from Mount Sinai Medical and
 Graduate Schools, New York)*
 Leonard D. Hamilton
 Lawrence V. Hankes
 Wolfgang Hauser
 Robert T. Havran
*(assigned from Mount Sinai Medical and
 Graduate Schools, New York)*
 Mitsuru Hoshi
(on leave from Osaka Univ., Japan)

Shane H.H. Hsieh*
(assigned from Mount Sinai Medical and
Graduate Schools, New York)

Junichi Iwai
(on leave from Univ. of Tokyo, Japan)

Mahendra P. Jamuar
(medical associate)

Darrel D. Joel

Horton A. Johnson

Stanley L. Johnson

Panayotis G. Katsoyannis*

Charles W. Kim

Arthur P. Klotz

(on leave from

Univ. of Kansas Medical Center)

Knud D. Knudsen

Kazuo Kubo

(medical associate)

Vaughn L. Larson

(on leave from Univ. of Minnesota)

Anthony F. Lo Monte

Robert A. Love

Harvard Lyman*

Monty J. Montjar*

Nobuyoshi Oji*

(on leave from

Osaka Univ. Medical School, Japan)

Shinichi Okuyama

(Eastern Leukemia Association Fellow)

Norbert I. Overweg

(assigned from Mount Sinai Medical and
Graduate Schools, New York)

Chandra S. Pande

(assigned from

State University of New York at Buffalo)

Paul S. Papavasiliou

Howard R. Pate

Mildred Pavelec

Nina B. Pluss

Edwin A. Popenoe

Kanti R. Rai

Paul N. Reilly

Ursula Reincke

(Damon Runyon Fellow)

James S. Robertson

Charles V. Robinson

Jean R. Scherrer

(on leave from

Clinique Médicale and Institut de Physique,
Université de Genève, Switzerland)

Lewis M. Schiffer

Max A. Schmaeler

Gerald P. Schwartz*

Arlen R. Severson*

(assigned from National Inst. of Health)

Walton W. Shreeve

Clyde R. Sipe

Yolante E. Skrzywan

(medical associate)

Richard D. Stoner

Rita F. Straub

George M. Tislar-Lentulis*

Anthony C. Trakatellis*

Donald D. Van Slyke

Paul C. Vincent

(Eastern Leukemia Association Fellow;
Fellow of the National Health and Medical
Research Council of Australia)

Roderich W. Walter

(assigned from Mount Sinai Medical and
Graduate Schools, New York)

Richard S. Welsh*

Clyde Zalut

Nuclear Engineering Department

Warren E. Winsche, Chairman

Peter D. Adams

Anthony Adin

George Adler

Arnold L. Aronson

Seymour Aronson

Paolo E. Ascarelli

(assigned from Frankford Arsenal)

Michael J. Attardo*

(postdoctoral appointment)

Clemens Auerbach

Allan Auskern

David S. Ballantine

(on leave to US AEC, Washington, D.C.)

Charles B. Bartlett

(on leave to US AEC, Washington, D.C.)

Morris Beller

Mulki R. Bhat

Fritz Bloch

John S. Bookless

William Bornstein

Joseph S. Bryner

Albert W. Castleman, Jr.

John Chen

Jack Chernick

Joe G.Y. Chow

John T. Clarke

Peter Colombo

John F. Conant

Helen R. Connell

Noel R. Corngold*

Anita J. Court

Dermott E. Cullen

John H. Cusack

Hywel A. Davies*

(postdoctoral appointment)

Joan M. Dickey

(postdoctoral appointment)

Russell N. Dietz

Robert F. Doering

Roy F. Domish

John J. Dorning, Jr.

Kenneth W. Downes

Raymond F. Drager

Orrington E. Dwyer

James J. Egan

Leonard C. Emma

Lester G. Epel

Seymour G. Epstein

Jack Fajer

Peter T. Fallon

Antonio G. Faucitano*

(on leave from Univ. of Pavia, Italy)

Stephen W. Feldberg

Richard M. Felder

Albert H. Fleitman

Jack J. Fontana

Joseph Forrest

Bernard R. Fox

Roberto V.A. Gabarain

(IAEA Fellow on leave from
Comisión Nacional de Energía Atómica,
Buenos Aires, Argentina)

Leonard Galanter

James M. Galligan

Meyer Garber

Theodore W. Gilbert, Jr.

(on leave from Univ. of Cincinnati)

Althea Glines

Murray D. Goldberg

Rubin Goldstein

Robert W. Goodrich

Barry M. Gordon

Yorio Gotoh

(assigned from

Japan Atomic Energy Research Inst.,
Tokai-mura)

Leon Green

(on leave to IAEA, Vienna, Austria)

Margaret W. Greene

David H. Gurinsky

Loranus P. Hatch

Michael A. Helfant

Robert L. Hellens*

Joseph M. Hendrie

Raymond J. Heus

Frank B. Hill

Manny Hillman

Leif R.D. Hjarne*

(on leave from AB Atomenergi, Sweden)

Peter J. Hlavac

Michael Hobdell

(postdoctoral appointment)

Frederick L. Horn

Chia-Jung Hsu

Anthony P. Ingraham*

Hugh S. Isaacs

Robert J. Isler

Stanley D. James*

Carl L. Johnson

Richard Johnson

Sheldon Kalish

Otto F. Kammerer

Mary T. Kinsley

George Kissel

Carl J. Klamut

Paul J. Klotz

Harold W. Koenigsberg

*Terminated before July 1, 1968.

Herbert J.C. Kouts
Theodore J. Kreiger
Krishnaswamy Krishnamurthy*
(on leave from Atomic Energy Establishment,
Trombay, India)

Lawrence E. Kukacka, Jr.

Michael J. Lancefield
(postdoctoral appointment)

Daniel F. Leahy

Gerald S. Lellouche

Melvin M. Levine

Steven Lewkowitz

George C. Lindauer

Hans Ludewig

Raymond A. Mackay
(on military leave of absence)

Donald R. MacKenzie

Benjamin Magurno

Bernard Manowitz

Victoria L. May

James J. McNicholas

S. Bradford McRickard*

George E. Meinken

Donald J. Metz

Paul A. Michael

Julius Milau

Francis T. Miles

Bertram Minushkin

Sophie O. Moore

M. Luis Muga
(on leave from Univ. of Florida)

Said F. Mughabghab

Albert C. Muller

Leonard Newman

Basil Nicolaenko
(postdoctoral appointment)

Odelli Ozer

Philip F. Palmedo

Raymond J. Parsick

Arthur Paskin

Sol Pearlstein

James P. Phelps

James R. Powell, Jr.

Thomas F. Prach

Glenn A. Price

Augustus Prince

Jacob Pruzansky

Chad J. Raseman

James J. Reilly, Jr.

Powell Richards

Francis X. Rizzo

Anthony Romano

Michael A. Rothbart

Alexander Sabosto

Jerome Sadofsky

Francis J. Salzano

César A. Sastre

Shoichi Sato

(assigned from
Japan Atomic Energy Research Inst.,
Tokai-mura)

Clifford H. Scarlett
Richard Schiller
Ursula M.R. Schulze
Donald G. Schweitzer
John T. Sears
Bal Raj Sehgal*
Thomas V. Sheehan
Takanori Shimooke
(assigned from
Japan Atomic Energy Research Inst.,
Tokai-mura)

Louis M. Shotkin

Robert M. Singer

Louis M. Slater*

Peter Soo
(postdoctoral appointment)

Louis G. Stang, Jr.

John R. Stehn

Meyer Steinberg

Thomas E. Stephenson

Gerald Strickland

Nils L.G. Stromberg

(on leave from
Research Inst. of National Defense,
Stockholm)

Sylvester C. Suda

Herbert Susskind

James W. Sutherland

Hiroshi Takahashi

Ignatius Ning-Bang Tang

Silvio J. Tassinari

Richard S. Thompson

Troy H. Tidwell, Jr.*
(on leave from North Texas State Univ.)

Richard J. Tivers

Walter D. Tucker

William J. Tunney

Edwin J. Tuthill

James O. Tveekrem

John D. Van Norman

Stephen J. Wachtel

Jean I. Wagner

Charles H. Waide

John R. Weeks

Eugene V. Weinstock

Allen J. Weiss

Jerome Weiss

George G. Weth

Robert G. Wilson

Virginia H. Wilson

John K. Wilmschurst

Henry H. Windsor

Edward Wirsing, Jr.

Richard H. Wiswall, Jr.

John J. Woods

(assigned from
Babcock & Wilcox, Lynchburg, Va.)

Wen-Shi Yu

Martin S. Zucker

Physics Department

R. Ronald Rau, *Chairman*

Robert J. Abrams
(postdoctoral appointment)
Sabine Ahrens
David E. Alburger
Jean Allitti
(on leave from
Commissariat à l'Énergie Atomique,
Essone, France)
Harvey A. Alperin
(assigned from
U.S. Naval Ordnance Laboratory)
José L. Alvarez-Rivas*
(postdoctoral appointment)
Eric W. Anderson
Richard Arndt
Elliot H. Auerbach
Charles P. Baker
Virgil E. Barnes
Allen Bashian
(graduate student from
State Univ. of New York at Stony Brook)
Robert H. Bassel*
Karl H. Beckurts
(assigned from Institut für Angewandte
Kernphysik, Gesellschaft für Kernforschung,
Karlsruhe, West Germany)
Mendel Beer
(graduate student from
State Univ. of New York at Stony Brook)
Robert H. Bell*
John A. Benjamin
Sheldon W. Bennett
(graduate student from Columbia Univ.)
Darlene Bentz
Robert H. Bergoffen
Bernard T. Bertman*
Charles C. Blank
Edward J. Bleser*
Harry R. Blieden
Frank A. Blood, Jr.*
(postdoctoral appointment)
Haywood Blum*
Martin Blume
Robert W. Brown
(postdoctoral appointment)
Gunter Brunhart
Brian Buck
Allan S. Carroll
Lai-Him Chan
(postdoctoral appointment)
Yau W. Chan
Ashoka Chandra
(postdoctoral appointment)
Chellis Chasman
George T.Y. Chen
(graduate student from Brown Univ.)
David Cheng
Robert E. Chrien
Suh Urk Chung
(postdoctoral appointment)
Eugene L. Church
(assigned from Frankford Arsenal)
Anne-Marie Cnops

*Terminated before July 1, 1968.

Victor W. Cohen
 Isaac W. Cole
 George G. Collins
 Malcom F. Collins
*(assigned from
 United Kingdom Atomic Energy Authority,
 Harwell, England)*
 Philip L. Connolly
 Ernest D. Courant
 David E. Cox
 Paul P. Craig
 David J. Crennell
 Kathleen M. Crennell
 Jack E. Crow
(postdoctoral appointment)
 Bernard B. Culwick
 Stephen A. Cutler*
 Arthur C. Damask
 Christopher J.S. Damerell*
*(assigned from
 Rutherford High Energy Laboratory,
 England)*
 William C. Delaney
 Alain Delapalme
*(assigned from
 Centre d'Études Nucléaires de Grenoble,
 France)*
 Claude M. Delorme
(assigned from Univ. of Rochester)
 Eduardo de Rafael
(postdoctoral appointment)
 Edward der Mateosian
 James A. DiCarlo*
(postdoctoral appointment)
 George J. Dienes
 Robert P. DiNardo
*(graduate student from
 Stevens Inst. of Technology)*
 William P. Dodd*
 Jean V. Domish
 John T. Donohue
(postdoctoral appointment)
 Peter J. Dornan*
(postdoctoral appointment)
 William E. Ellis
(graduate student from Vanderbilt Univ.)
 Victor J. Emery
 Cavid Erginsoy
(deceased December 6, 1967)
 Peter D. Esser
(graduate student from Adelphi Univ.)
 Orrin D. Fackler
*(graduate student from
 Massachusetts Inst. of Technology)*
 John R. Ficenec
*(assigned from
 Virginia Polytechnic Inst.)*
 Vincenzo Flaminio
*(on leave from
 CERN, Geneva, Switzerland)*

Kenneth J. Foley
 Hugie L. Foote, Jr.
 William B. Fowler
 B. Chalmers Frazer
 Joseph L. Friedes
 Donald I. Garber
 David A. Garelick
 William Gelletly
 G. Norris Glasoe
 Eli Glazer*
 Allen N. Goland
 Malcolm Goldberg
 John J. Golden, Jr.*
 Gertrude S. Goldhaber
 Samuel A. Goudsmit
 John J. Gould
 Paul D. Grannis
*(assigned from
 State Univ. of New York at Stony Brook)*
 William R. Harris
(postdoctoral appointment)
 Sigrun Hechtl*
(postdoctoral appointment)
 Patrick J. Herley
(assigned from Picatinny Arsenal)
 Benjamin H. Hertzendorf
 David G. Hill
 Donald V. Hirst
 John Hornbostel
 Paul V.C. Hough
 Theodore L. Houk
(assigned from Harvard Univ.)
 James M. Howie
*(assigned from
 CERN, Geneva, Switzerland)*
 James J. Hurst, Jr.
 Frederick R. Huson
 Richard T. Imossi
 Shelby P. Jessup
 Robert A. Johnson
 Keith W. Jones
 Roger S. Jones*
 Sidney H. Kahana
 George R. Kalbfleisch
 Walter R. Kane
 Uri Karshon
*(on leave from
 Weizmann Inst. of Science, Rehovoth, Israel)*
 David T. Keating
 Peter J. Kemmey
(assigned from Picatinny Arsenal)
 Ian R. Kenyon
 Stuart H. Kern*
 Robert R. Kinsey
 Janos Kirz
*(assigned from
 State Univ. of New York at Stony Brook)*
 Ottmar C. Kistner
 Thomas A. Kitchens, Jr.
 Michael J. Koczak
*(graduate student from
 Univ. of Pennsylvania)*

Abe I. Korn
*(graduate student from
 Queens College, City Univ. of New York)*
 Thaddeus F. Kycia
 Kwan Wu Lai
 Franklin T. Langdon
 James D. Larson
 Benny E. Lautrup
(postdoctoral appointment)
 Otto W. Lazareth, Jr.
 John A. Leake*
(postdoctoral appointment)
 Barbara Lebowitz
 Hyung J. Lee
 Paul Hoong-Chien Lee
*(graduate student from
 McGill Univ., Montreal, Canada)*
 Kurt Lengweiler
 Boran A. Leontic
 Michael J. LeVine
(postdoctoral appointment)
 Paul W. Levy
 Kelvin K.Y. Li
 Seymour J. Lindenbaum
 Frederick P. Lipschulz*
(postdoctoral appointment)
 Frederick Lobkowicz
(assigned from Univ. of Rochester)
 Georges W. London
*(on leave to
 École Polytechnique, Paris, France)*
 Robert I. Louttit
 William A. Love
 Dierk Luers*
 Mario A. J. Mariscotti
 Brian R. Martin
(postdoctoral appointment)
 Peter L. Mattern
 Michael McKeown
 Herbert Meister
(assigned from Euratom, Ispra, Italy)
 Jack Menes
 Wesley J. Metzger
(postdoctoral appointment)
 Daniel N. Michael
(postdoctoral appointment)
 David J. Miller
(postdoctoral appointment)
 Vincent J. Minkiewicz
 Paul M. Mockett
 Jaime B.A. Moragues
*(assigned from
 Comisión Nacional de Energía Atómica,
 Buenos Aires, Argentina)*
 Thomas W. Morris
 Bernard Mozer*
 John F. Mucci
(graduate student from Carnegie-Mellon Univ.)
 Alfred H. Mueller
 George T. Mulholland
 Yorikiyo Nagashima
(assigned from Univ. of Rochester)

*Terminated before July 1, 1968.

Joseph A. Nardi, Jr.
 Robert Nathans
 John W. Olness
 John S. O'Neill
(postdoctoral appointment)
 E. Boyd Osgood
(postdoctoral appointment)
 Claude J. Ouannes*
(on leave from
Centre National de la Recherche Scientifique,
Paris, France)
 Tom Oversluisen
 Satoshi Ozaki
 Harry Palevsky
 Robert B. Palmer
(on leave to CERN, Geneva, Switzerland)
 Robert S. Panvini
 Laurence Passell
 Simon Pasternack
(Editor of The Physical Review)
 Ronald F. Peierls
 Francis C. Peterson
(graduate student from Cornell Univ.)
 Robert H. Phillips
 Jerry L. Pietenpol*
(postdoctoral appointment)
 Edward D. Platner
 Alan R. Poletti*
 David C.L. Price*
(postdoctoral appointment)
 Albert G. Prodell
 Carroll A. Quarles, Jr.*
 David C. Rahm
 Karim Rimawi
(graduate student from
State Univ. of New York at Stony Brook)
 Herbert Ringel
(graduate student from
Queens College, City Univ. of New York)
 Paul C. Rogers
 David C. Rorer
 Roy Rubinstein
 Terence M. Sabine*
(on leave from
Australian Atomic Energy Commission)
 Colin K. Scott
(graduate student from
McGill Univ., Montreal, Canada)
 Vance L. Sailor
 Mark Sakitt
 Nicholas P. Samios
 Alfred C. Saulys
 James M. Scarr
 Robert I. Schermer
 Thomas G. Schumann*
(postdoctoral appointment)
 Arthur Z. Schwarzschild
 Chia-Chang Shih
(postdoctoral appointment)
 Gen Shirane

Clifford G. Shull*
(on leave from
Massachusetts Inst. of Technology)
 Ralph P. Shutt
 Jovan M. Simic*
(postdoctoral appointment)
 W. Dwain Simpson
 John Skalyo, Jr.
 Ian O. Skillicorn
 Olaf Skjeggstad*
(on leave from
Univ. of Oslo, Blindern, Norway)
 Gary A. Smith
 Joseph E. Smith
 C. Lewis Snead
 Jeffrey B. Sokoloff
(postdoctoral appointment)
 Lauren Sompayrac
(graduate student from
Massachusetts Inst. of Technology)
 John H. Sondericker
 Carmelo A. Spirio
 Rudolph Sternheimer
 Richard C. Strand
 Myron Strongin
 Andrew W. Sunyar
 Richard J. Sutter
 Dubravko Tadic
(on leave from
Univ. of Zagreb, Yugoslavia)
 Stuart K. Tewksbury
(graduate student from Univ. of Rochester)
 Pedro A. Thieberger
(on leave to Research Inst. for Physics,
Stockholm, Sweden)
 Alan Thorndike
 Jayashree R. Toraskar
(graduate student from Columbia Univ.)
 George L. Trigg
(Editor, Physical Review Letters)
 William L. Trousdale*
(on leave from Wesleyan Univ.)
 T. Laurence Trueman
 Frank Turkot
 William A. Tuttle
 Ronald P. Uhlig
 Hiromichi Umebayashi*
(postdoctoral appointment)
 Erminia Vaccari*
 Vance D. VanderBurg
 Ernest K. Warburton
 Oren A. Wasson
 Richard E. Watson
 Medford S. Webster*
 Harvey E. Wegner
 Joseph Weneser
 Theodore L. Werntz
 William B. Whitten
 Gian Carlo Wick
(on leave to Columbia Univ.)
 Colin Wilkin*
(postdoctoral appointment)

Erich H. Willen
 Ernest Windschauer
 Estarose Wolfson
 Yasusada Yamada*
(on leave from Osaka Univ., Japan)
 Luke C.L. Yuan
 Andres P. Zuker
(postdoctoral appointment)

Plant Engineering and Planning Division

Maxwell M. Small, *Manager*
 Gordon K. Ahlers
 Frederick E. Baumfalk
 Stephen C. Biemer
 Henry G. Bornbusch
 John J. Brennan
 Alfred J. Brunini
 Louis P. Caiola
 Robert E. Doerr
 Domenick J. Donato
 Darnley Eversley
 Harold R. Euler
 William A. Fleischer
 Henry C. Gordon
 Henry B. Hansteen
 Louis A. Harson
 John J. Hennessy
 William L. Homer
 Robert B. Hupper
 John F. Iulo
 Arnold J. Kazdin
 Joseph F. Krikawa
 Thomas P. Lanigan
 John F. Lorenc
 Donald A. MacCornack
 Alfred Mahlmann
 Thomas A. Marrion
 Pierre A. Mercier
 Paul V. Mohn
 James H. Montgomery
 Donald W. Oakley
 William G. Reid
 Nicholas Sanfilippo
 John W. Schluter
 Abe Seifert
 Edward E. Shelton
 Ralph P. Taylor
 Robert C. Terwilliger
 George C. Wagner
 Paul L. Walser
 Paul H. Weitzel
 Arthur G. Worthington, Jr.

Reactor Division

Robert W. Powell, *Head*
 Frederick Allenspach*
 Michael H. Brooks
 William J. Brynda

*Terminated before July 1, 1968.

Paul Colsmann
Francis A. Dugan
John J. Floyd

*Terminated before July 1, 1968.

John R. Halpin
Gerald C. Kinne
Paul E. Mamola
Charles L. Osborne
John A. Penney

Jack E. Phillips
dePuyster G. Pitcher
Seymour R. Protter
Walter H. Reed*
Paul R. Tichler

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