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Seventh Semiannual Report

OF THE

ATOMIC ENERGY COMMISSION

January 1950

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LETTER OF SUBMITTAL

WASHINGTON, D. C.
31 January 1950

SIRS: We have the honor to submit herewith the Seventh Semiannual Report of the United States Atomic Energy Commission, as required by the Atomic Energy Act of 1946.

Respectfully,

UNITED STATES ATOMIC ENERGY COMMISSION

GORDON DEAN.
SUMNER T. PIKE.
H. D. SMYTH.
LEWIS L. STRAUSS.
DAVID E. LILIENTHAL, *Chairman.*

The Honorable

The President of the Senate

The Honorable

The Speaker of the House of Representatives

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FOREWORD

In 1949, the Nation's long-range program for the peacetime development of atomic energy set new bench marks of accomplishment.

In November, the Commission authorized the building of the first experimental breeder reactor. With the start of construction of this unit, the program for producing more fissionable material and for generating power for factories and homes and ships from the energy of nuclear fission moved from pencil and paper planning over to the building of full-scale test machines.

Three new reactors, including the breeder, are to be built at the Reactor Testing Station established in Idaho earlier in 1949; a fourth near Schenectady, N. Y. All are either in the advanced stages of design or the first stages of building. As construction of these experimental machines gets under way, reactor development scientists and engineers are making preliminary plans for the machines to be built in the subsequent phases of the reactor development program.

Weapons development and stock piling moved on at a growing pace during the year. Production of weapons was changed to an industrial type of operation. Design of weapons advanced. Preparation began for future proof-testing at the Eniwetok Proving Ground in the Pacific. AEC activities were coordinated more closely with military activities and military training.

Essential to both the power-production program and the weapons program is an adequate supply of uranium ores. This is being obtained at present. Negotiations abroad and mining and processing plant developments at home during 1949 placed the prospects for continuing supply on a firmer basis.

The construction program of the past two years began to yield its fruit in 1949. New facilities for making feed materials and fissionable materials went into operation. The output of fissionable material set new records. New laboratories and research machines were put to work and the building of still others advanced. Basic processes for improving chemical separation of fissionable material from fission products were worked out and construction was started on facilities.

The technical and scientific staffs were recruited more nearly to the desired levels both in quantity and quality. Industrial strength was added to the program by new contractors in various fields, but especially in weapons and reactors. Basic research was put upon a broader base with many new university contracts for research.

Some of the problems of labor-management relations became more susceptible of solution. The Atomic Energy Labor Relations Panel

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assisted in reaching settlements of disputes in which its services were invoked.

This is not to say that the program operated in all its phases without hitch or flaw, or at the speed and with the results desired. Many technical problems await solution through basic and applied research. We have made only a beginning at providing industry with the information service it is entitled to expect. The declassification of scientific and technical information which need no longer be held secret does not proceed at a pace rapid enough to satisfy all of the demands for such data.

Financial controls and reporting were substantially improved during the year. A continuing effort is being made to meet more adequately the requirements of flexible operation, for keeping account of where projects stand financially at all stages, and for reporting accurately and clearly the financial status of programs at frequent intervals.

To speed its atomic energy program, this Nation requires, above all else, technical men of talent and training. Other vital development programs of industry and government have comparable demands for scientists and technicians. It is important that the Congress and the people of the United States recognize the critical need for fundamental research and the training of scientists, engineers, and technicians.

On September 23rd the President announced to the American people that an atomic explosion had occurred in the USSR. The President pointed out that U. S. policy and operations in atomic energy had always taken into account the likelihood that other nations would in time develop atomic weapons. The President's announcement, by its revelation of Russian achievement, emphasizes the importance of the most efficient possible utilization of the resources available for this Nation's atomic energy program.

The Congress in mid-October modified, in the interests of speed, the construction rider in the 1950 appropriations for the national atomic energy program. In early October the President released budgetary reserves so as to advance by some months the start of a quarter-billion dollar expansion program, then at the drawing-board stage and planned for construction in subsequent fiscal years. Some of this work is now actually under way and will require supplemental appropriations at an early date. This action was discussed by the Commission with the Congressional committees concerned.

Maintenance of the United States position requires a vigorous, growing program of basic and applied research in nuclear science and engineering. Because of the vital importance of this work, the second part of this Seventh Report to the Congress is devoted to the research program in these fields.

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Though successful development of atomic energy depends first of all upon men, it also depends upon information. Policies for the control of atomic energy information are aimed at the basic objective of advancing our own program while giving as little aid as possible to the program of inimical interests. The measures for accomplishing this obviously need to be adjusted to the presently known facts as to rival development.

Adjustments in declassification procedure are being undertaken by the three nations—Canada, the United Kingdom, and the United States—which participated in the wartime atomic energy program and which have adopted uniform declassification policies covering the information they hold in common.

Technical studies looking toward adjustments began on September 24 during the third international declassification meeting then in session at Chalk River, Canada. These studies have been continued in each nation during the past four months.

The results will be coordinated at forthcoming international conferences. The resulting recommendations will be submitted for consideration by the atomic energy agencies of the three nations.

As in previous years of the Commission's tenure, there has been gratifying and helpful cooperation from all agencies of the Government whose operations touch upon those of the atomic energy program, or which are enlisted under special arrangements to carry on specific tasks. The Commission's relationship with the Military Liaison Committee was further strengthened. The continuous and extensive work on mutual problems by the staffs of the two agencies contributed substantially to effective coordination of Department of Defense and AEC activities.

The General Advisory Committee has continued its diligent and effective work of analyzing the problems of atomic energy development, particularly in the scientific and technical lines, and providing fruitful recommendations for policies and programs in those fields. Other advisory groups appointed by the Commission have made substantial contribution to the progress of 1949.

There was a considerable increase in the exchange between the Joint Committee on Atomic Energy and the Commission. Including the sessions held in connection with a long series of hearings into charges of Commission mismanagement, there were during the year, 24 public and 37 executive meetings between the Committee and the Commission dealing with current operational and policy matters. The flow of correspondence and reports from the Commission to the Committee, totalling some 375 reports and communications during 1949, is an indication of the volume of information supplied to members of the Committee. Members of the Committee and the Com-

mittee staff visited the sites of operations in the atomic energy program and familiarized themselves in detail with the progress and the problems of the enterprise.

With full awareness of the deficiencies that continue to exist in scope and speed of operations and development of smooth-working relationships throughout the program, the Commission nevertheless feels that at the end of three years of its stewardship, the Nation's atomic energy enterprise is on a sound footing.

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Part I

Activities and Developments in Atomic Energy Program During 1949

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I

PRODUCTION

During 1949, advances were made in the main phases of production operations: procurement of raw materials, processing of feed materials for the production plants, and manufacture in these plants of fissionable plutonium and uranium 235 for use in weapons, power development, and research.

RAW MATERIALS

Progress in exploration, ore buying, and ore processing during 1949 helped assure that future ore supplies, both from abroad and from sources in the United States, will be adequate for the operation of the atomic energy program.

Exploration

The Nation-wide search for uranium-bearing ores is carried on both by the Government and private individuals. The Government program is conducted by the Atomic Energy Commission in collaboration with the U. S. Geological Survey, which among other work carries on extensive drilling operations on the Colorado Plateau. Moderate amounts of workable ores have been located that add to the supply for area processing plants. In addition to the drilling program, 3,860 square miles of territory have been mapped and radiometric traverses totaling 28,000 miles made by auto.

The amount of ore processed in the Colorado Plateau area increased in 1949. The Commission continued its investigations to locate and measure the extent of the large low-grade deposits in various parts of the country which might be worked if processing costs were no object.

Mineralogical research was initiated to determine the origin and manner of occurrence of uranium and its associated elements and to identify the primary minerals of uranium ores. Columbia University and the University of Minnesota are assisting in these investigations.

Growing interest of individuals and firms during 1949 in the search for uranium was evidenced by:

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a) Receipt during 1949 of about 1,200 samples of ore each month from private individuals as compared to about 400 a month received in 1948.

b) Receipt by AEC of about 700 inquiries each month concerning the domestic uranium program.

c) Sale by private dealers to private buyers of about 400 Geiger counters per month.

d) Sale of approximately 40,000 copies of the prospector's guide since its issuance in June. This booklet, jointly issued by the U. S. Geological Survey and the Atomic Energy Commission, and titled, "Prospecting for Uranium," is on sale by the Superintendent of Documents, Washington, D. C.; its price is 30 cents; it gives the laws and regulations which affect uranium prospectors, and tells how to use Geiger counters and other devices for detecting radioactive minerals.

As a result of intensified exploration, a large number of uranium occurrences were reported during the year. Though most of these will be of no commercial importance, a few now being explored promise to be of some value in production.

Ore Mining and Buying

Domestic production is still confined to the ores of the Colorado Plateau and is carried on by mining companies and small operators on both privately owned and Government-owned properties.

Within the last year, the number of mines being operated increased nearly 100 percent and mine employment over 200 percent. Deliveries have been stimulated by:

a) Guaranteed prices for uranium-vanadium ores for 5 years.

b) Procurement of ores previously unmarketable, such as high lime carnotites.

c) Leasing of Commission-owned properties to private mining companies.

The ores are delivered to privately owned processing plants and to the AEC plant at Monticello, Utah. An ore-buying station at Monticello is operated for the Commission by the American Smelting and Refining Company. Carnotite ores containing a high percentage of lime are accepted only at the AEC Monticello buying station.

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Ore-Processing Operations

Five plants for the production of uranium precipitates and concentrates from domestic ores are now operating on the Colorado Plateau. Two of these five plants started operation within the last 6 months. The Vanadium Corporation of America plant in the White Canyon District started in July. (Copper-uranium ores are being processed at this plant only.) The Monticello processing plant, owned by the Commission and operated by the Galigher Company, was the latest to be placed in operation, starting the first of September.

A sixth plant, the last and largest of the plants in the original program, will begin operation during the first part of 1950, as soon as rehabilitation is completed. This is the U. S. Vanadium Corporation-owned plant at Uravan, Colorado.

Foreign Sources

Steps were taken during the year to assure a continuing supply of raw materials from foreign sources.

In November representatives of the U. S. and the U. K. continued discussions with representatives of the Government of the Union of South Africa in Johannesburg on problems relating to the eventual production of uranium in that country. Uranium has been found occurring as a minor constituent in certain South African gold-bearing ores. Further discussions are expected.

FEED MATERIALS

The Commission and its contractors have considerably increased the efficiency of operations producing feed materials in their various phases—brown oxide and green salt of uranium, uranium hexafluoride gas, and uranium metal. The plants improved processes, consolidated flow lines of materials, and instituted additional safeguards over workers' health. Satisfactory stockpiles of feed and intermediate materials were built up to assure continuity of production.

There were major developments in the feed materials system during the year. The New Brunswick Laboratory for assaying materials came into full operation with a schedule of approximately 1,300 chemical determinations a month. Operations began in a new process plant for making brown oxide of uranium. Construction started on a new uranium metal plant. Plans were drawn for a new uranium hexafluoride plant which will cut costs and increase productivity. Design was initiated for a new green salt plant. This plant and the new metal plant both will improve health conditions for workers,

give better control over quality, and help assure continuity of production.

FISSIONABLE MATERIALS

The plants at Hanford and Oak Ridge turned out more fissionable materials during 1949 than in any previous year. This production was accomplished in facilities, initially constructed during 1942–45, which have been improved with consequent extension of their useful life, increase in output, and lower costs per unit of product. During this year of record output there were fewer employees engaged in the production of fissionable materials than at any previous time.

Completed during 1949 and put into operation at Hanford were a new reactor to produce plutonium, and a large new plant to fabricate plutonium metal. At Oak Ridge, construction started on an addition to the gaseous diffusion plant which separates fissionable uranium 235 from nonfissionable uranium 238. The new plant incorporates advances in design to improve the efficiency of this process.

The 165-mile pipeline to supply natural gas for the steam-electric plant of the gaseous diffusion operation was completed, and the Oak Ridge installation entered 1950 with greater assurance of uninterrupted fuel supply and a lower cost of power generation.

Future Construction

Detailed plans were worked out during the year, for still further expansion of the plants for producing fissionable materials. The plans call for an expenditure of about 226 million dollars over a period of some 3 years by the Atomic Energy Commission. In addition, the Tennessee Valley Authority plans to erect facilities to help meet expanded power needs at Oak Ridge resulting from this program. The AEC plans include another large-scale addition to the gaseous diffusion plant at Oak Ridge (besides the expansion mentioned above), additions to the plutonium production plants at Hanford, Washington, plus other auxiliary facilities. In October, the President authorized the beginning of this program, drawing on funds available to the Commission. By the end of the year preliminary work was well advanced. Ground had been broken at several of the sites. Parts of the construction will be finished during 1950, and the current program should be completed in 1952.

Construction will start during the first half of 1950 on the first of the new facilities for an improved process of separating plutonium from the irradiated slugs. The first facilities are expected to be completed early in 1951, and the entire system ready about a year later.

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COMMUNITY OPERATIONS IN PRODUCTION CENTERS

The communities of Oak Ridge and Richland during 1949 continued to develop as desirable places of residence. Costs of operation to the Government were cut. Highlighting the trend at Richland was considerable privately financed commercial development. Oak Ridge sharply reduced costs of community operations, and plans further reductions through the present and next fiscal year.

Richland, Washington

Construction of commercial buildings by private capital at Richland reached a peak during the last half of 1949. Estimated investment by private capital in this town of 21,000 totals $1,302,300 to date.

In the last 6 months of 1948 construction started on two structures for two businesses at an estimated total cost of $198,000. During the first half of 1949, construction started on eleven buildings to house 18 businesses at an estimated cost of $270,700. During the past 6 months' period, private capital undertook the financing of construction on 18 structures to house 30 businesses at an estimated cost of $833,600.

Church organizations are leasing land and building churches.

Oak Ridge, Tennessee

A long-term leasing policy was adopted at Oak Ridge, a town of 32,000, during the last 6 months which establishes favorable conditions for private commercial development at that location. Church organizations are buying sites at Oak Ridge and are erecting their own churches.

Actual costs incurred for Oak Ridge community operations during the fiscal year 1949 were $7,371,906. For the present fiscal year, it is estimated that operating costs will be approximately 42 percent lower. These reductions are due principally to:

a) Reorganization which reduced operating personnel, including employees of schools and contractors, from a total of 5,172 on July 1, 1948 to 3,145 on June 30, 1949, and will further reduce it by June 30, 1950.

b) Rental increases resulting in increased revenues.

c) Reductions in Government-furnished services to residents and concessions.

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d) Transfer of operation of the hospital to a board of trustees organized as a nonprofit corporation.

e) Various operating economies resulting from a critical analysis of the operation of municipal activities.

This program of reducing community operating costs at Oak Ridge will complete the initial comprehensive program to place this community on an efficient operating basis. Further reductions are expected, but these undoubtedly will be less spectacular and must come from refinements of individual features of the community management program.

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II

MILITARY APPLICATION

Progress in the United States program for development of atomic energy was marked during 1949 by significant action in the field of military application, including:

a) Change-over in the weapons production system from a laboratory to an industrial type of operation.

b) Establishment of the branch laboratory at Sandia, near Albuquerque, New Mexico, as a separate facility and transfer of its operating contract to an industrial contractor.

c) Developments in weapons leading to the requirement for full-scale test operations and improvements to proving ground facilities.

d) Construction of facilities to replace temporary war-built structures at Los Alamos Scientific Laboratory.

e) Improvement of community facilities and services maintained for the personnel of the weapons research center at Los Alamos.

PRODUCTION

The program for establishment of the weapons manufacturing activity on a production basis, reported on previously, was practically completed in 1949. This was, in effect, a change-over from what might be called a laboratory operation, stemming from the "custom built" nature of the original bombs, to a system in which the product as well as the facilities, equipment, and production techniques have been designed and engineered with a view to faster and more efficient production.

Several significant advantages have been gained by this change-over. The Los Alamos Scientific Laboratory has been relieved of a burdensome production operation which interfered, and was inconsistent, with the primary responsibility of the Laboratory in the field of research and development. A strategically important dispersal of the production facilities has been effected, thus reducing the vulnerability of the weapons production chain in event of war. In addition, it permits new developments to be incorporated more rapidly in the finished weapons.

SANDIA LABORATORY

The change in status of the Sandia Laboratory from a branch of the Los Alamos Scientific Laboratory, operated under a research contract with the University of California, to a separate facility under an industrial contractor, was an important factor in the general expansion of the weapons program. On November 1, 1949, the management and technical direction of the Sandia Laboratory was taken over by the Sandia Corporation, a wholly owned subsidiary of the Western Electric Company formed for this purpose.

The Sandia Laboratory is the field point of coordination of weapons development with the armed forces. The laboratory is located adjacent to the military installation directly concerned. The proximity of the Los Alamos facilities and personnel makes possible an effective integration of all interests involved.

TEST OPERATIONS

In the summer of 1947, the Commission established a proving ground at Eniwetok in the Marshall Islands for the testing of atomic weapons. Proof-testing is a necessary and continuous part of any weapons development program. During the last year, the Commission found it necessary to make substantial improvements in the facilities at Eniwetok, both to restore and replace wartime structures damaged by the elements and to provide more adequate technical facilities.

The planning for test operations is naturally closely geared to weapons research and development progress. In order to obtain the fullest possible return on any given test operation, very extensive preparations must be made among a large number of agencies of the Department of Defense and the Commission. In connection with the current weapons development activity, a series of tests is being planned and a joint task force has been formed to carry out the operations.

CONSTRUCTION

During the war years, buildings were located and erected at Los Alamos on a time schedule which permitted scant consideration for long-range adequacy, desirable working conditions, cost of maintenance or operating efficiency. Quick housing for men and equipment was the governing standard.

Shortly after the war, work was begun on plans for a permanent laboratory, with modern and efficient buildings for research operations in the fields of weapons technology, chemistry, physics, metallurgy, and shopwork. Construction was started in 1948 on new research

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facilities removed from residential and administrative areas, and in 1949 considerable progress was made toward completion of the permanent facilities.

The technical facilities construction program envisions the eventual replacement of the temporary structures built during the war to house weapons-research operations. Demountable frame structures, metal huts, and various temporary buildings will be replaced by buildings designed for the specific types of work, less costly to maintain, easier to protect, and safe and efficient for continuing work.

A replacement and expansion program is nearing completion at Sandia. New laboratory and test facilities, administrative and shop buildings, utilities, roads, and housing are included in the program.

LOS ALAMOS COMMUNITY

The community of Los Alamos has continued to develop facilities and services which make it a more satisfactory place to live. A separate Los Alamos County was established and added measures for self-government by the residents were developed.

Commercial Facilities

The only major expansion of commercial facilities during 1949 was in the community center cafeteria. However, continued growth of the community has necessitated developing plans for additional construction and commercial concessions. The Lodge and the community eating facilities no longer are operating at a deficit.

Plans were virtually completed for transferring the hospital to a board of trustees, which will administer the hospital as a nonprofit corporate entity under a contract with the Commission. As a first step, the board of trustees has appointed a trained lay hospital administrator.

Housing Program

The following comparative figures on the Los Alamos housing program show the increase in permanent dwellings and the reduction in temporary quarters:

Type of Accommodation	*Jan. 1, 1949*	*Dec. 31, 1949*
Family-type quarters	1,952	2,637
Dormitory rooms	1,333	1,301
Barrack beds (open bay—Army type)	573	215
Trailer spaces	160	160

During the year over 900 family-type facilities were approved for construction.

Self-Government

By an act of the Congress approved March 4, 1949 (P. L. 14, 81st Cong.), the Federal Government gave back to the State of New Mexico its exclusive jurisdiction over the Federal lands included in the Los Alamos project, in Sandoval and Santa Fe counties, New Mexico, so that the people of the community could become citizens of the State. The Federal Government still owns the land, but by this action, and the acceptance of the retrocession by the Governor of the State of New Mexico, Los Alamos passed under State law. The New Mexico State Legislature established the federally owned land on which Los Alamos is located as Los Alamos County. The Governor of New Mexico appointed three county commissioners who, in turn, have appointed the necessary county officials. Los Alamos citizens now have available the legal remedies and recourse to State courts enjoyed by citizens in all other parts of the State. Los Alamos County is a legal entity for voting purposes, and the county sheriff can enforce State laws within the county.

The Los Alamos County School Board took over operation and management of the school system in September. An agreement between the board and the Commission provided that the board will use the AEC-owned school plant and that the Commission will furnish to the board financial assistance for school costs. The board is responsible for the academic standards of the school operation. Pursuant to the State law the Los Alamos school system received $160,000 in State grants for its operations in the school year 1949–1950. It is expected that the State distribution of school grants will increase and finally stabilize at a higher figure as a result of the creation of Los Alamos County.

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III

REACTOR DEVELOPMENT

In advancing the development of nuclear reactors, during the last year, the Commission—

a) Established the Reactor Testing Station in Idaho and started work in preparation for the first two reactors to be built there.

b) Contracted for construction of a nuclear reactor intended to test the practical feasibility of converting nonfissionable material into fissionable material more rapidly than it consumes its nuclear fuel (the Experimental Breeder Reactor). Ground has been broken for this reactor at the Reactor Testing Station in Idaho.

c) Brought to final stages of engineering design a reactor of high neutron intensity to be used to test materials for use in other reactors (the Materials Testing Reactor).

d) Advanced engineering design upon a reactor to produce useful power and to test the feasibility of breeding fissionable materials at the intermediate neutron-energy levels while producing power (the Intermediate Power-Breeder Reactor).

e) Carried out research directed toward planning a land-based prototype of a nuclear reactor designed to power a submarine or other naval vessel. Engineering design is expected to begin during 1950.

f) Sponsored and carried out research directed toward the design of other promising types of reactors, particularly for use in airplanes, and further supported research toward the solution of the scientific and engineering problems of reactor design (discussed in Part II of this report).

The Reactor Development Division of the Atomic Energy Commission, organized a year ago with responsibility for directing the programs in this field, carried forward construction at the laboratories and other installations under its direction; took over and set up operations offices; initiated and participated in numerous programs for cooperation between the atomic energy industry and other industries; and arranged for the training of engineers and scientists in the par-

ticular problems of reactor design and operation (Chapter VII). The Reactor Development Division's operations offices are:

SCHENECTADY, N. Y., home of the Knolls Atomic Power Laboratory, operated for the AEC by the General Electric Company.

CHICAGO, Ill., home of the Argonne National Laboratory, operated for the AEC by the University of Chicago, and center of reactor development.

IDAHO FALLS, Idaho, near the new Reactor Testing Station.

THE REACTOR PROGRAM

Nuclear reactors are machines for putting nuclear energy to work under controlled conditions. In contrast, an atomic bomb explosion is instantaneous, an uncontrolled nuclear reaction. Under controlled conditions, the amount of nuclear fuel that is destroyed in a small fraction of a second by an explosion may be utilized for months and perhaps even years to give off useful energy.

Reactors vary enormously according to the purpose for which they are intended. Some may operate at temperatures below the boiling point of water; others may generate heat which must be carried off or put to work by the use of molten metals as coolants. A reactor, using high energy neutrons to cause fission—a so-called "fast" reactor—might fit into a good-sized studio living room. A reactor such as those at Hanford, using slow neutrons moderated from their high initial energies by graphite, may be as high as a five-story building. A reactor to generate useful power will be designed primarily for high temperatures; a reactor to breed fissionable material will have as its primary design feature the utmost conservation and utilization of the neutrons it produces and may also be designed for generation of useful power.

The reactors now operated for the national atomic energy enterprise are used for research and to produce fissionable material and radioisotopes for scientific, medical and industrial use.* The reactors of the future, developing from those being designed, or from others planned on the basis of expanding knowledge, may generate useful power, drive ships or airplanes, or breed extra fissionable material.

After consulting with various interested groups, including the General Advisory Committee, the Commission decided upon four

*The nuclear reactors in operation at AEC installations include: in the thermal neutron energy range, the Hanford reactors, two reactors at Argonne, one at Oak Ridge, and the Los Alamos "water boiler;" in the fast neutron range (in which neutrons cause fission at energies above several hundred thousand electron volts), the Los Alamos fast plutonium reactor.

Being designed, or under construction, are three thermal reactors, the one at Brookhaven, a Navy ship propulsion reactor, and the Materials Testing Reactor; in the intermediate neutron energy range, the Knolls Intermediate Power-Breeder Reactor; in the fast neutron range, the Experimental Breeder Reactor.

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from among a number of reactors proposed by different scientists. In the following sections, this report discusses the reactors currently being designed and others being advanced by preliminary research.

Experimental Breeder Reactor

Late in 1949, preliminary construction started on the Experimental Breeder Reactor at the Reactor Testing Station in Idaho. A contract was awarded to the Bechtel Corp., of San Francisco, to perform the major construction work on this reactor, the first to be built at the new station. Work is scheduled to be completed by the end of 1950.

This is a reactor designed to test the feasibility of transmuting non-fissionable material into fissionable material in the "breeding" process that produces more fissionable material than it consumes. The nuclear design of this reactor was completed by the Argonne National Laboratory and detailed architect-engineer design work was done by the Austin Co., of Cleveland.

The Bechtel Corporation will build the steel, brick, and concrete reactor structure, and install the ventilation, cooling, and other auxiliary equipment. The reactor core—heart of the nuclear machine—will be furnished by the Argonne National Laboratory, where it is being designed and built.

The EBR will operate with fast neutrons and, besides testing the feasibility of breeding, will investigate the application of molten metals to the removal of fission-produced heat from reactors at high temperatures. The reactor is designed to produce a small amount of useful power as a byproduct. It will be built at a remote site so that it may be operated at as high a power level as possible.

Materials Testing Reactor

The Materials Testing Reactor was in advanced stages of engineering design by the Blaw-Knox Co., of Pittsburgh, as the year ended. Choice of a construction contractor is expected during the winter. Actual construction at the Reactor Testing Station is expected to get under way this spring. The scientific design of this reactor is a cooperative effort by the Oak Ridge and Argonne National Laboratories.

This reactor's primary purpose will be to provide facilities to test the materials which may be used in future reactor construction. It is important to learn in advance how various materials that might be used in the structures, cooling systems or shields will behave under intense neutron bombardment.

This test reactor will help particularly in the development of reactors for the propulsion of aircraft, since it points in the direction of

compact, high radiation density reactors of a sort which must ultimately be developed if aircraft are ever to be propelled by atomic energy.

Intermediate Power-Breeder Reactor

Engineering design by the General Electric Co. on the Intermediate Power-Breeder Reactor neared completion at the end of the year. The General Electric Company is now drawing up a feasibility report, a complete engineering design, and a cost estimate. If the design and cost estimate are approved, it is hoped that construction can begin in 1950 at the West Milton reactor site near Schenectady, N. Y.

The intermediate power-breeder reactor is designed to explore fully the possibility of producing significant amounts of electric power by utilizing neutrons in the intermediate energy range while breeding fissionable material at the same time. If successful in both, this reactor would represent a major step in the direction of the production of useful power without depleting—and possibly even increasing—the national supply of fissionable material. To date, no reactor has been built to operate in the intermediate energy range. As in the Experimental Breeder Reactor, the heat energy of the intermediate reactor will be removed by molten metal. This heat will then be used to generate power through conventional means.

Prototype Navy Thermal Reactor

The Argonne National Laboratory and the Westinghouse Electric Corporation are developing designs for a land-based prototype of a thermal reactor suitable for submarine or ship propulsion.

This reactor will be a single purpose machine designed specifically for the purpose of producing large amounts of heat under conditions that will permit conversion to power for naval vessels.

Research and development work is well advanced, and detailed engineering design of a ship propulsion reactor is scheduled to begin during 1950. Engineering work is under way to develop the novel equipment and components required in a complete nuclear power plant to adapt them to the special conditions to be encountered in the generation of power from nuclear energy.

Research on Other Reactors

The four reactors described above are under construction, are being designed, or are in an advanced stage of development. A number of

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others are in much earlier stages of investigation or study. Probably not all will be designed and built.

Prototype intermediate Navy reactor. Late in the year, effort was stepped up on studies by the General Electric Company toward an intermediate energy, liquid metal-cooled nuclear reactor for ship and submarine propulsion. This study will benefit from experience with the Knolls intermediate power-breeder reactor which will serve as prototype for a number of features of design.

Homogeneous reactor. Another possible new type of reactor is called a homogeneous reactor. All reactors constructed in the United States so far, except for one small experimental unit at Los Alamos, have been built upon the principle of embedding fissionable fuel elements in other solid materials used for reflecting and moderating purposes. Scientists have studied and restudied the question of whether they could design a feasible and practical reactor in which fuel, moderator and coolant were all mixed together—hence, the term "homogeneous reactor."

These studies are being carried further, since they present the interesting possibility that the nuclear reaction, the removal of energy, and the reprocessing of nuclear fuel could all be put together in one extended unit, and production of fissionable material, for example, might be carried on in continuous, instead of "batch," operations.

Improved research reactor. Studies are being carried out on the design of an improved research reactor by North American Aviation, Inc. The goal is a unit, designed primarily for research and training, which can be built at a much more modest cost than any of the reactors discussed here.

Aircraft Reactors

During the second half of the year, the Atomic Energy Commission pooled efforts with the U. S. Air Force, the National Advisory Committee for Aeronautics, and the Navy's Bureau of Aeronautics in a cooperative program for developing aircraft nuclear propulsion. The AEC's part of the research is being carried on at the Oak Ridge National Laboratory.

Last fall, a committee composed of the technical directors of the laboratories working on the aircraft nuclear propulsion program was formed to give technical guidance to the program.

In this program, the Oak Ridge National Laboratory is engaged primarily in making shield measurements with the research reactor there, and in developing materials that will resist high temperature and intense radiation. The Laboratory is also beginning an over-all study of the proposed reactor itself.

These AEC activities follow a coordination of the work of various agencies toward the use of nuclear power in aviation achieved through the Ad Hoc Committee for Aircraft Nuclear Propulsion.

The present course of action is in accordance with the recommendations of the so-called Lexington report, prepared in 1948 by the Massachusetts Institute of Technology under contract with the Commission.

REACTOR TESTING STATION

In the interest of public safety, operational economy, and security, the Commission in the fall of 1948 determined to establish in a remote location a Reactor Testing Station capable of accommodating a number of the newest and most powerful reactors then under design. Accordingly, with the cooperation of the U. S. Army Corps of Engineers and the U. S. Geological Survey, more than 70 possible locations in various parts of the country were surveyed on the basis of such factors as isolation, accessibility, availability of water supply and favorable meteorological conditions.

As a result of the surveys, the Commission last March announced that it had selected a 400,000-acre site in the Snake River plains of southern Idaho—including 173,000 acres of Naval Proving Ground property near the town of Arco—as the best location for the new station.

Development Under Way

The Commission's Idaho Operations Office, set up in May at Idaho Falls, Idaho, started development of the site last summer. By December 1, when custody of the Naval Proving Ground was formally transferred from the Navy to the Commission, work on roads, water lines, wells, excavations, and utilities was under way. Ownership of the Naval Proving Ground property, including shops, warehouses and other buildings, is to be transferred to the Commission early in 1950, in accordance with authorization contained in the Independent Offices Appropriation Act for fiscal year 1950.

At the end of 1949, a survey to determine the precise boundaries of the remainder of the site was being carried out with the assistance of the U. S. Bureau of Land Management and the U. S. Army Corps of Engineers. All except about 20,000 acres of the land to be taken over already is owned by the Federal Government or the State of Idaho.

The Commission is now preparing to build two of its new nuclear reactors at the Idaho Testing Station—the Experimental Breeder Reactor and the Materials Testing Reactor.

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Committees

A special committee has been appointed by the Idaho Operations Office to advise on chemical and metallurgical processing in the development of the Reactor Testing Station.

During 1949, the Reactor Safeguard Committee of the Atomic Energy Commission represented the United States at a three-nation conference on reactor safeguards and related subjects held in the United Kingdom. Topics included: environmental and meteorological studies connected with handling radioactive wastes; studies of biological tolerances to radiation of plants, animals, and human beings; reactor hazards as a result of malfunction of reactor structure or controls, accidental errors of operation, and sabotage.

Findings of the committee helped fix standards for locating the Station, and have been of fundamental importance in determining ultimate design characteristics and locations of reactors now programmed.

West Milton Reactor Site

In the fall of 1948 the Commission concluded that location of the planned Intermediate Power-Breeder Reactor in the Schenectady area would substantially enhance the value of the General Electric Company's contribution to reactor development by encouraging maximum utilization of the company's specialized facilities and manpower. After consideration of seven sites in the Schenectady area, the West Milton location was selected and acquired. Preliminary development was under way when the year closed.

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IV

BIOLOGY AND MEDICINE

The Atomic Energy Commission continued to sponsor research on medical and biological applications of atomic energy.

As part of its general program for medical research, and to assist in supplying technical information useful in civil defense planning, the Commission has put new emphasis upon diagnosis and treatment of radiation injury. In the field of biology, research includes soils, plant diseases, radiobiology, aquatic biology, genetics, animal pathology, and physiology.

Progress in research in all these fields was reported in some detail in the Sixth Semiannual Report, submitted to the Congress in July 1949, and work with isotopes was covered in a special report issued in October. These findings, and a flow of information distributed in professional circles through many scientific and technical reports (see pp. 161–169), are the results of the research work of some 1,250 scientists in various medical and biological fields.

During the fiscal year 1950, the AEC is investing about 19 million dollars in biological and medical research, distributed 10 million dollars for investigations in major Government-owned installations, 2 million dollars in three major university-owned, atomic energy laboratories, and 7 million dollars for research in private industrial, and educational institutions and in other Government agencies.

MEDICAL RESEARCH

The AEC sponsored medical research in the general field of acute radiation effects and their control at the Brookhaven National Laboratory; the Argonne National Laboratory; and the AEC projects at the University of California, Los Angeles; University of California, Berkeley; and the University of Rochester. In addition, research contracts involving direct attacks on the problem are active at New York University, University of Chicago, the Army Medical Center, and the University of Oregon. These investigations are beginning to bear fruit.

For some time it has been realized that with the depression in the blood cells and antibodies that occurs with radiation injury, individuals are markedly sensitive to infection. The result of infection was evident in the Japanese victims at Hiroshima and Nagasaki who

showed extensive ulceration and blood poisoning in many instances. One highly important advance has been the demonstration at the Atomic Energy Project, University of Rochester, that the antibiotic aureomycin, which helps control infection, has decreased the mortality rate in rats and dogs exposed to lethal and near-lethal doses of radiation. Aureomycin appears to prevent invasion of the blood stream by many disease-producing organisms. Attention is now also being directed to the effects of penicillin, streptomycin, and other antibiotics on the acute radiation syndrome which develops in people exposed to lethal and near-lethal doses of radiation.

Cooperative work on antibiotics carried out at the Argonne National Laboratory and the University of Chicago and supported jointly by AEC and the Army, seeks to determine the effects of antibiotics in animals exposed to acute radiation with particular emphasis on (*a*) bacteriological studies, and (*b*) tendencies toward bleeding met with in this condition. In the same laboratories, work supported by the AEC has pointed up the remarkable effect achieved in reducing the mortality of experimental animals when a radiation-resistant shield, such as lead, is placed about the animals' spleens at the time they are exposed to acute radiation.

At the University of California in Los Angeles similar striking reductions of mortality have been obtained by another method. At the time the experimental animal is exposed to radiation, it is deprived of normal air and inhales an atmosphere consisting almost entirely of nitrogen gas. Animals exposed to an ordinarily lethal dose of radiation under these conditions have survived the exposure.

This type of research is now being supported at a level of approximately one million dollars annually, and is expected to continue at this, or a higher, level in the immediate future.

Research on chemical and radioactive hazards associated with handling essential materials in the atomic energy enterprise continues to receive a major share of the emphasis at the national laboratories and other AEC projects. Support for this work alone, excluding the general field of radiation effects from high energy sources, radioactive waste handling studies and the like, is at a level of well over 3 million dollars a year.

In addition to the above, the AEC is currently sponsoring investigations at several universities at a level of approximately $100,000 a year on the problem of radiation cataracts—a blindness caused by opacity of the lens connected with radiation exposure.

BIOLOGICAL APPLICATIONS

The program on the effect of atomic energy and its products on the various forms of animal and plant life was expanded in both AEC in-

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stallations and through the support of work at colleges and universities. Important advances have been made during the year towards understanding the mechanism of the biological effects of radiations. For example, the occurrence of genetic changes from radiation is directly related to the amount of oxygen available to the cells or organism irradiated, a discovery which finds an echo in the work described above concerning animals exposed to radiation when they are deprived of oxygen during the exposure.

At the Hanford Plant the toxicity of fission products to aquatic life has shown that many lower forms of life, such as plankton (which include many forms of life from protozoa to jellyfish) tolerate very high levels of fission radioactive material. There is a species difference of more than tenfold among fish in their ability to tolerate radiations. A new biology building and animal experiment farm has made it possible to expand work with laboratory animals and with large animals on the toxicity of fission products.

At Oak Ridge a laboratory was completed this year for work with domestic animals. The laboratory operated by the University of Tennessee is studying the effects on cattle of the dust outfall from the atomic bomb tested at Alamogordo in July 1945. Radioactivity of the various tissues and organs is being determined, the pathological effects, if any, are being studied.

In the field of agriculture, important research contributions have been made on the rate of uptake and utilization of nutrients from fertilizers which may mean a saving of thousands of dollars to the farmers of the country. They have found that certain forms of phosphate are poorly utilized by crops, and that soil acidity is an important factor in the utilization of phosphate fertilizers by certain farm crops.

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V

FINANCE

The Commission has put into operation some improved methods of cost control and financial reporting. A budget has been prepared for the fiscal year 1951, which is based on accrued costs and performance. The 1950 budget has been converted to such a cost basis. Periodic reports have been prepared which compare costs of the Commission's activities and programs with budget estimates. The information needed to provide a firm beginning balance sheet for the current fiscal year has been developed, and financial statements similar to those used by industrial concerns are being prepared.

As a part of continuing study given to the integration of budgeting and accounting within the Commission, early consideration had been given to presenting the Commission's annual budget on the basis of costs of various operations and activities. During the spring of 1949 it appeared that this was not only feasible but had become essential. Integrating the budget and the cost accounts with the general accounts posed a technical and administrative problem so long as the long-term commitments of the Commission were financed through annual appropriations.

In the Commission's 1950 budget, as in previous budgets, funds had been requested on the basis of estimated obligations by programs and activities. As a result of the difficulties inherent in presenting the budget request on such a basis, the House Committee on Appropriations stated in its report that, although the Commission's presentation was substantially improved over the previous year's, it was imperative that future budget estimates be integrated with accounting results and procedures. At the same time, the Congress facilitated the solution of accounting problems incidental to annual appropriations by providing for merging the unexpended balances of prior-year appropriations with the 1950 appropriation. The Commission immediately took steps to correlate its budget and its accounts and to prepare budget estimates for fiscal year 1951 on a cost basis.

THE COST-PERFORMANCE BUDGET

The general form and method of presentation of a cost-performance budget are different from those of the conventional Government-type budget. Standard Government fiscal practice has been to account

for funds on the basis of obligations and expenditures, recorded by object class and functional or organizational breakdown. Under such a system, an obligation is incurred and recorded when some evidence of the dedication of funds to a specific purpose occurs. The obligation is normally liquidated by the payment of funds. In budgeting, standard Government practice has been to budget for the obligations to be incurred in a given fiscal year and to relate such obligations to the things or services to be acquired, or to the agency's functions or organizational pattern. This type of accounting and this type of budget go together and can be related. Neither takes into account receipt of materials or services prior to payment, nor to any change in the use of assets after the payment occurs as, for example, the use of inventories.

By July 1, 1949, the Commission had installed an accounting system on the accrual basis as described in the Fifth and Sixth Semiannual Reports. In such a system, cost is incurred and is recorded when goods or services are used, not when the obligation is incurred or when the payment is made. This is the most satisfactory way to account for the activities of AEC or any similar enterprise. Under this system, the cost of lumber, for example, is charged to a function when the lumber is put into a specific job. It is usually impossible, at the time the lumber is received and paid for, to be sure how it will be consumed.

Tying Accounts to Budget

A difficult early financial problem experienced in the AEC was the inability to tie together cost reports and budget estimates. When the accounting reports were on a cost basis, it became logical to put the budget on a cost basis and integrate it with the accounts. In this way the budgeted cost for each program, subprogram and category is established, and the actual cost experience is matched with it month by month. In this way the AEC receives the full benefit of budgetary controls.

The budget on cost basis is the true performance budget now finding favor in Government. The usefulness of such a budget was stressed in the reports of the Commission on Organization of the Executive Branch of the Government. For the AEC, such a system has been established by budgeting for the cost of each program, subprogram and category under operations and construction. Programs, subprograms and categories are no longer presented on a basis of individual obligations, and the confusion in distinguishing between costs and obligations is thereby eliminated. After the cost has been estimated for each division and subdivision of the Commission's activities, the sum of the estimated costs is converted to a single total of obligations, by taking into account other transactions which also

require obligations. In the main, these transactions are changes in inventory, in working funds and in unliquidated obligations. Increases in these items are added to costs, and decreases are deducted from costs so as to arrive at the total obligational authority necessary.

In addition to presenting the budget estimates for 1951 on a cost basis, the Commission has restated the budget for 1949 and 1950 on a comparable basis. The Commission's accounting system provides for recording depreciation as a cost, but since the Commission requests funds for replacement of fixed assets only when such a replacement is actually required, the costs used in the budget estimates do not include depreciation.

To illustrate how the Commission's budget estimates are presented under the the cost-performance budget, the form used for setting forth the Commission's budget request is reproduced here.

Activities	Actual, Previous Year	Estimate, Current Year	Estimate, Budget Year Ahead
Operating program costs:			
Source and fissionable materials			
Weapons			
Reactor development			
Physical research			
Biology and medicine			
Community operations			
Program direction and administration			
Total			
Plant and equipment costs:			
Production facilities			
Research facilities			
Community facilities			
Administrative facilities			
Multipurpose facilities			
Total			
Cost of reimbursable work performed for other agencies			
Total costs incurred			
Increase or decrease in stores inventory			
Increase or decrease in cash working capital			
Increase or decrease in unliquidated obligations			
Transfers to or from other agencies without reimbursement			
Total obligations			

Once the budget has been established in this way, month-by-month performance can be judged and controlled by setting forth the monthly cost, the cost for the year to date, and changes in the items listed in the last section of the form—and comparing them with the corresponding amounts in the approved budget.

Since the Commission to an extent is pioneering in using this type of integrated accounting and budgeting, it expects to refine and improve the system as experience shows the way. Several years will probably be required to put the system on a smooth operating basis and to reduce its procedures to routine.

Summary of Costs

Estimated costs of the Commission's activities during the fiscal years 1949 and 1950 reported in the President's budget for the fiscal year 1951 are as follows:

	(*Millions of dollars*) Fiscal year	
	1949	*1950*
Operations	$293	$358
Plant and equipment	338	340
Totals	$631	$698

With the installation of a modern industrial accounting system, and development of a common basis for budgeting and reporting, those responsible for managing the atomic energy project are now beginning to get information of the type generally considered essential for effective financial administration. In addition to periodic financial statements on current operations of each AEC office and its contractors, the Commission receives reports comparing operating costs as incurred with the budget estimates—information not available before.

PROPERTY ACCOUNTING AND MANAGEMENT

A financial appraisal of the Commission's physical facilities, conducted with the assistance of public accounting and engineering firms, was substantially completed during 1949. This survey was preliminary to establishing accounts and procedures to provide better control over the Commission's plants and equipment.

The AEC has improved cost controls and cost accounting for its construction projects. Beginning in July 1949, all operations offices have prepared monthly cost statements on additions to, and retirements of, physical facilities. These reports help detect potential overruns on original estimates by making possible a comparison of costs incurred on individual projects with current estimates and the budget.

By the end of fiscal year 1949, all AEC offices and their major cost-type contractors had established accounts and procedures for inventory control over stores. Monthly inventory reports will provide information on current requirements and the size of stocks on hand, and also serve as a basis for inventory control.

Reducing Excess Property

Inventory reports will help solve the problem of excess property. The Commission has considerable excess property, some held over from Manhattan Engineer District, some held for construction of standby plants, and some left over because of cutbacks in construction

or modifications in design. Approximately 17 million dollars worth of AEC property was declared excess during the fiscal year 1949. Of this amount about 25 percent was utilized by AEC installations, about 25 percent transferred to other Federal agencies either directly or through the General Services Administration, and about 50 percent was on hand as of June 30, 1949.

During fiscal year 1949, the number of motor vehicles owned by the Commission was reduced by 15 percent. The Commission has over 7,000 passenger and cargo vehicles which are Government-owned but are operated and maintained for the most part by its contractors. Included are four fare-collecting bus systems. With the cooperation of the Bureau of the Budget, the Federal Interdepartmental Motor Committee, and the General Services Administration, the Commission is advancing toward its goal of providing safe and economical service with a minimum investment and low operating and maintenance cost.

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VI

AEC AND CIVIL DEFENSE PLANNING

The Atomic Energy Commission's chief responsibility in civil defense matters is to provide to the appropriate agencies, and to the public, such technical data as will help in planning in case of an atomic war. Methods, techniques, and areas of knowledge, of interest in this work, particularly knowledge about the effects of atomic weapons, are developed by the AEC in carrying out its primary functions.

The AEC has been designated by the National Security Resources Board as a participant in wartime disaster relief, over-all responsibility for which was assigned to the Government Services Administration.

Within the Atomic Energy Commission, the Division of Biology and Medicine is responsible for coordination of civil defense activities and for necessary liaison outside of the Commission. Other AEC divisions are responsible for preparation of information and for technical consultation in their respective functional areas.

TRAINING IN RADIOLOGICAL MONITORING

Training is one of the most important aspects of the national civil defense planning program. With the approval of the National Security Resources Board, the AEC has developed plans for two training courses, to begin early in 1950, which will deal with radiological monitoring and with the detection and treatment of radiation injury.

Courses in Monitoring

The first course, in radiological monitoring, will train individuals to detect, measure and interpret the levels of radioactivity which might result from an atomic explosion. This type of activity is entirely new, so far as civil defense is concerned, and requires the "teaching of teachers" who then can further disseminate the necessary information.

Courses will be offered at the Brookhaven National Laboratory, at Oak Ridge jointly by the National Laboratory and the Oak Ridge Institute for Nuclear Studies, and the Atomic Energy Project at the University of California in Los Angeles. Qualified teachers will be in-

vited to attend courses, after which they can establish programs for training individuals who would be responsible for actual monitoring. To provide instruction materials, the Commission is preparing a handbook and is arranging for other teaching aids including motion pictures, lantern slides and documents.

Medical Courses

The second teacher training course is designed to instruct physicians, nurses, dentists, and allied professions in the medical effects of atomic explosion. The disease state which results from acute overexposure to radiation is relatively new in medical education, and many physicians, nurses, and dentists require training in successful detection and treatment of the injuries and illnesses.

The first medical courses will open in March at three locations: Atomic Energy Project, University of Rochester; the Atomic Energy Project, Western Reserve University School of Medicine; and the Argonne National Laboratory. In April, similar courses will be initiated at the Johns Hopkins University School of Medicine; the University of Alabama School of Medicine; University of Utah School of Medicine; and the Atomic Energy Project of the University of California, Los Angeles. These courses will run for approximately one week and will cover modern methods in diagnosis and treatment of atomic injuries. Graduates of these courses will be expected to initiate similar courses in their own home areas.

EFFECTS OF ATOMIC WEAPONS

The Commission's knowledge concerning the effects of atomic weapons in each of six areas, listed below, is being constantly augmented through research and development programs. The areas include: (*a*) blast effects on personnel, (*b*) burns, (*c*) ionizing radiation injury, (*d*) shielding, (*e*) medical care for casualties and refugees, (*f*) radiological safety, including instrumentation for the detection and measurement of radiations.

Documentary Material

Both the Manhattan Engineer District and the Atomic Energy Commission have conducted research and published information on several of the above subjects. Some 160 documents issued by the MED or the AEC are useful in civil defense planning and operations and are unclassified or have been declassified. The majority of these have been published in professional and technical journals. Most of the

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medical and biological work will be included in the volumes of the National Nuclear Energy Series. (See Appendix 7.)

Additional classified papers have been made available to those officials and agencies entitled to such information. In addition, several hundred other classified studies provide background information. Unclassified medical papers, about 90 percent of the total issued, are regularly sent to 1,200 hospitals and institutions in all parts of the country.

A bibliography of pertinent unclassified documents has been prepared and forwarded to the National Security Resources Board for distribution to State and local civil defense authorities. An up-to-date revision of this bibliography will soon be available for purchase from the Government Printing Office, Washington, D. C.

The process of compiling material that will be valuable to those concerned with defense against atomic attack goes on continuously. As reported in the Fifth Semiannual Report of the Commission, the Department of Defense and AEC have jointly sponsored preparation, under the supervision of the Los Alamos Scientific Laboratory, of a book on the effects of atomic weapons. This volume is now complete and is being reviewed for declassification and publication. Two papers, based on its material, already have been forwarded to the NSRB for distribution by that agency to State authorities for use in civil defense planning. One paper dealt with the medical effects of atomic explosions, the other with blast damage to buildings and other structures.

The volume itself, first proposed by the Weapons Effects Classification Board established by AEC to advise on classification of weapons effects data, is designed both to aid in establishing limits on the unclassified areas of weapons effects information, and to contribute to military training and to civil defense planning. The basic scientific and technical data on which the weapons effects book is based are drawn largely from voluminous classified or unclassified reports within the Commission and the Department of Defense. If possible, the final technical volume will be published in its entirety as an unclassified document. If it is impossible to declassify for public use some information deemed vital for military training, the volume will be published in classified form and an abridged version will be prepared, unclassified, for general use.

OTHER ACTIVITIES USEFUL IN CIVIL DEFENSE

Throughout the atomic energy program are a number of projects and activities of value in general civil defense. For example, the Commission and contractors have—

a) Reviewed the hazards that might exist in AEC installations in event of an atomic disaster or attack and considered the best ways of

meeting them. Special studies have been made of Oak Ridge, Hanford, and the Washington Office.

b) Studied, selected, and begun assembling types of radiation detection instruments for use in event of an emergency.

c) Begun organizing in the Commission's major installations groups of emergency monitoring personnel trained to make radiation hazard surveys.

d) Collected (and are continuing to collect) all available data on the effects of atomic explosions on man, animals, plants, and physical structures.

e) Carried on research on the effects of radiation on living matter and its constituents. This is being done in AEC laboratories, in universities, hospitals, and in other research laboratories. Such research is essential in the Commission's efforts to develop methods for protection or treatment.

f) Arranged for training programs in the medical and biological sciences as they relate to atomic energy and health physics. Such trained personnel may well prove useful in radiological defense measures and in training others for such purposes.

g) Sponsored, in cooperation with the Armed Forces, special training courses in the medical aspects of atomic energy for selected Army, Navy, Air Force, and Public Health Service officers at Oak Ridge, Los Alamos, and four AEC regional training centers.

h) Participated on the Interdepartmental Working Committee of the National Security Resources Board on underground structures and protective construction.

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VII

INFORMATIONAL AND EDUCATIONAL SERVICES—PUBLIC AND INDUSTRIAL

The Atomic Energy Commission took steps during the last year to open new channels, within the limits imposed by the requirements of national security, for providing informational service to the public and to industrial, technical, and educational groups. New advisory committees and working committees were established. Additional training courses open to industrial engineers were initiated. Assistance was given public school systems in a number of teacher-training programs.

In August, a three-man advisory committee from the electric power industry was appointed to study the AEC reactor-development program, to search out areas of mutual interest to the industry and the Commission, and to make recommendations for continuing cooperation. The Commission believes that the activities of this committee may point up ways and means by which cooperative arrangements may be worked out with other industrial interests that do not directly take part in the atomic energy program.

In September, a working committee of representatives of engineering societies, and of the business press, was appointed and cleared under security regulations, to examine classified technological information and determine whether metallurgical data and techniques developed in the atomic energy program may be of potential use to industry generally. Where it is determined that the value to industry of certain types of information may outweigh the value of keeping it secret, the information will be considered for declassification.

In the field of general public information, the Commissioners established a policy of holding monthly press conferences in an effort to keep the public better informed about atomic energy activities. Press seminars were held, at the instance of correspondents and of members of the American Society of Newspaper Editors: in Minneapolis by the University of Minnesota in January; in Washington in March; and in San Francisco-Berkeley by the University of California in September. In addition to its regular semiannual reports, the AEC issued special reports on isotopes, and on handling radioactive wastes, and supplied background material to civil defense agencies. Jointly with the U. S. Geological Survey, the Commission in

May issued "Prospecting for Uranium." Two booklets were issued: one describing how to do business with the Commission was issued to assist smaller business concerns; another to assist contractors.* (Scientific and technical information—for the public and within the atomic energy enterprises—is handled through an extensive program discussed on pp. 161–169.)

Cooperating with various State and city school systems and schools of education throughout the country, the Commission has aided in the establishment and conduct of in-service training courses and workshops for teachers, intended to acquaint them with the facts and implications of atomic energy, and thus better to prepare them for presenting the subject in the classroom. To date, some 20 such teacher-training programs have been conducted, of varying periods of duration—from a few days to 20 weeks.

All such programs have been sponsored, financed, and operated by individual colleges, universities, school boards, or teacher associations.

Teacher-training programs in which the Commission has aided include those sponsored by such groups as the New England School Science Council, Harvard University, the Rhode Island College of Education, Keene (N. H.) Teachers' College, the Board of Education of the City of New York, the Board of Education of the City of Baltimore, the Board of Education of the City of Chicago, the University of Illinois, the State University of Iowa, the University of Nebraska, New York University and the Reno, Nevada, Classroom Teachers' Association.

TRAINING COURSES

Among various training courses sponsored by the Commission were those connected with work in development of nuclear reactors. To help provide the combination of skills required for men who can work on reactors, operate these machines, and take part in their application to power generation, as well as to assist in introducing this type of education, the Commission has cooperated in a number of short courses open to engineers of industrial firms and is planning others.

Navy courses. Nearly 300 persons participated in four courses of 17 to 28 weekly lectures at the Bureau of Ships, Navy Department, Washington; Babcock & Wilcox Co., Alliance, Ohio; Allis-Chalmers Co., Milwaukee, Wisconsin; and Westinghouse Electric Corp., Pittsburgh, Penna. These were briefing courses aimed at acquainting officers and civilian enginers employed in the design of ships—and,

*"Contracting and Purchasing Offices and Types of Commodities Purchased" and "A Guide for Contracting of Construction and Related Engineering Services." Superintendent of Documents, Washington 25, D. C., 10 cents each.

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in industrial concerns, the executives—with installation of reactors on shipboard. A new Navy course, to start in January 1950, will include representatives from the Chief of Naval Operations, the Joint Chiefs of Staff, and the Atomic Energy Commission. Additional courses are planned for early presentation at the Portsmouth Naval Shipyard, Portsmouth, N. H., and at the Electric Boat Company, Groton, Conn.

Oak Ridge course. To give more highly specialized training, the Atomic Energy Commission Reactor Development Training School has been established at Oak Ridge National Laboratory. The school will accept engineers from industrial organizations who will remain on their companies' pay rolls, employees of other atomic energy laboratories or other Government agencies, or recent college graduates engaged by Oak Ridge National Laboratory who, after training, will be available for transfer to other reactor groups. The industrial participation is in accord with proposals made to the Commission by professional and engineering groups. The school will operate continuously; courses will last 9 months each year, starting in September 1950, and 90 students will be taken at a time. A small pilot group of trainees will start a course in March 1950.

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VIII

ORGANIZATION AND PERSONNEL

LABOR-MANAGEMENT RELATIONS

Since its appointment in April 1949, the Atomic Energy Labor Relations Panel has handled 6 labor-management cases in atomic energy installations. All of these were resolved without either work stoppage or formal recommendation by the Panel.

A difficult case during recent months arose at the Oak Ridge National Laboratory. Concerning negotiation of this settlement, the Commission on October 12, 1949, wrote Mr. William H. Davis, chairman of the Labor Relations Panel, as follows—

> We learn with great gratification of the latest success of the Panel in settling the dispute at the Oak Ridge National Laboratory. The admirable way in which the Panel has taken hold, effectively but with self-restraint, is a source of great reassurance to us all.

During the last year, virtually all operating and maintenance contractor-operators and recognized unions at AEC installations accepted a major recommendation of the President's Commission on Labor Relations at AEC installations—to avoid all interruptions of vital operations during negotiations and bargaining. A report of the Atomic Energy Labor Relations Panel on its work between April and November of 1949 is included in this report as Appendix 8. The full report of the President's Commission was included in the Sixth Semiannual Report of the AEC.

A stoppage of construction work at Oak Ridge occurred on December 7, 1949. The stoppage, which involved a dispute about employment of non-union workers by one contractor, was ended the following day with the assistance of the Federal Mediation and Conciliation Service and the Atomic Energy Labor Relations Panel.

AEC PERSONNEL SECURITY REVIEW BOARD

During 1949, the AEC Personnel Security Review Board reviewed 12 personnel security cases, appealed by individuals or referred to it by the General Manager, and submitted formal recommendations to the General Manager concerning the disposition of each of these cases.

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The Board also reviews and makes recommendations on questions of personnel security policy and procedures which are referred to the Board by the General Manager.

The former chairman of the Board, Charles Fahy, resigned effective December 15, 1949, after having been appointed a judge of the United States Court of Appeals for the District of Columbia. He has been succeeded as chairman by Ganson Purcell, of Washington, D. C., former chairman of the Securities and Exchange Commission.

FEDERAL EMPLOYEE PERSONNEL MANAGEMENT

Specific personnel policies and procedures were issued during 1949 to carry out the general principles contained in the AEC Federal Employee Personnel Policy (reprinted in Fifth Semiannual Report, Appendix 10). The most important of these is the Policy and Procedure for Recruitment, Selection, Promotion and Transfer of Personnel issued in September. This is designed to assure that appointments to all types of positions in the AEC are made on merit principles, and to provide transfer and promotion opportunities that will make full use of the demonstrated skills and abilities of individual employees.

The Policy and Procedure for Review of Employee Grievances, issued in July, emphasized informal adjustment of grievances at the supervisory level. Provision is made for formal review of any grievance by an impartial advisory board, at the option of the employee. Decisions of Managers of Operations in grievance cases are subject to final review by the General Manager. The procedure represents an attempt to establish a single channel of review for all types of employee grievances.

New pay scales in line with those set forth in the Classification Act of 1949 were made effective on October 30, 1949, for all Commission employees occupying positions paying salaries up to and including $11,000 per annum. A plan for the adjustment of salaries above $11,000 per annum is under consideration.

In compliance with provisions in the Independent Offices Appropriation Act for 1950, personnel offices throughout the Commission were reorganized and the staffs curtailed. The number of the personnel staff is now limited to 1 to each 115 AEC employees served by the personnel offices—a total of 44 personnel staff for AEC throughout the country.

SAFETY AND FIRE PROTECTION

AEC fire losses during 1949 were far below comparable national averages. Community losses were 74 percent lower and industrial losses 98 percent lower. No significant interruption of production processes was suffered because of fire.

Accidents and fires in atomic energy operations resulted, as in previous years, from causes normally encountered in industrial operations and community activities rather than from hazards inherent in the nature of nuclear production. Thus, no serious radiation injuries have been reported from contractors handling radioactive isotopes or fissionable materials. On the other hand, serious injuries were caused by unsafe practices on scaffolding, improper operation of motor vehicles, disregard of safety regulations in operating machinery, and careless handling of office equipment.

The main effort has been to provide hazard-free facilities and buildings. Additional standards of safe practice were issued during the past year in the planning of new buildings; and occupancy of new buildings reduced many of the hazards formerly presented by temporary or inadequate work places. Guides and national codes for building construction and fire protection have been issued for the communities. National Board of Fire Underwriters' classification for municipalities has been adopted.

Contractor-AEC Meetings

Joint meetings of contractor and AEC safety and fire protection personnel were held in May and October of 1949. These meetings proved effective in developing accident prevention measures, in emphasizing contractor responsibility for reduction of injuries, damage, and fire losses, and in reducing detailed controls by AEC. Commission and contractor personnel are collaborating on guides for evaluation of accident and fire risks, measurement of performance, dissemination of information, safety education, and engineering standards.

Injury Reporting

During the year, an audit was made of all injury records to assure uniformity and accuracy in reporting systems and improvements in reporting procedures have resulted. This audit revealed that injury reporting was fairly consistent with the American Standards Association method. Record system improvements include the

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adoption of standards for fire experience summaries. To decentralize the records somewhat, fewer reports are being sent to Washington and more attention is being given to statistical data at the field offices. Further progress has been made in the cost records and in reduction of the cost of preventive work.

Safety Personnel Decreased

There was an over-all decrease in the number of personnel administering the safety program for the Commission, largely through removal of detailed control at contractor-operated installations. Generally, no increase in accidents has occurred where it has been found advisable to remove detailed control. AEC safety engineers are no longer required at each of the Oak Ridge plants. At Brookhaven, the AEC safety engineer was removed at the same time a safety engineer was installed on the staff of Associated Universities, Inc. At Dayton, Ohio, and Berkeley, California, AEC safety engineers have been removed; Massachusetts Institute of Technology now has a safety engineer on its staff; and at Los Alamos the total AEC safety engineering staff has been reduced from 17 to 11. At Oak Ridge and Hanford, safety and traffic engineering functions in the town sites have largely been turned over to the municipal authorities.

Fire Prevention Costs Reduced

Although the fire prevention staff has been strengthened, the over-all operating costs have been reduced an estimated 25 percent, chiefly as a result of installing automatic fire devices, developing industrial employee fire brigades, and other organizational changes.

Safety Performance

Over-all, accident frequency and severity rates in manufacturing operations, and in Government, traffic, laboratory, and community activities moved downward during the year 1949. However, construction contractor frequency rate increased from 5.72 lost-time accidents per million man-hours in 1948 to 8.55 in 1949. This increase resulted from a decrease in major construction and an increase in the percentage of accidents experienced among smaller and more diversified construction contractors.

The total lost-time industrial casualty experience for the first 11 months in 1949 was 4.64 lost-time injuries per million man-hours as against 5.07 for the first 11 months in 1948. Severities of injuries de-

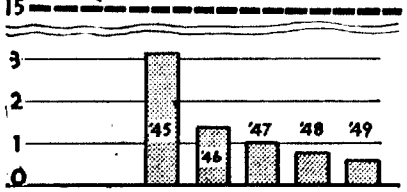
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AEC-CONTRACTOR FIRE & ACCIDENT EXPERIENCE

★ Year 1949 includes 10 months, January to October inclusive.

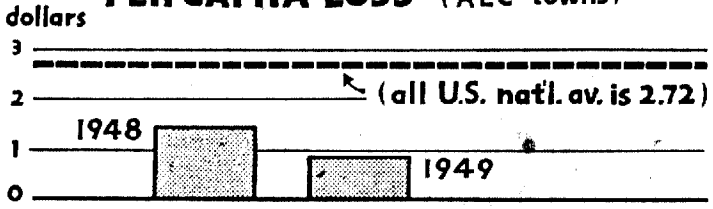
LOSS RATIO

Loss per $100 worth of property

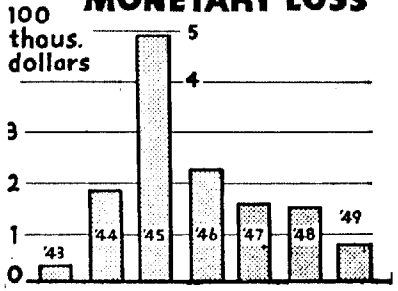


FIRE LOSSES

PER CAPITA LOSS (AEC towns)



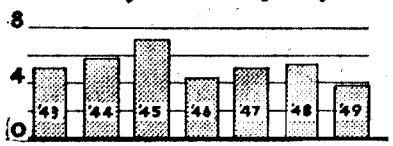
MONETARY LOSS



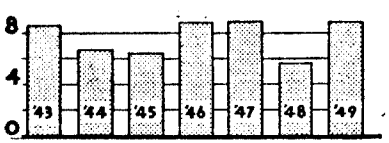
OCCUPATIONAL INJURIES

Frequency ... Injuries per million man-hrs.

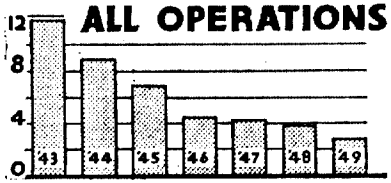
AEC gov't. employees



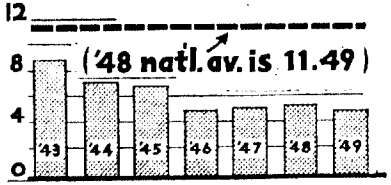
ALL CONSTRUCTION



ALL OPERATIONS

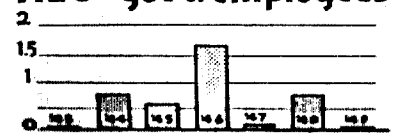


TOTAL

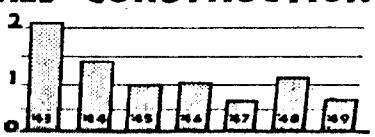


Severity ... Days ch'g'd. per thou. man-hrs.

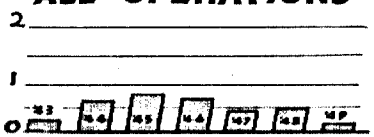
AEC gov't. employees



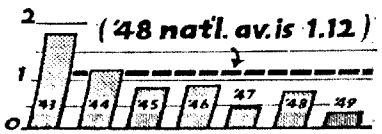
ALL CONSTRUCTION



ALL OPERATIONS



TOTAL



creased. The number of occupational fatalities was reduced from 11 in 1948 to 5 during the first 11 months in 1949, representing a ratio of 8.45 per 100,000 workers as against the national average occupational fatality rate of 29 per 100,000 employees. The total number of lost-time accidents for all operations for the first 11 months of 1949 was 508 as compared with 611 for the first 11 months of 1948.

The town of Oak Ridge completed 1,422 days without a traffic fatality. Traffic accidents in other AEC communities have continued to be lower than in other towns of similar size.

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IX

SECURITY

In December, the Atomic Energy Commission named an advisory panel to assist in a survey of the organization and functions of its Security Division. The panel has been asked to submit recommendations on the following matters:

a) The functions of a Division of Security.

b) The manner in which the functions of a Division of Security can best be discharged as a part of the whole management job of the Commission, e. g., whether as a staff or line function, and the consequent relationships of the Director of Security to the other staff and line organization.

c) The special qualifications desired in a Director of the Division of Security.

d) Possible candidates for the position of Director of Security.*

The work of the panel is expected to take about two months. It is under the chairmanship of John S. Bugas, vice-president of the Ford Motor Company in charge of industrial relations, and at one time agent-in-charge of the Detroit office of the Federal Bureau of Investigation. The other members of the panel are:

DAVID LUKE HOPKINS, banker, Baltimore, Maryland, vice-president, Board of Trustees, Johns Hopkins University.

Dr. PAUL E. KLOPSTEG, Director of Research, Technological Institute, Northwestern University.

J. ARTHUR MULLIN, president, Glenvale Products, Detroit, Michigan.

PERSONNEL SECURITY CLEARANCE

During the year, 37,561 requests for investigation of atomic energy project employees, or prospective employees, were forwarded to the Federal Bureau of Investigation. As of November 30, 1949, all but 5,266 of these investigations had been completed by the FBI or had been acted upon by the AEC. This latter figure includes not only those cases which are in various stages of analysis or review in Offices of

*The post of Director of Security has been vacant since May 1949, when Admiral John Gingrich resigned to return to duty with the Navy. During this period the work of the Division has been carried on under an Acting Director.

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Operations and AEC Headquarters, but also those cases in process of investigation by the FBI. It is believed that this figure, while possibly subject to further slight reduction, represents the approximate number of cases which may be expected to be pending at any one time assuming the continuation of present personnel clearance criteria and volume of employment.

Security clearances of AEC personnel, and of contractor and licensee personnel who will have access to restricted data, are initiated by the security divisions of the Offices of Operations and by the Security Operations office of the Washington headquarters. Under the General Manager's directive (GM–80, effective April 15, 1948) complete processing of personnel clearance cases was delegated to the field office managers, except in those cases which, following analysis, were evaluated as containing substantially derogatory information about the person involved. Such cases remained the responsibility of the General Manager.

At the time that GM–80 was issued, it was anticipated that a further delegation of authority to field office managers would be made, empowering them to initiate the Administrative Review Procedure and to deny, or to revoke, clearance in those cases where substantially derogatory information had been received—the authority which was specifically reserved to the General Manager—and this intention was stated in the Fifth Semiannual Report.

Experience has shown that the present limited decentralization provides for efficient personnel security clearances and that it is not desirable at this time to delegate further authority in this area to the field office managers. Present centralized authority to deny or revoke clearances provides a systematic and uniform evaluation of clearance cases and holds to a minimum the possibility of conflicting interpretations of the criteria for determining eligibility for security clearances.

Under these circumstances, the Commission has decided against further decentralization of authority at this time on personnel security clearances, and the authority to deny or to revoke such clearances remains centralized in Washington.

Other aspects of the security protection of installations, materials, documents, and personnel, as they relate to physical research, are discussed in Part II of this report (pp. 172–176).

Part II

Research in Physical Sciences and Progress in Atomic Energy

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THE TASK OF RESEARCH

The atomic energy enterprise calls for bold moves, for rapid progress. It is especially important that our progress be rapid in the field of basic nuclear science. It is no secret that our great structure of nuclear technology has been built on an extraordinarily slim foundation of basic knowledge about the atomic nucleus. Only in time of grave national emergency would anybody even have thought of expending 2 billion dollars on a project whose scientific basis was so flimsy. It was a magnificent gamble and we won. But the time for strengthening our foundations is here and we should proceed with all possible vigor.

The chief goal of science is not to develop weapons of war; it is not to develop new or improved industrial products; not even to find cures for human disease. The primary goal of science is to understand nature. Its purpose is not to invent but to comprehend. Its aim is not to produce gadgets but to discover knowledge. Its most valuable and important products are not atomic bombs, radar, or penicillin, but new facts and new laws concerning the behavior of the natural world.

How do new discoveries in science get applied to solving the problems of everyday life, to advance human welfare or national security? The development of new applications of scientific knowledge is not the main task of science as such, but the task of technology. Technology has as its primary aim the bringing of the results of science to the direct service of man, for such specific uses as may be deemed at the moment to be important or useful or profitable.

I do not wish to imply any derogatory comparison between science and technology, or to suggest which is the most important. There is no use entering an argument about the hen and the egg. All I wish to point out is that there is a hen and there is an egg.

Science and technology are similar in the instruments and the techniques they use, similar as to the type of training required for the workers engaged. Science is aimed at new knowledge; technology toward new devices. Technology builds its aims for the future on science's achievements in the past. After electromagnetic waves were discovered in a science laboratory, wireless communication could be developed—and not before. After Faraday discovered electromagnetic induction, the tools and techniques of a modern electric industry could be developed. After the discovery of nuclear fission, an organized effort to develop an atomic bomb could be initiated.

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The future strength and progress of technology depends on the present strength of science. If all our efforts and funds are poured into technology while science starves, then the technology of tomorrow must wither and die. In other words, the most impractical thing we can do is to give our whole attention to what we call practical research. Even if we disregard—which we should not—the intrinsic values of science itself, the essential intellectual and spiritual values of understanding nature; even if we are solely interested in building a better industrial or military technology of tomorrow, still the most practical, indeed the only way of assuring that aim is to maintain a strong basic science today.

—LEE A. DUBRIDGE, president, California Institute of Technology, and member, General Advisory Committee to the United States Atomic Energy Commission, in an address at Berkeley, Calif., Nov. 16, 1949.

I

OBJECTIVES OF THE AEC RESEARCH PROGRAM

In stating the purposes of the Atomic Energy Act of 1946, the Congress gave front rank to research and accompanying technical development. Of the five major programs provided for in Section 1 (b), the first three were designed to further the atomic energy enterprise of the people of the United States through the acquisition and use of knowledge—

1) A program of assisting and fostering private research and development to encourage maximum scientific progress.

2) A program for the control of scientific and technical information which will permit the dissemination of such information to encourage scientific progress, and for the sharing on a reciprocal basis of information concerning the practical industrial application of atomic energy as soon as effective and enforceable safeguards against its use for destructive purposes can be devised.

3) A program of federally conducted research and development to assure the Government of adequate scientific and technical accomplishment.

Further particularizing these purposes, the Congress in Section 3 of the Act, titled *Research*, directed the Commission "to exercise its powers in such manner as to insure the continued conduct of research and development activities in the fields specified below by private or public institutions or persons and to assist in the acquisition of an ever-expanding fund of theoretical and practical knowledge in such fields."

The *Research* section of the Act further directs the Commission "to conduct, through its own facilities, activities and studies of the types specified . . . above."

The specified fields included nuclear processes; the theory and production of atomic energy; utilization of fissionable and radioactive materials for medical, biological, health, or military purposes; utilization of these materials and processes entailed in their production for other purposes, including industrial uses; and the protection of health during research and production activities.

In each of the previous Semiannual Reports to the Congress, the Commission has summed up the general advances made in research. The Fourth and Sixth Reports also extensively reviewed research and development programs and their results in the fields of utilization of fissionable and radioactive materials for medical, biological, health, and industrial purposes, and of protection of health during research and production activities.

The following sections of this Seventh Semiannual Report present a similar extensive review of the programs set up by the AEC and, so far as they can be publicly stated, the results attained in the physical research programs dealing with nuclear processes, the theory and production of atomic energy, and the utilization of fissionable and radioactive materials for military purposes. This report obviously does not cover all research in nuclear fields; private research, not supported in any way by the AEC, is not reported. Within the AEC program, work which involved restricted data necessarily has been omitted.

There is no need to belabor the fact that pure and applied research in the physical sciences are both indispensable to fulfillment of national policy for atomic energy development. This is recognized by the Congress in the Act. It is continually emphasized by scientists and technologists. The General Advisory Committee has steadily kept it before the Commission in its reports and recommendations. The importance of basic research in meeting the paramount objective of the national atomic energy program—to assure the national defense and security—was summed up in a letter of July 28, 1949, from Commissioner Henry D. Smyth to Senator Brien McMahon, chairman of the Joint Committee on Atomic Energy. He wrote, in part—

> I am discussing only the military security of this country and am confining myself to results that might be obtained in the next 10 years. Though I believe the Commission should support activity in the general field of science which might not bear fruit for a much longer period, I shall exclude that.
>
> The weapons whose production now concerns us have developed from discoveries made in the realm of abstract science in 1939—just 10 years ago. I do not believe that anyone 11 or 12 years ago could possibly have foreseen this development. Similarly, we cannot foresee what may happen in the next decade, but we can start from certain obvious facts.
>
> The weapons which we are producing involve principles of nuclear physics. This is a subject on which our knowledge is still extremely fragmentary. These weapons

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also depend on the use of electrical equipment, and on the behavior of materials under such conditions of temperature and pressure as have never heretofore been achieved on the earth. In all these fields, our knowledge is scanty. It is hardly conceivable that the further study of nuclear physics, of gas dynamics, including the dynamics of explosion, of electrical equipment, and of high temperatures and pressures will not produce information that would be of fundamental value in the design and manufacture of future weapons.

In order to produce weapons we must have the materials of which they are made. Both the Hanford and the Oak Ridge plants use entirely novel production processes. The metallurgical and chemical problems which they have presented in the past and still present open up fields of research in which our ignorance is almost boundless. In such matters as the chemical separation processes, the behavior of little known metals in the presence of intense radiation, and the value of newly discovered isotopes, we can hope for very little advance without basic research in the chemical, metallurgical, and radioactive fields.

The biological and medical fields at first sight appear more concerned with peacetime applications. This is in some measure true. Nevertheless, if we are to consider the protection of workers in our plants, and particularly, if we are faced with the possibility of attack involving radioactive materials, it is essential that we should know what the effects of radiation and radioactive substances are and in what way people can be protected against them.

In outline these are the reasons why it seems to me unrealistic to separate research from the other parts of the atomic energy program as if it were not relevant to the military position of the country.

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II

MEN, MACHINES, AND LABORATORIES FOR PHYSICAL RESEARCH

The physical research program of the national atomic energy enterprise makes progress only as men of talent and training can be enlisted to work in it, and the unique machines and special and standard laboratory equipment placed at their command.

Employing the broad authorities granted by the Congress in the Atomic Energy Act, the Commission depends upon different means of drawing on the talents of American men of science and technology, training new talent, and furnishing the necessary equipment.

THE LABORATORIES

For carrying on both applied and basic research, the Commission maintains eight major installations at which the land, buildings, and equipment are completely owned or leased by the Government and all costs of staff and supply are reimbursed to the university or industrial contractors who operate them. This group of installations includes:

ARGONNE NATIONAL LABORATORY, operated by the University of Chicago in Du Page County, Illinois.

BROOKHAVEN NATIONAL LABORATORY, operated by Associated Universities, Inc., at Upton, Long Island, N. Y.

KNOLLS ATOMIC POWER LABORATORY, operated by General Electric Company at Schenectady and West Milton, N. Y.

LOS ALAMOS SCIENTIFIC LABORATORY, operated by the University of California at Los Alamos, N. Mex.

MOUND LABORATORY, operated by Monsanto Chemical Co., at Miamisburg, Ohio

OAK RIDGE NATIONAL LABORATORY, operated by Carbide and Carbon Chemicals Corp., at Oak Ridge, Tenn.

SANDIA LABORATORY, operated by the Sandia Corporation at Albuquerque, N. Mex.

WESTINGHOUSE ATOMIC POWER DIVISION laboratories, Bettis Field, near Pittsburgh, Pa., operated by Westinghouse Electric Corporation.

Four other installations are maintained on university campuses with buildings and equipment financed in large part by the Commission and with staff and supply expenses wholly reimbursed. These are:

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AMES LABORATORY, operated by Iowa State College, Ames, Iowa.

RADIATION LABORATORY (including Donner Laboratory of Medical Physics and Crocker Laboratory—Medical Physics) operated by the University of California at Berkeley, Calif.

ROCHESTER ATOMIC ENERGY PROJECT, operated by the University of Rochester, at Rochester, N. Y. (biological and medical reesarch only).

UCLA ATOMIC ENERGY PROJECT, operated by the University of California at Los Angeles (biological and medical research only).

But such installations, with plants and staffs financed in the main by the Government, constitute only a part of the Nation's resources which can find use in the atomic energy program. Exclusive of reactor development, about 15 percent (4 million dollars) of the Commission's physical research budget during the fiscal year 1949 was for work carried on by scholars on the staffs and in the laboratories of many universities, research institutes, industrial organizations, and Government agencies other than the Commission. By contract with them for salaries and operating expenses, the Commission has drawn into the program a considerable volume of additional talent and equipment. It is expected that by 1951 expenditures for these relatively small contracts will have more than doubled.

Basic research is being conducted through these contracts to an increasing extent. The research is usually conducted through the contribution of a part of the institution's manpower and equipment and without undue interference with regular teaching and research. A similar program for basic research is maintained by the Office of Naval Research, and the Commission has joined with this office in the support of some 63 physical science projects at 39 institutions. The Commission wholly supports 90 more physical science projects at 55 institutions.

Examples of the establishments at which physical research is done on developmental problems are the Battelle Memorial Institute, Columbus, Ohio; the Brush-Beryllium Corporation, Lorain, Ohio; the Sylvania Electric Projects Company, Inc., Bayside, Long Island, N. Y.; the National Bureau of Standards, the United States Geological Survey, Washington, D. C.; Washington University at St. Louis; Columbia University in New York; and the Massachusetts Institute of Technology at Cambridge, Mass.

MANPOWER AND MONEY FOR RESEARCH

In all, about 8 million dollars is likely to be spent for physical research this year through off-site contracts, compared with about 23 million dollars in the 12 major atomic energy research laboratories. These sums pay only salaries and laboratory operating expenses, plus occasionally the cost of some minor equipment. Construction of fa-

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cilities and major equipment is budgeted separately. Scientific and technical personnel engaged in the 31-million-dollar physical research program number about 2,150, almost a fourth of the technically trained people employed in all operating phases of the Commission's research and development program.

In reactor development, the operating budget for this fiscal year calls for another 12 million dollars in off-site contracts. This is in addition to about 21 million dollars in Government-owned laboratories.

The table below shows expected dollar costs and scientific employment in the AEC programs in the physical sciences and reactor development in fiscal 1950, compared to the corresponding figures for the biological and medical sciences. The 27 million dollars for work outside the 12 major laboratories includes basic research funds in colleges and universities totalling 6.5 million dollars in the physical sciences and 4.3 million dollars in the biological and medical fields. Included also among the 2,500 scientists in this off-site group are over 500 graduate students working on the university contracts. (The AEC training program is discussed in Chapter V.)

Money and manpower for research and development, estimated, 1950

(Approximate figures)

	Physical Sciences		Reactor Development		Biological and Medical Sciences		Total	
	Millions of dollars	Numbers of scientists	Millions of dollars	Numbers of scientists	Millions of dollars	Numbers of scientists	Millions of dollars	Numbers of scientists
9 major Government-owned atomic energy laboratories	18	750	21	900	7	300	46	1,950
4 major university-owned atomic energy laboratories	5	600	----------	----------	3	350	8	950
Many off-site industrial, educational, research, and Government activities	8	800	12	1,000	7	700	27	2,500
Total	31	2,150	33	1,900	17	1,350	81	5,400

The 5,400 total of scientific and technical personnel among these laboratory and off-site groups is more than half of the total employed on the Commission program. Of the others, nearly 4,000 work on the development of new weapons and on research and development projects directly associated with the production of fissionable material. Another 500 are on the Commission's staff in Washington and in the several field offices.

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NEW FACILITIES AND EQUIPMENT

In addition to the 31 million dollars for operating physical research, 25 million dollars is being spent during this fiscal year on the construction of new physical research facilities and equipment. Among the major items are $250,000 for completion of a research building at Ames, $125,000 for the start of a new research reactor at Argonne, 4.5 million dollars for work on the bevatron at the Berkeley Radiation Laboratory, over 2 million dollars on the cosmotron at Brookhaven, and about 5.4 million dollars for permanent buildings at the Oak Ridge National Laboratory.

For the construction of reactors and associated plant and equipment costs, 41 million dollars will probably be spent this year. Of this, 8.5 million dollars is going into the new Reactor Test Station at Idaho, nearly 3 million dollars for the Intermediate Power Reactor at the Knolls Atomic Power Laboratory, and about 22 million dollars at Argonne. New laboratories at Bettis Field for the Westinghouse contract are costing over 3.5 million dollars.

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III

ATOMIC ENERGY RESEARCH

Under the broad program for physical research outlined in the Atomic Energy Act of 1946, the Nation's investment of money, scientific manpower, and research equipment is directed toward finding out—

a) How atomic nuclei are put together and what forces operate within

numbers of particles and target atoms are involved that some hits are certain. Further, the projectile output is known, and there are ways of counting those that miss the target and measuring the angle of flight of those that glance off.* Thus, one can calculate with accuracy the size of the target. When target atoms disintegrate under direct hits, something is learned about what they were made of.

Charged Particle Bombardment

It is conceivable that if all the necessary observations and cross-section measurements could be performed, one might gain an understanding of what happens inside a simple nucleus—of the basic structure and the forces at work. An atom of gold containing 197 nucleons, or one of uranium with 238, is too complex to be examined in detail within the foreseeable future. But an atom of deuterium with just 2 nucleons, or an atom of tritium with 3, is a better object for close observation. Common hydrogen, with but a single proton in its nucleus, makes an obvious target for bombardment and the detailed study of results.

INFORMATION ABOUT LIGHT NUCLEI

Proton-Proton Reactions

At Berkeley Radiation Laboratory, birthplace of the high-energy particle accelerator, two machines are in use to study one of the simplest of all interactions, that of protons with protons. The target bombarded is hydrogen, sometimes as a pure gas, sometimes in a solid substance such as paraffin. The projectiles are 32 million electron volt (Mev) protons from the linear accelerator and 350 Mev protons from the 184-inch synchro-cyclotron, most powerful accelerator known today. As long as the velocity of the approaching proton is not too great, two protons repel each other in accordance with Coulomb's law, which states that the repelling force between similarly charged particles increases as the inverse square of the distance between them. The repelling force between two protons close enough together to be in the same nucleus reaches the magnitude of 40 pounds.

*The probabilities that certain ones of these various events will happen, with a given target and projectile, depend upon the so-called *cross-sections*. The "capture cross-section" of lithium 7 for protons of 1 million electron volts (1 Mev) energy, is actually the *apparent* size of the lithium nucleus for this particular event. If lithium 7 captured many protons, the physicist would say that it had a large capture cross-section for 1 Mev protons. The apparent size of nuclear cross-sections is stated in terms of a new unit of measurement called the *barn*. The barn is defined as an area of 10^{-24} square centimeters, an area chosen because it is of the order of magnitude of the area of many atomic nuclei. Thus if lithium 7 were said to have a capture cross-section of 2.5 barns for 1 Mev protons, this would mean that the effective target each nucleus presented for this particular event would be 2.5×10^{-24} square centimeters (0.000,000,000,000,000,000,000,002,5 square centimeters).

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The Particles of the Nucleus

Scientists who study the nuclei of atoms speak in terms of the following entities they are able to detect and measure:

Proton

The nucleus of a hydrogen atom is called a *proton.* This particle has a positive electric charge equal numerically to the negative electric charge of the electron and is so small that it takes 2.72×10^{26} to make a pound. The nuclei of atoms of other substances contain a number of protons equal to the atomic number of the element.

Neutron

The nuclear particles which have no electrical charge are called *neutrons.* They weigh approximately the same as protons.

Nucleon

The word "nucleon" means either a proton or a neutron.

Beta Particle

One of the radiations found shooting out of certain radioactive materials, named the beta particle, appears to be the same kind of electron that is found in the outer structure of all atoms. It has a unit negative charge equal and opposite to the positive charge of the proton and is nearly weightless, having less than 1/1800th the mass of a proton.

Positron

Like the electron, the positron has a unit charge of electricity but is positive instead of negative; *i. e.*, it has the same charge as the proton. It is evanescent, dissipating itself in a flash of radiation as soon as it encounters an electron, which disappears with it.

Meson

Predicted from theory as a particle necessary to explain the forces of nuclear structure, the meson was observed for the first time in 1936 in the violent nuclear shattering caused by high-energy cosmic rays in the upper atmosphere. Several varieties exist, both positive and negative, their mass averaging about one-sixth that of the proton.

Neutrino

A nearly weightless particle, without charge. Like the neutron, the neutrino was predicted on theoretical grounds; but it has not yet been observed, as the neutron had not been observed before 1932 and the meson before 1936.

Gamma Rays

These are not particles in the same sense as those above, but flashes of electromagnetic radiation emitted by the nucleus when it has excess energy. These flashes are often called *photons.*

NUCLEAR PROCESSES

An atom is so small that about a hundred billion billion of them are contained in the head of a pin. The nucleus—the object of study in nuclear science—is some 10 thousand times smaller than the atom. If an atom were expanded to the size of a concert hall, its central nucleus would be smaller than a housefly. The nucleus constitutes nearly all of the mass of the atom and, consequently, the mass of all things. A piece of solid nuclear material the size of a child's marble would weigh more than 200 million tons.

The most generally used method for finding out about atomic nuclei is to bombard atoms and observe what happens to them and to the bombarding particles. True, there are ways other than bombardment for studying the nucleus: measuring the electric charges and weights of nuclei and nuclear particles by projecting them through magnetic fields, or measuring the magnetism possessed by these particles and determining their polarization—that is, the way the individual axes of rotation of particles are tipped. But bombardment remains the work horse of nuclear investigation.

The nature of bombardment experiments differs depending upon whether the projectiles used are charged particles or neutrons (which carry no charge). AEC laboratories and contractors that have particle accelerators—the Radiation Laboratory, University of California; Los Alamos Laboratory; Argonne Laboratory; Brookhaven Laboratory; and Columbia University, for example—carry on programs of charged particle bombardment. Neutron research is concentrated at Oak Ridge, Argonne, and Los Alamos, where nuclear reactors are available, although particle accelerators at other laboratories are much used as secondary sources of neutrons. (Brookhaven Laboratory is now building a nuclear reactor.)

Measuring Bombardment Effects

In bombardment, the hits, misses, and near-misses all supply information about the structure of the nucleus and the forces within it. The thing that happens most frequently when a particle enters a target is that it goes right through. Even this result contributes to knowledge. The number of hits scored as compared to the number of misses and near-misses permits calculations of how much of the volume of the target material consists of atomic nuclei.

Although hitting or missing a nucleus with an "incident particle" (a particle arriving from outside) is a matter of chance, such large

(*Continued on page 58.*)

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When the incident protons are above a certain energy, however, some of them are able to approach the target protons so closely that the little understood cohesive force of the nucleus comes into play and the protons no longer behave like simple electrified bodies.

One object of the experiments is to measure the force that holds the nucleus together and to try to get a better mathematical description of it. A tentative report on progress concludes that "it is apparent that present theoretical concepts must be modified, and perhaps new concepts introduced, before a satisfactory mathematical description of the proton—proton force will be at hand."

Studies of Hydrogen 3 and Helium 3

Hydrogen 3 or "tritium," the artificial radioactive isotope of hydrogen (half-life about 12 years*), has an unstable nucleus which contains a proton and two neutrons. By the emission of a beta particle tritium decays into helium 3, an isotope of helium with two protons and one neutron, which occurs in natural helium in the proportion of about one part in a million. When H 3 transforms itself into He 3, the changes that occur in such characteristics as the magnetism and spin of the three nucleons can be measured. In addition, there is special interest in He 3 because it is the only known stable atomic nucleus that contains more protons than neutrons. For these reasons, and because of the relative simplicity of the nuclei, physicists and chemists have sought to produce H 3 and He 3 for use in research. Argonne Laboratory announced in September 1948 that it can supply some quantities of both isotopes to scientists outside the atomic energy project, and both are now in use in studies of nuclear structure.

Important information has been gained at Argonne, Los Alamos, and other AEC laboratories. Studies are being made of interactions between protons, deuterons, tritons, helium 3 nuclei, and alpha particles (or, in other terms, nuclei of H 1, H 2, H 3, He 3, and He 4).

Deuterons are bombarded with tritons, and tritons with deuterons, to study reactions in which these two particles first combine then split into an alpha particle and a neutron. As the energies of the bombarding particles from a Cockcroft-Walton accelerator increase toward 100 thousand electron volts (100 Kev) the probability of the reactions occurring also increases (the triton's cross-section for deuteron capture is higher). But when energies of the incident par-

*The *half-life* is a convenient measure of the instability of radioactive nuclei, i. e., nuclei that are unstable and "decay" into other usually more stable isotopes, at the same time emitting particles and energy. It is the period of time in which one-half of the nuclei decay. In the next similar period, one-half of the remainder will decay, leaving one-fourth, and so on.

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ticles are raised still higher by using a Van de Graaff generator, the capture cross-section falls off sharply.

Tritons and protons. In a series of experiments with a Van de Graaff generator, tritium was bombarded with high-energy protons. The scattering of protons by tritons at various angles and energies was measured to derive data fundamental to the understanding of nuclear forces. At higher particle energies, the reactions in which the proton is captured by the triton were studied. In one of these reactions the resulting combination became an "excited" alpha particle which converted itself to the stable state by emitting radiant energy in the form of 20-Mev gamma rays.

In a second reaction observed, the proton-and-triton combination split into a neutron and a nucleus of helium 3. This latter reaction was of interest because it proved reversible; that is, helium 3 bombarded with neutrons yielded protons and tritons.

"It was possible here," the report of the experiment states, "since good measurements existed on this reaction going in either direction, to verify a well known theorem of statistical mechanics which relates the reaction probabilities of such a reversible system; this was the first time that an experimentally adequate check of the 'principle of detailed balance' had been made for a nuclear reaction."

Mass of the neutron. These reactions permitted more accurate determination than ever before of the size of the mass difference between the neutron and the proton, and consequently of the mass of the neutron itself. Results obtained in other laboratories confirmed these findings and did away with previous discrepancies.

HIGH-ENERGY BOMBARDMENT

In the bombardment of light elements, the stream of particles, its energy closely controlled, is a deft implement for studying simple nuclear structures. But there is a more heavy-handed approach to the bombardment of the nucleus—the way of the atom smashers. In the proton synchrotron ("Bevatron") now being built at the Radiation Laboratory, Berkeley, the protons in their race around the 400-foot acceleration track will attain an energy of 6 billion electron volts (Bev). Each proton will travel 300 thousand miles—farther than from the Earth to the Moon—in less than 2 seconds, and will approach the target at 184 thousand miles per second, 99 percent of the speed of light. With this machine, it may be possible actually to create out of energy a heavy nuclear particle, say a proton.

Cosmic Rays

But even such a machine will not equal the forces of nature. The most energetic bombarding particles that man has ever observed are

in the cosmic rays that plunge into the Earth from space. Since the middle 1930s, much pioneering work in nuclear bombardment has been done with cosmic rays. The difficulty is that they are diffuse and essentially uncontrollable.

To work with cosmic rays, scientists take instruments to mountain tops, or send them up in balloons. By the latter means they are able to reach altitudes where the primary particles from outer space have not yet smashed their way through the atoms of the Earth's atmosphere. These particles have the highest energies yet measured. The Commission is financing a limited amount of this high-altitude research through arrangement with the Office of Naval Research (see descriptions of AEC–ONR research contracts in Appendix 6).

A second way of improving the chances of observing cosmic ray collisions is to leave the instruments in the laboratory but to enlarge and improve them. Brookhaven Laboratory is adopting this course. Among other new instruments, it is building a large cloud chamber which will compress target gases to 300 times the normal pressure of the atmosphere. (On pages 74 to 77, some of the instruments used to detect, observe, and count the results of nuclear bombardment are pictured and described.)

Results with Today's Machines

However, the main line of development of high-energy bombardment research lies in the big machines that supply streams of particles of many varieties and of controlled energies. Late in 1946, the 184-inch synchro-cyclotron at Berkeley began to produce deuterons at 200 Mev, and since then it has been used to produce 400-Mev alpha particles and 350-Mev protons. These energies are greater by tenfold than any available before. Before particles of these energies were available, such reactions as those brought about by a proton coming into a target nucleus and causing the ejection of one or two neutrons were almost the only basis of our knowledge of what happens when energy is pumped into a nucleus. With the advent of the big machine, it became possible to see what would happen when energies tenfold greater were used.

The phenomena observed in such high-energy encounters have proved to be most complex, and only the broad outlines have been worked out at the present time. It has been found that there is a wide variation in the amount of energy which different nuclei can accept and that there are many ways in which the highly excited nuclei can lose their energy. (*Continued on p. 68.*)

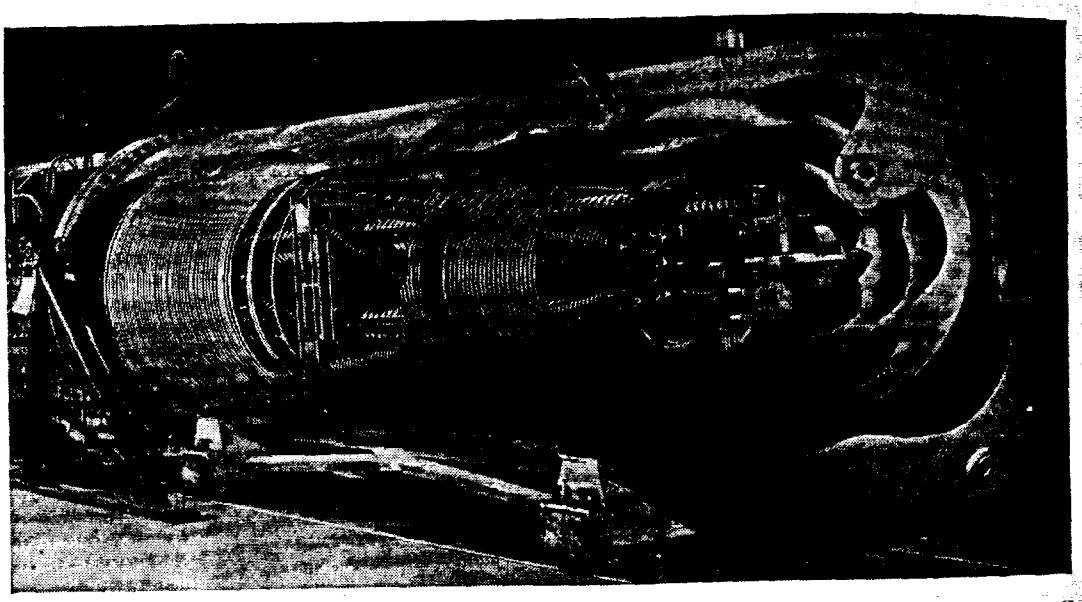
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Particle Accelerators for Research

The first bombardment of atomic nuclei was performed with a make-shift piece of laboratory equipment, not much larger than a shoe box, in which Rutherford used the 5-million-electron-volt alpha particles of natural radium as projectiles. The newest particle accelerator, now being constructed, will be a precise scientific instrument 110 feet in diameter which will accelerate particles, with 1,000 times the energy available to Rutherford—5 billion electron volts and more.

The first machines used to accelerate nuclear projectiles gave them a single pulse of electrical energy, as does the Van de Graaff generator pictured below, which gives 5-Mev energy to protons. Later, ways were devised to impart electrical impulses in series so that particles gained greater and greater velocity. The linear accelerator (opposite) thus can give particles 32 Mev by 30 successive thrusts. One cyclotron (the 184-inch), gives 11.4 million impulses per second to particles which in this way attain an energy of 350 Mev.

With the pictures on the following pages, this report indicates the progress made, in the years since Rutherford's experiment in 1919, in the design and construction of these important tools of nuclear science.

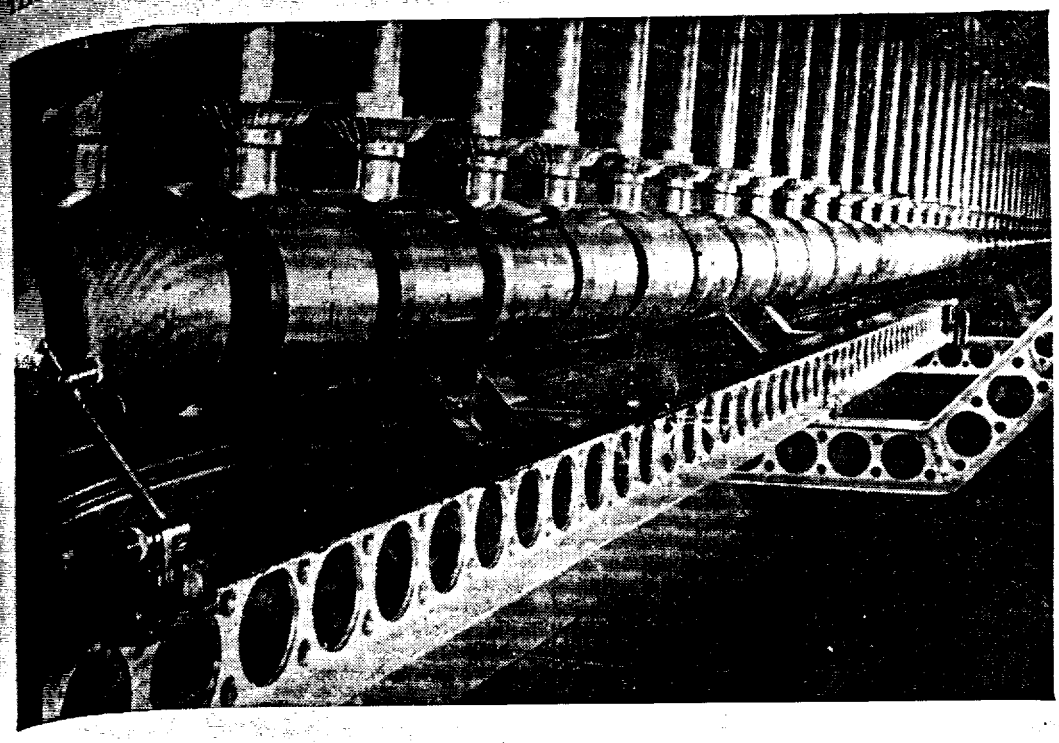


Cut-away photograph above shows the 5-million-volt Argonne Van de Graaff electrostatic generator which can give ions nine-tenths the velocity of light. The electric charge is built up on the innermost shell or "cap" and insulated against discharge by nitrogen gas held within the outermost shell (7 feet in diameter) at a pressure of 150 pounds per square inch. The ion beam of this machine is much less energetic than that of some other accelerators, but it is constant, extremely well defined, and thus very useful for certain experiments.



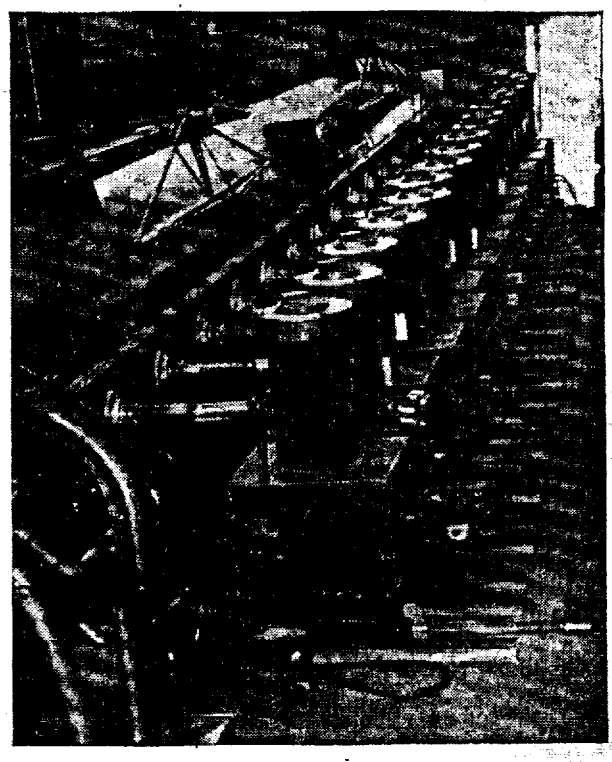
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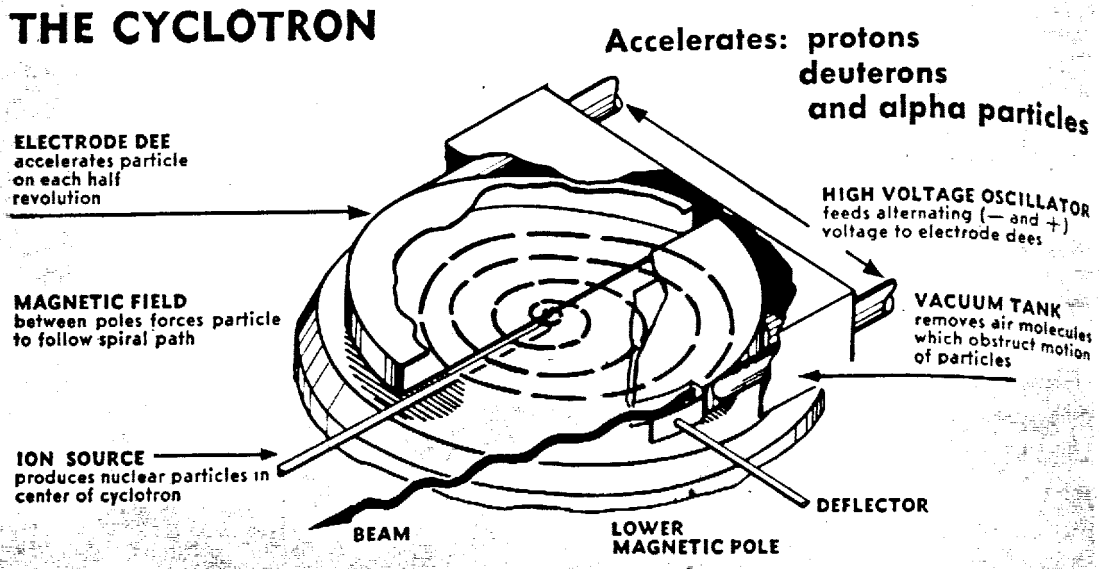
One of the early successful particle accelerators that used a series of stages to step up the energy of bombardment particles, instead of imparting all energy in a single stage, was the linear accelerator. The picture above shows the inside of a 40-foot linear accelerator at Radiation Laboratory, University of California. A 4-million-volt Van de Graaff accelerator, similar to that shown on the preceding page, shoots protons into the first of the series of "drift tubes" which, in the photograph, make a diagonal from left to right. The protons receive additional energy each time they cross a gap between two of the tubes, moving faster and faster until they leave the accelerator with 32-Mev energy.

The devices that impart energy to the protons in the linear accelerator are shown at the right. The drift tubes are in the center of the cylinder, or envelope, in the left foreground. The positively charged protons, inside the envelope, are drawn at accelerating velocity past the gaps between the tubes by alternating electrical fields. A negatively charged drift tube attracts a proton; a positively charged tube repels it. Each drift tube is alternately given a negative, and then a positive, electrical charge by the devices along the right side of the envelope. These are high frequency radar transmitters, each connected with a drift tube.

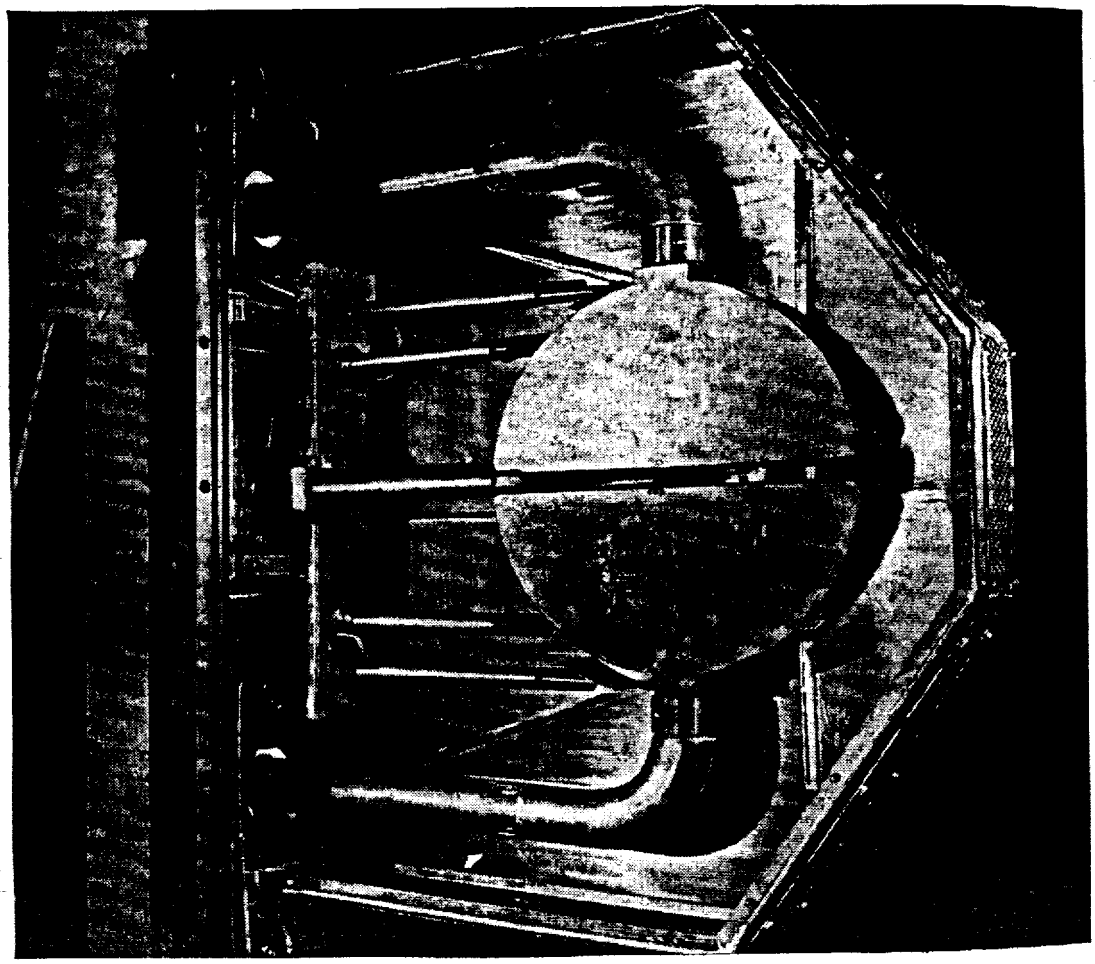


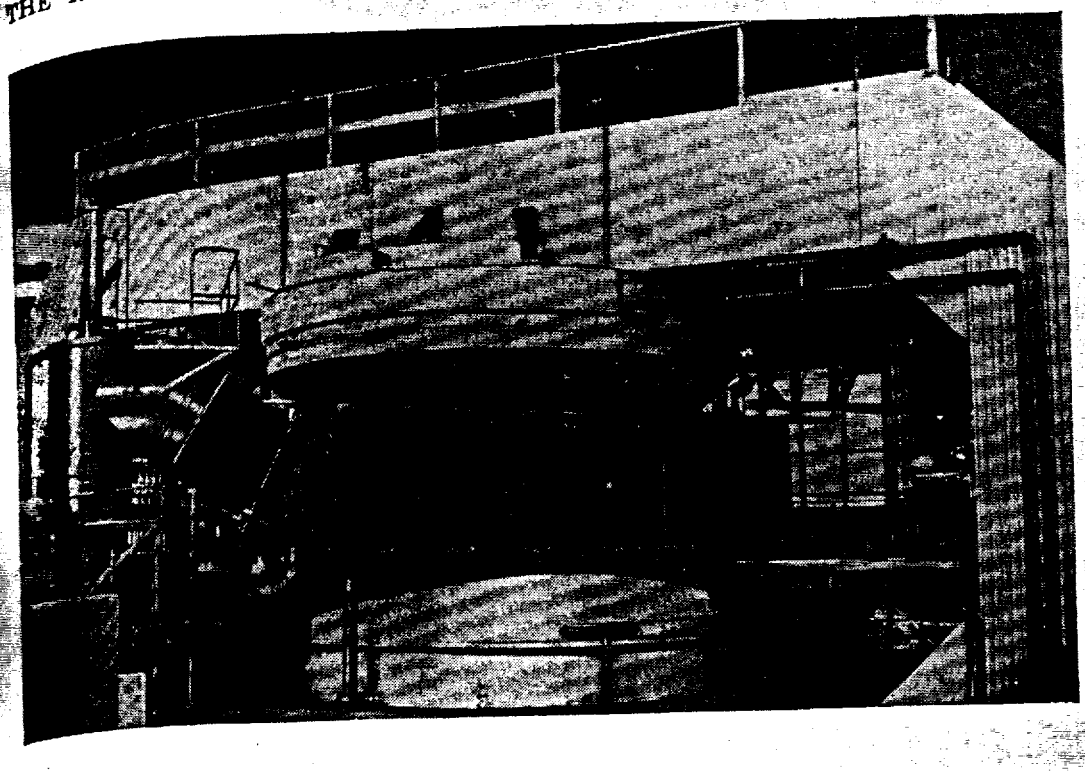
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THE CYCLOTRON



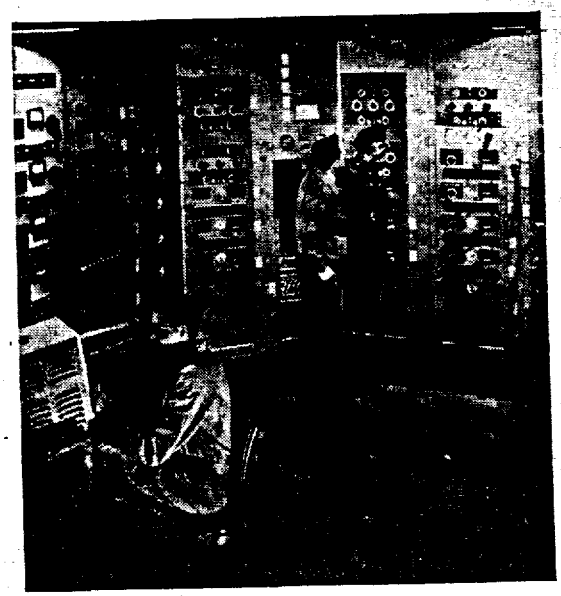
The cyclotron accelerates particles by using alternating electrical fields, as does the linear accelerator, but instead of accelerating in a straight line the cyclotron employs a magnetic field to force the particles to travel in a circular orbit. The diagram above indicates the parts and principles of a cyclotron. Instead of "drift tubes," the cyclotron has two "Dees" (or sometimes only one), in which alternating electrical fields accelerate particles. Particles start at the center (see diagram), move toward the exit point in an expanding spiral as velocity increases. Below is shown a small cyclotron at Y–12 in Oak Ridge. The circular portions are the dees; the magnet is vertical to the plane of the dees.

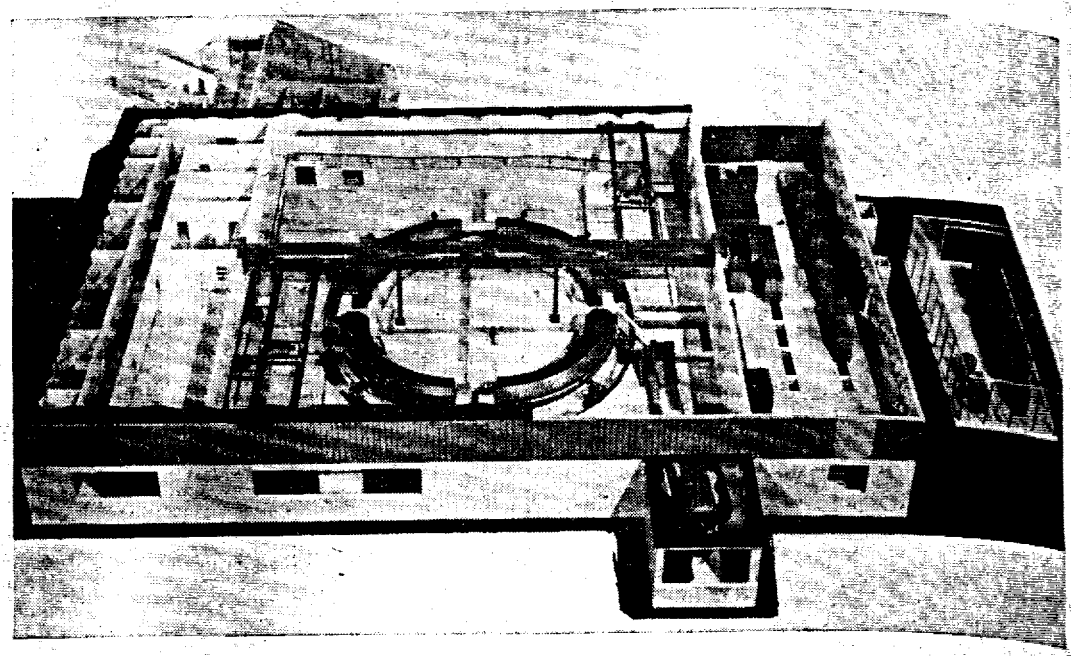




To increase the efficiency of particles as nuclear projectiles, the Radiation Laboratory built the cyclotron above which has magnets with faces 184 inches across. In this cyclotron protons reach energies of 350 Mev. The yoke coils of the magnets are encased in the conical hoods; the dark box-like structure crossing between the hoods contains vacuum pumping equipment. Evacuating gases from the "envelope" of all accelerators is essential since molecules of gas deflect and impede accelerating particles. The pump shown exhausts gases until all the molecules left within the envelope between the 15-foot magnets would, if compressed to sea level pressures, fill no more volume than the head of a pin. To protect people from the radiation of the cyclotron, 10-foot blocks of concrete are used as a shield (below left) and the cyclotron is operated from a remote control room (below right).





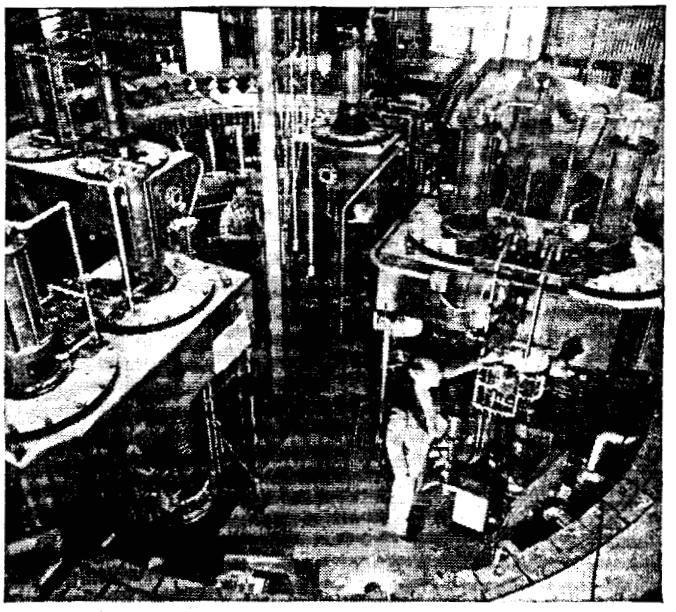


The particle accelerators shown on these two pages are designed to produce particle energies 10 to 20 times greater than those of the 184-inch cyclotron—proton energies of 3 to 5 billion electron volts in the *Cosmotron* at Brookhaven (model pictured above), of 5 to 7 Bev at Radiation Laboratory (facing page, below). The Cosmotron will be 75 feet in diameter (the dark circle within the model building), the Bevatron 110 feet across. Both machines will be of the type known as "proton synchrotrons" and will supply, for the first time, ample controlled beams of particles which rival the energy of some of the cosmic rays. They are at present under construction and working models are testing their operating principles.



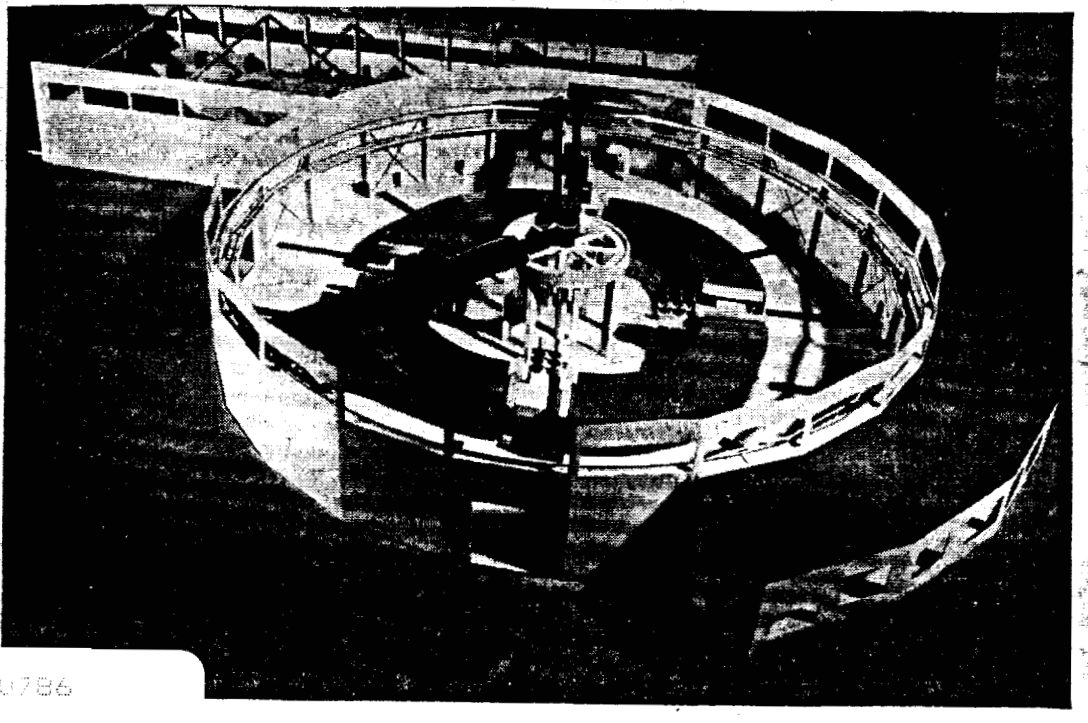
At the left, workmen are moving into place one plate for a Cosmotron magnet. The proton synchrotrons use magnetic fields to control projectile particles, but differently from the same way cyclotrons do. The field of a cyclotron magnet operates at constant intensity. It forces particles to move in a circular orbit, but permits their increasing velocity to swing them in an expanding spiral. In the proton synchrotron, the magnetic field's intensity is held low when particle velocity is at a minimum, then increased as velocity rises so that the particles continue in a constant elliptical path.

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In the quarter-scale model of the Bevatron (right: the units beside the men are vacuum pumps), Radiation Laboratory tested variable magnetic fields as a means of keeping particles in a constant path. The model also incorporates a design principle which helps overcome a natural phenomenon that would otherwise prevent particles in the Bevatron from reaching billion-volt acceleration. As particles near the speed of light, their mass increases; the more massive particles lag and get out of step with the alternating electrical field which propels them. The proton synchrotron overcomes this by reducing the alternations per second of the electrical field, so that it keeps in step with the growing mass of the particles.

When the Bevatron is complete (scale model below) it will cover almost an acre of ground. It is expected to accelerate protons to within one percent of the 186,000-mile-a-second speed of light. Two 85-ton flywheels will provide 100,000 kilowatts of power to the 10,000-ton magnet which will be wound up with 140,000 feet of 2-inch copper cable. The generator or cyclotron, used to inject the particles into the Bevatron, will start them with energies of 10 Mev. Completed, the Bevatron will provide the most powerful machine yet built for exploring atomic nuclei and the forces within them.



High-Energy Fission

One major effect from high-energy bombardment has been the fission of bismuth, lead, gold, and other elements that cannot be split by less energetic particles.

Careful examination of the fission products provided by high-energy bombardment of bismuth, including the identification of about 50 isotopes and measurement of their yields, disclosed that such products are quite different from those of the uranium fission process. In the slow-neutron fission of uranium and plutonium, the most frequently occurring mode of cleavage is asymmetric; that is, the nucleus splits into two fragments, one of which is considerably larger than the other. In fast-particle fission on the other hand, symmetrical cleavage is most often found.

Neutrons in the Nucleus

It has long been known that the more protons a nucleus contains, the more neutrons it must have, proportionately, for stability. If a nucleus contains relatively too few neutrons it will be radioactive, emitting a positron when it decays; if it contains too many neutrons it will again be radioactive, emitting this time a negative electron when it decays. Stable light elements are found to have equal numbers of protons and neutrons, but the heavier elements contain increasing proportions of neutrons to protons.*

When a heavy element fissions into two lighter nuclei we might expect both products to have nearly the same neutron-proton ratio as the parent, and consequently to have far too many neutrons for stability. We might further expect that the products would be beta-radioactive, emitting electrons. The spilling out of a few surplus neutrons at the instant of fission would not be surprising. But when we find a uranium 235 nucleus fissioning with slow neutrons in an unsymmetrical fashion, with one product nucleus considerably heavier than the other, and we further find that the two products are equally unstable, we know that a re-shuffling of nucleons has taken place. The lighter product has a smaller excess of neutrons than does the heavier.

But in the fast-particle fission of bismuth at Berkeley, whenever the two fission products are of unequal size, the light fragment has relatively too many neutrons for stability, and the heavy fragment too few, as though the nucleus had been cut with a knife before any neutrons and protons could redistribute themselves. It appears then that

*Thus stable helium 4 has two protons and two neutrons in the nucleus; halfway up the table of the elements a typical nucleus—a stable isotope of silver—has 47 protons and 60 neutrons, a neutron-proton ratio of 1.28; and, at the top of the table, uranium 235 has 92 protons and 143 neutrons, a neutron-proton ratio of 1.55.

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high-energy-induced fission takes place much more rapidly than low-energy fission.

Another way in which fission induced by high-energy particles differs from low-energy fission is that in the first case neutrons are "boiled off" by the nucleus when it splits. At Berkeley this was found to be just as true for uranium as it was for bismuth and other lighter elements; the energy of the incident particle seemed to be the deciding factor.

Results of these experiments with high-energy fission are a mine of information for the theoretical physicists and mathematicians who attempt to understand how the nucleus is put together and how its energies can be released and controlled. An incidental but important benefit has been the production of some 150 varieties of neutron-deficient isotopes of the common elements, which are of great interest and utility to research workers in other laboratories.

Spallation

Fission is not the only type of break-up of atomic nuclei subjected to bombardment by million-electron-volt particles. All sizes of pieces may be chipped off them, and the term "spallation" is applied to this chipping process. Spallation reactions in a target struck by 350-Mev protons may produce as many as 100 different products (some of which, of course, are the result of high-energy fission). After uranium has thus been bombarded, nearly every one of the known elements may be found in the target.

On occasion, the Berkeley workers have found among their bombardment products elements three places higher in the atomic scale than the element being bombarded. They have been able to explain this phenomenon only by assuming that a three-proton chip—in other words, the proton part of a lithium atom—has been knocked off one target nucleus and immediately taken into another target nucleus.

Spallation, like fission, has produced substances never before known, many of which are of great value to research. It is not yet known just how the reaction occurs or what its entire significance or use may be. It is a new fact, and most facts of this type sooner or later have found application.

The Meson

Nuclear research is aimed at answering the central problem of nuclear structure—the question of what holds the nucleus together. What is the cohesive force that overcomes the tremendous disruptive

force—the disruptive force that attains the magnitude of 40 pounds where only two protons are involved? The high-energy particle accelerators are trained directly on this problem. Two years ago one of them achieved a major break-through by producing the meson.

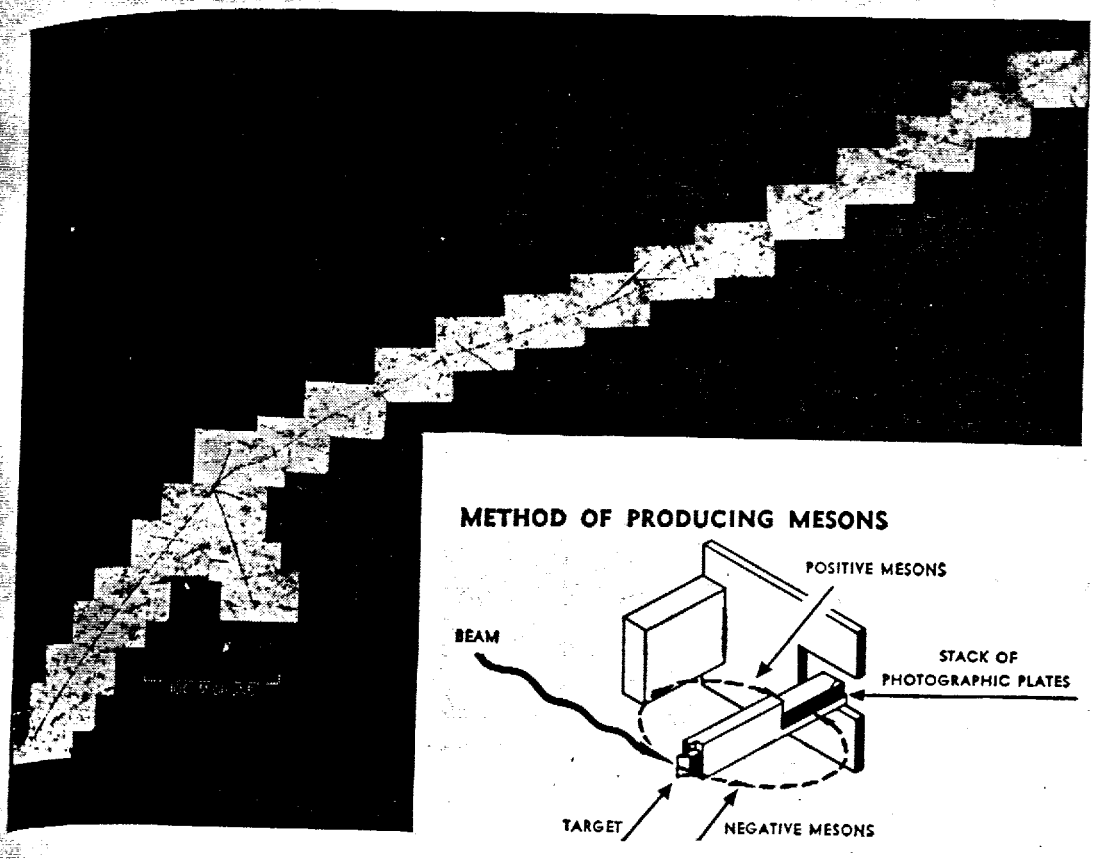
One working theory is that nuclear cohesion may be brought about by an "exchange force" operating between nucleons. There is an analogy in chemistry, where an exchange force apparently explains the stability of certain molecules. The simplest type of chemical molecule that illustrates this phenomenon is the so-called "hydrogen molecule ion" consisting of two protons separated by a short distance and sharing a single electron between them. The positive electrical charges of the two protons would force them to fly apart if the exchange of this electron back and forth from one to the other did not result in a net binding force holding them together.

The meson theory. In 1935, a Japanese physicist postulated the existence of a particle to perform a similar binding function in the nucleus. He named it the *meson* because he supposed its mass to be intermediate between that of the electron and a nucleon. In this theory, a neutron is composed of a proton plus this negatively charged meson. A neutron and proton in close proximity to one another are attracted and held together by the rapid exchange of the meson between them. The analogy between nuclear binding and that in the hydrogen molecule ion is a very rough one, but physicists immediately began seeking for mesons both in cosmic rays and in the radiation near artificial accelerators and soon found in cosmic rays something very like the particle postulated. Cosmic ray research accumulated a great deal of information about mesons during the following 13 years and was climaxed in 1947 by a series of brilliant researches in England that established the existence of mesons of two different masses—named *pi* and *mu* mesons—through studies of specially prepared photographic plates exposed at high altitudes.

During all this time, of course, workers with the more powerful particle accelerators were looking for evidences of mesons around the targets they bombarded, since laboratory production under controlled conditions would make the gathering of information incomparably easier. Success came at last in early 1948, when it was demonstrated that the 184-inch Berkeley machine was hurling particles fast enough to make mesons.

Trapping the meson. When protons and alpha particles in the cyclotron spiral outward around its track and finally strike the target with an energy close to 350 Mev, a large number of processes occur. The bombarding particles are scattered with a great variety of energies in all directions. Also spraying out are the "secondary" protons, deu-

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Method of trapping mesons, and the record of a catch. In the diagram: when the beam of high-energy particles from the 184-inch cyclotron at the Radiation Laboratory, University of California, strikes the target, mesons that are produced will follow circular tracks (dotted lines) under the influence of the powerful magnetic field—the positive mesons circling in one direction, the negative in the other. A block of copper (not shown), with hollowed-out channels shaped like the tracks, allows mesons but no other nuclear particles to enter the stack of special photographic plates. The photograph shows the result. A negative heavy meson, entering at the upper-right-hand corner, travels through the photographic emulsion until it is captured by an atomic nucleus, whereupon its energy causes the ejection of several nuclear particles.

terons, alpha particles, and heavier nuclei produced by the reactions in the target. A great deal of intricate work went into the task of trapping the tiny and short-lived meson and proving that it existed. The device to trap mesons, as it is now used, consists of a block of copper in which there has been a cut a channel 1-inch wide and in the shape of a half-circle of 4-inch radius. Long experience and close calculation has made it possible for the experimenters to be sure that the negative meson is the only particle with the mass and charge required to make it follow the curve of this hollowed-out track under the influence of the powerful magnetic field. Against the exit end of the channel in the block, they place special photographic plates, stacked edgewise, so that particles emerging will make tiny microscopic tracks in the photographic emulsion and some will actually stop there. In this way the tracks of mesons are recorded.

Mass of the meson. One of the first things to be discovered about the meson, thus located, is its mass. British cosmic-ray experimenters earlier had worked out the necessary relationships between the mass, the energy, and the lengths of the track in the emulsion, and had thought that the mass of the heavier, or *pi* meson, was between 300 and 400 times that of an electron. Using machine-produced mesons under far easier conditions, the experiments at Berkeley have refined this figure to a narrow range between 270 and 282 electron masses. The first thing to be noticed about this result is that it does not agree at all closely with the original postulation of the man who predicted mesons: that the particle should account for the weight difference between a proton and neutron. This situation recurs frequently: theory predicts facts and lights the way for new experimentation; experiment, in its turn, finds fact and often shows that the predictions were partly right and partly wrong; theory then is reconstituted on the basis of known fact to make new predictions and lead to further experiments.

Two kinds of mesons. The British high-altitude observers had found that only one variety of meson, the heavier *pi* meson, was directly produced by bombardment and that the lighter *mu* meson was a product of *pi*-meson decay. Experiments at Berkeley and Brookhaven have confirmed this fact and given more precise measurements of the reactions involved. The life-span of the average *pi* meson is of the order of magnitude of a hundred millionth of a second, after which it becomes a *mu* meson with a mass about 200 times that of the electron. This in turn decays (after about 2 millionths of a second) into an electron and one or more unknown neutral particles. Brookhaven experiments, with bombarding particles from cosmic rays, employ systems of Geiger-type counters separated by various shielding materials and controlled by electronic circuits, which can distinguish between different kinds of mesons and reveal many other facts about them. The new Brookhaven cloud chamber, when in operation, will further increase ability to observe mesons.

The new proton synchrotrons at Brookhaven and Berkeley (the "Cosmotron" and the "Bevatron") will provide bombarding particles in the billion-electron-volt energy range. Work to date with the existing machines of lesser energies has advanced understanding of mesons from a very preliminary realization that two types existed to the point of accurate statement of their masses, charges, decay schemes, life spans, production cross sections, and perhaps a somewhat more adequate conception of their role in nuclear forces than existed a decade ago. The picture is far from complete. Knowledge is scanty concerning nuclear scattering of mesons and the probability of their capture by nuclei before they come to rest. Again, there is the possibility that there may exist particles of mass intermediate be-

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tween the *pi* meson and the proton. A few events recorded in the plates exposed to cosmic rays indicate that this may be so.

Gamma Rays from Mesons?—An Hypothesis

Observers at particle accelators study the energy radiations, as well as the particles, emitted from targets under high-energy bombardment. At Berkeley, for example, the gamma radiation coming out of a block of carbon bombarded by protons has been measured through the range of energies from zero to 345 Mev.

Charged particles hurtling into a material target lose velocity because of the "friction" or "drag" exerted upon them by the atomic forces around the nuclei. The energy that they thus lose is given off as radiation. This is the way common X-rays are produced when fast-moving electrons strike the target provided in the machine.

The gamma radiation produced in the Berkeley experiment behaved according to the known laws for X-rays until the bombardment energy reached about 180 Mev. More low-energy gamma rays were produced than high-energy ones. As the observers continued to increase the bombardment energy, however, they met with a surprise. They found that an unexpected number of gamma rays of high energy were produced. By the time the bombardment energy reached 340 Mev, 100 times more high-energy gamma rays were found than the X-rays laws predicted. To date, the most probable explanation of the phenomenon pictures the high-energy protons as knocking mesons out of the target carbon and those mesons then decaying with production of gamma rays. If this hypothesis can be substantiated, it will tie this new observation neatly into man's present knowledge about the nucleus.

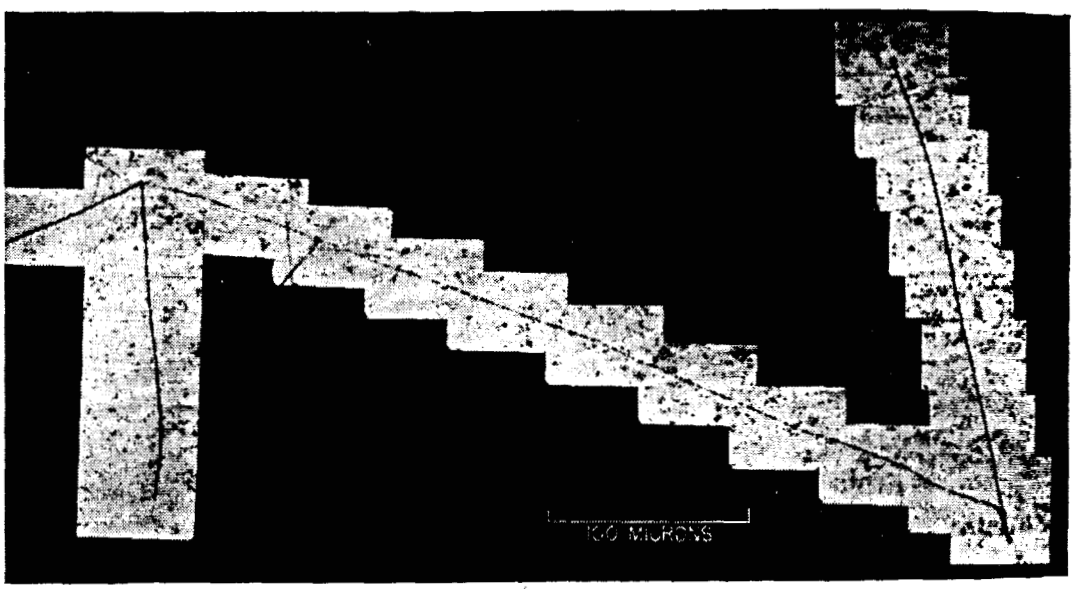
Research with Neutrons

The neutron is the particle most effective in penetrating the nucleus; having no charge, it is not repelled by the electrical fields that surround it. Only nuclei of a particularly stable number and arrangement of the nuclear components can keep the neutron out. Many nuclei are not stable, and wandering neutrons are continually causing disruptions and transmutations among the natural elements.

The effects of neutrons of all energies upon atoms and materials must be known for atomic development, because, unlike the protons, deuterons, and other charged particles, neutrons can have violent effects at low energies. It is a "thermal" or "drifting" neutron that most readily splits uranium 235 and plutonium atoms and releases atomic energy. One of the greatest problems of the nuclear scientists is to produce neutrons of various measured energies so that they may make experiments and learn more about the way the neutrons behave, and their effects upon materials. (*Continued on p. 78.*)

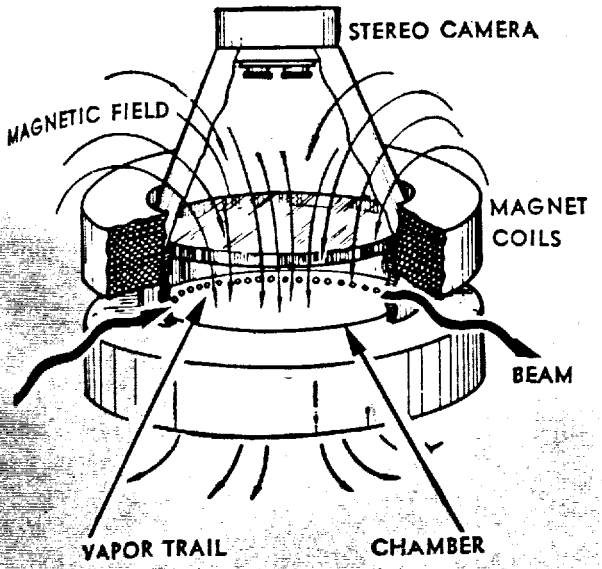
Detection Instruments

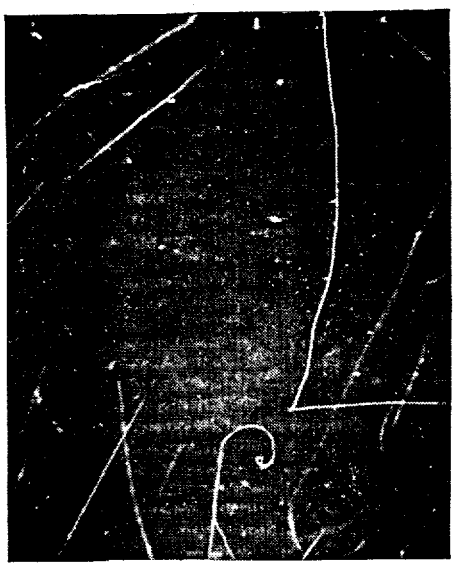
The nuclear particles studied by science—protons, neutrons, electrons, positrons, mesons—are so small they would have to be magnified hundreds of millions of times to be visible to the naked eye. They travel at tremendous speeds—thousands of feet per second—and the invisible events in which they take part are measured in millionths of a second. Yet the properties and behavior of these particles must be studied for the development of nuclear science and atomic energy. In the typical experiment, the nuclear scientist deals with very large numbers of particles and needs to identify them, estimate their numbers, and measure their energies. For these purposes he depends mainly upon ionization tubes and the kind of electronic equipment pictured on pages 76 and 77. However, he is also able to observe single particles and make records of individual nuclear events. The picture record below was obtained on specially prepared photographic plates in which electrified nuclear particles produce visible tracks by ionizing (electrifying) the sensitive grains of the emulsion. The photograph is greatly magnified. A micron is 4 hundred-thousandths of an inch; and the long track of a meson shown below, center, is actually not as long as the diameter of the period at the end of this sentence. Experimenters search many plates with microscopes to find such a track.



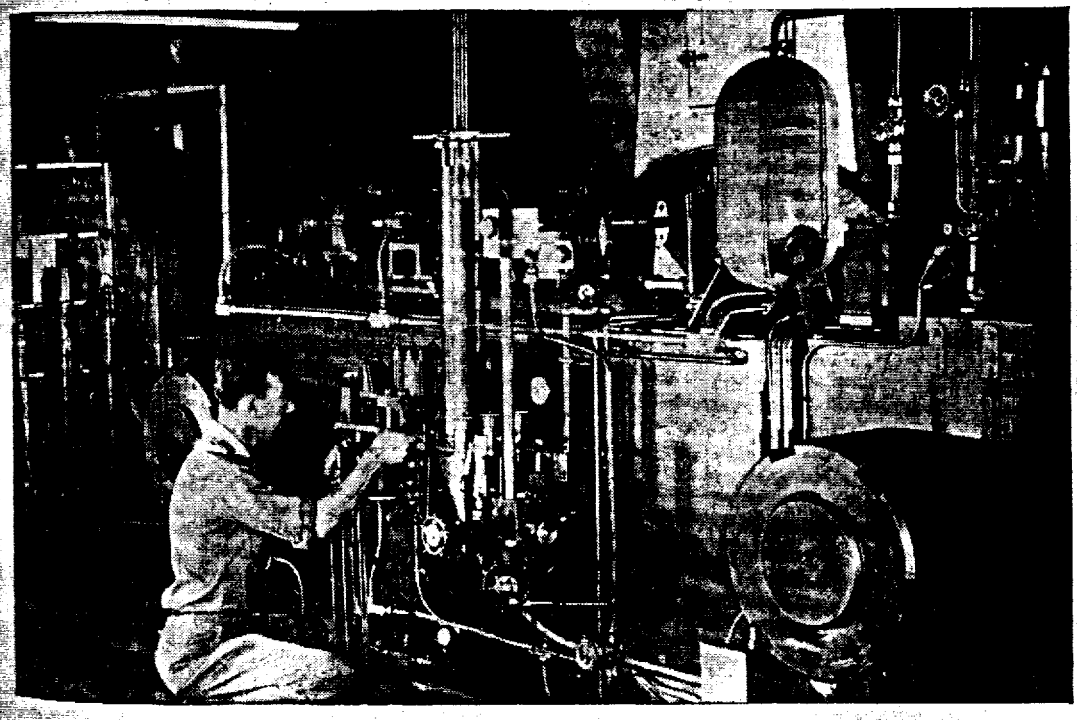
The picture above records a nuclear event caused by 270-Mev protons accelerated in the 184-inch cyclotron at the Radiation Laboratory, University of California. A neutron (leaving no trail because it carries no electrical charge) strikes an emulsion atom at upper left, producing a negative heavy meson and two heavier particles, probably protons. The meson moves to the right, stopping in another emulsion atom and giving up its energy by knocking out another heavy particle, probably an alpha particle.

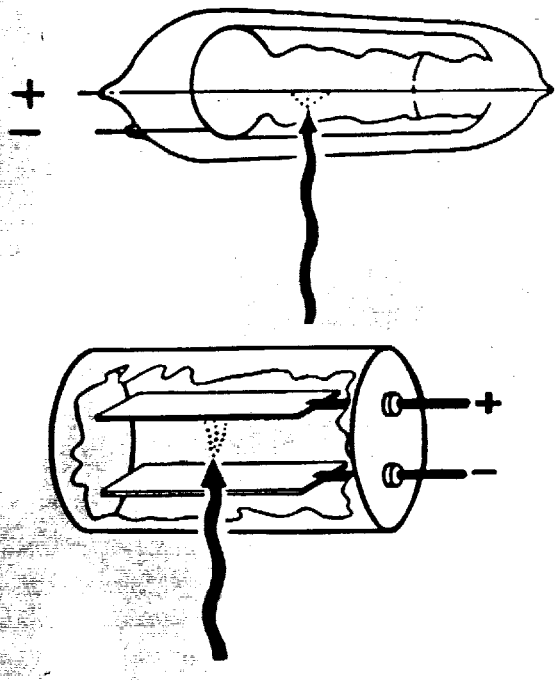
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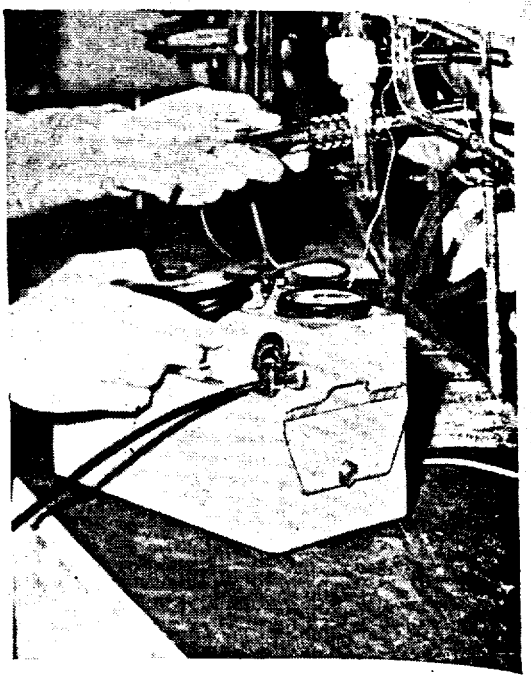




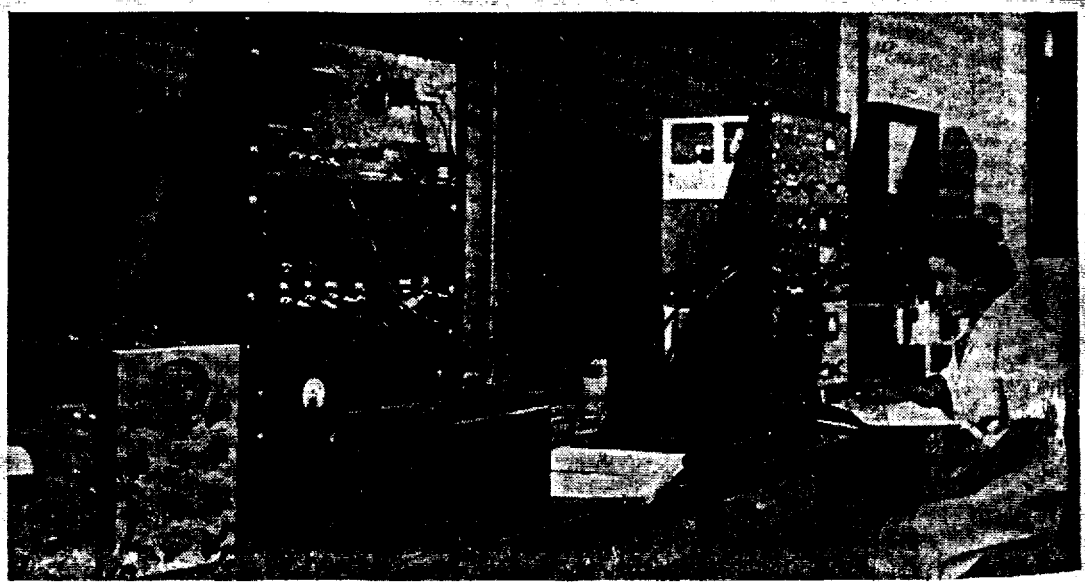
Like photographic emulsion, the cloud chamber also makes possible picture records of events in the invisible world of nuclear particles. This instrument, diagrammed above, consists of a glass-topped chamber containing moist air or gas which can be suddenly cooled by mechanical expansion. The resulting supersaturated vapor condenses on the ionized trail of a moving electrified particle making it visible, like the vapor trail of a high-flying airplane. The above cloud chamber photograph shows a meson descending at the right and decaying with the emission of an electron, and also an electron of lower energy entering the chamber at the bottom. The magnetic field surrounding the chamber helps identify the particles; it is this force that causes the second-mentioned electron to spiral to rest in the vapor and provides the observer with a measure of its energy. Largest cloud chamber ever built is now nearing completion at Brookhaven Laboratory (below). Its advanced design, employing a 70-ton steel yoke magnet and vapor pressures up to 300 times that of the atmosphere, will permit more efficient studies of cosmic ray and other particle bombardments than ever before.







A single sample of radioactive material may give off millions of nuclear particles every second. In both research and production operations throughout the atomic energy program it is essential to have instruments that will count or otherwise measure quantities of radiation. Evacuated tubes of the kinds diagrammed above are the most commonly used detectors. Energetic particles or rays from outside ionize atoms of the gas in the tube; that is, they knock off electrons so that the atoms are no longer electrically neutral. The ions move to the electrodes, resulting in an increased flow of current, or a series of pulses of current, in the electrical circuit to which the tube is connected. These current variations are amplified so that they can be recorded. The photograph above shows the use of a portable model of the well-known Geiger counter, the dial of which registers the intensity of the radiation coming from the material contained in the chemical apparatus. Such relatively simple devices are used for the detection of radiation and the protection of personnel wherever radioactivity is encountered. For nuclear research, however, where great accuracy and a variety of information are required, the electronic devices become complex. The picture below shows the kind of equipment that is used to give accurate counts of radiation emitted over predetermined periods of time.



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The energies, as well as the numbers, of emitted particles must be known in nuclear research. There are many varieties of "spectrometers" for this purpose. One of the newest is the scintillation spectrometer, shown above, left, at Oak Ridge Laboratory, which both counts and measures the energies of particles by means of the flashes of light that they cause in certain crystals. The Argonne Laboratory neutron spectrometer, above, right, mechanically chops a beam of neutrons into bursts so that the velocities of the various neutrons can be analyzed by a series of detectors. The complex pulse analyzer, shown below, makes possible the identification of radioactive isotopes by showing the energies of the various alpha particles that they emit.



SOURCES OF NEUTRONS

The neutron is difficult to control, because—

a) Being electrically neutral, it cannot be slowed down or speeded up by electrical and magnetic fields. The only way to change its motion is through collisions.

b) For the same reason, it can only be contained or stopped in its movements by thick barriers or, for lower speeds, by relatively small thicknesses of certain elements such as cadmium and boron, which capture it readily.

c) It is evanescent, with a half-life of 30 minutes or less.

Broadly speaking, there are two ways to produce neutrons: (*a*) knocking them out of nuclei by bombardment, as in a radium-beryllium source, and (*b*) producing them by nuclear fission in a reactor.

Neutrons from Bombardment

The first neutrons observed in the laboratory were produced when the alpha particles emitted by radium were allowed to strike a target of beryllium, causing the beryllium atoms to emit the neutral particles. The radium-beryllium source, still used today, gives neutrons with a variety of energies, ranging up to about 5 Mev and averaging between 2 and 3 Mev (a neutron with 1 Mev energy travels at a speed of about 30,000 miles a second—something like one-sixth the speed of light). To get neutrons of other energies, a large number of techniques have been developed. Experimenters in AEC laboratories have, among other things—

a) Used a Van de Graaff generator to bombard deuterium with tritium. The reaction between the "tritons" and the "deuterons" produces alpha particles and neutrons with energies ranging between 13 and 19 Mev. Counting the positively charged alphas gives a measure of the number of the neutrons being produced.

b) Bombarded tritons with protons, again using the Van de Graaff, getting a reaction that produces neutrons between 50 thousand electron volts (0.05 Mev) and 1.7 Mev.

c) Used a cyclotron to bombard deuterons with deuterons, thus getting some of the desired neutron energies between 6 and 13 Mev.

d) Bombarded tritons with deuterons, again with the cyclotron, this time getting neutrons of 28 Mev.

An advantage of the Van de Graaff generator over other types of accelerators for this type of work is that it allows close regulation

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of the energy of the particles striking the target. In some energy ranges this means that the energies of the neutrons knocked out of the target can be controlled, and one can sometimes take advantage of the fact that these neutrons emerge in different states of energy depending upon the direction of their flight—whether it is in the same direction as the particle beam from the Van de Graaff, or at right angles to it, or in a backward direction. This technique is most successful in getting neutrons of around 1 Mev.

Neutrons Wholesale—The Chain Reaction

These key facts involving the neutron brought about the development of atomic energy:

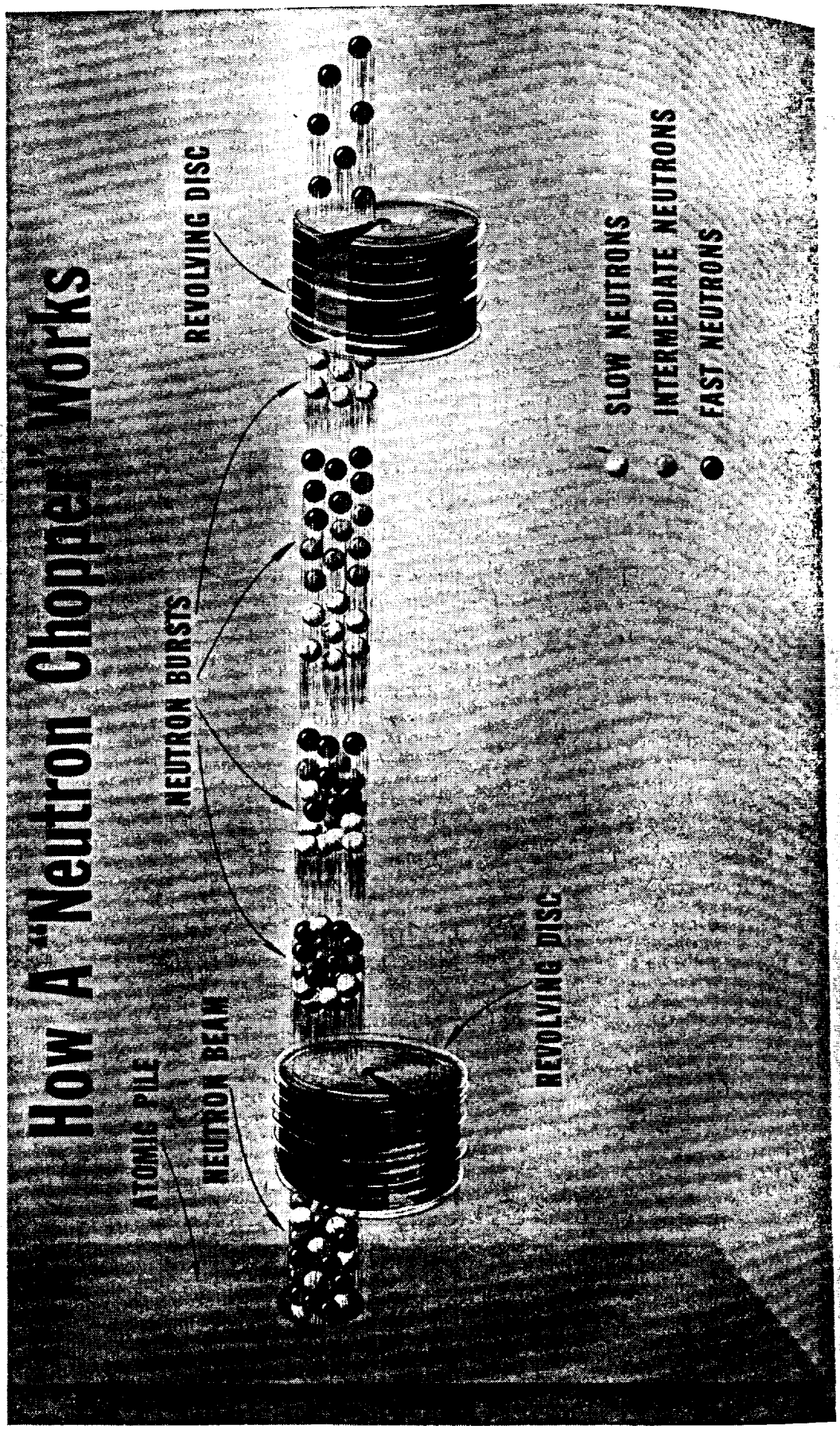
First, it was discovered that a "thermal neutron" (a neutron with energy the same as that of the atoms surrounding it) would split the nucleus of the uranium 235 atom, and release energy.

Second, it was deduced on theoretical grounds that the uranium nucleus, when split, would eject two or three neutrons, and thus perhaps fission other atoms of uranium. The possibility of the chain reaction was plain to see.

In a sufficiently large block of pure fissionable material, if each fissioning uranium atom were to emit just 2 neutrons, and each of these caused another atom to fission, then the nuclear chain reaction would grow with a "multiplication factor of 2." In other words, the original fission would cause 2 more fissions; these 2 would cause 4; and the successive generations would run: 8, 16, 32, 64, 128, etc. The tenth generation would have 1024 fissions, the twentieth more than a million, the thirtieth more than a billion. In 90 generations, a billion, billion, billion atoms will have fissioned. Each one of these generations would require about one-millionth of a second and 90 generations less than one ten-thousandth of a second.

In reactors the multiplication of neutrons is controlled; the over-all power generated can be held constant. Some of the excess neutrons are swallowed up in control rods containing boron or some other neutron-absorbing material. Other neutrons are put to use—at Hanford for manufacturing plutonium; at Oak Ridge for producing radioactive isotopes; and at Oak Ridge, Los Alamos, and Argonne, for research work requiring large quantities of neutrons.

At all of these places, as a general rule, materials are "irradiated" inside reactors to determine neutron effects. But the neutrons inside most reactors have a wide range of energies. Frequently, research and development workers in atomic energy need to know the effects of neutrons of selected energies.


How A "Neutron Chopper" Works
REVOLVING DISC
NEUTRON BURSTS
ATOMIC PILE
NEUTRON BEAM
REVOLVING DISC
SLOW NEUTRONS
INTERMEDIATE NEUTRONS
FAST NEUTRONS

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Sorting Neutrons

The Argonne "neutron chopper", diagram opposite, illustrates some of the problems faced by the research workers who need to sort monoenergetic neutrons (neutrons of the same energy) out of the mixed lot that streams from an opening in the concrete shielding of a reactor. In the picture, three degrees of shading are used to represent fast, intermediate, and slow neutrons, although in actuality there are thousands of variations of energy in the beam. The first rotating disc chops the beam into separate bursts of neutrons. It is a strange "disc." To stop the very penetrating neutrons, it is 16 inches thick and of high-strength steel. It is 4 inches in diameter, driven at 40,000 revolutions per minute by a 3-horsepower motor, and pierced, in actuality, by six slits instead of the one shown for illustration.

Each of the separate bursts, as it travels toward the second revolving disc, stretches out as the neutrons of highest energy take the lead and the others, with their various slower speeds, lag behind. Consequently, the second disc can be timed to chop from the extended burst only the fastest neutrons—as in the diagram—or any other segment that is desired. Possible selections at the Argonne reactor lie between 0.03 and 1,000 electron volts.

The neutron chopper is only one of a varied class of instruments known by their function as "velocity spectrometers." Another such instrument developed at Argonne also using the "time-of-flight" principle has just one rotating disc, to chop the beam into bursts, and beyond that a system of intricately wired detectors that can time the arrival of neutrons of varying speeds. Brookhaven Laboratory is working on a modified version of the neutron chopper.

There are several other principles used to sort monoenergetic neutrons from the wide spectrum of available energies. Certain crystals when placed in a reactor beam will reflect neutrons of different energies at different angles and spread them out in orderly fashion, in somewhat the way a prism spreads out the visible spectrum of light.

Argonne Laboratory, which has a special interest in the behavior of fast neutrons because it has been developing the design of a fast neutron reactor, has used many ingenious ways of sorting out high-energy neutrons. Samples to be tested under bombardment have been wrapped in cadmium of a thickness calculated to let only the fast neutrons through and capture all the rest. Also, a piece of uranium 235 has been placed in the neutron beam issuing from the reactor so that fission would occur within it and produce fast neutrons.

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Polarizing Neutrons

The energy of a neutron is not the only characteristic it possesses that affects its interaction with target material; its "polarization"—or the way its axis is tipped, so to speak—can sometimes be important. Neutrons and other nuclear particles are like the Earth in that they spin and possess magnetism, and consequently have "north and south poles." Modern physicists have found means of ascertaining which way these poles are tipped. Such problems as determination of the magnetic properties of various types of steel can be solved more easily if the angle at which a neutron pole is tilted after bouncing off the crystals in a sample of target material can be discovered. But the neutrons in an ordinary beam are tilted at random, in all directions; and thus there can be no coherent information obtained by observing their positions following the collision. What is needed is a *polarized* beam, in which the neutron axes are all tilted the same way.

Argonne Laboratory has achieved such a polarized beam. Neutrons, like light, will bounce off a properly prepared surface if the angle at which they strike is far enough from the vertical. The Argonne experimenters prepared a polished and magnetized cobalt mirror (photo opposite), which would reflect some of the neutrons. When a beam from a reactor strikes this plate at a slight angle (close to parallel), the neutrons reflected all have the same "tilt", and the result is a reflected beam that is 100 percent polarized.

Neutron Detectors

An ordinary Geiger counter will not react to neutrons, but if its tube is filled with the right kind of gas—boron trifluoride is one—the instrument will register the presence of neutrons, since as the neutrons enter atoms of the gas, the latter give off charged particles—ionizing radiation—that can be counted.

One of the difficulties experienced with this type of detector is that the quantities of ionizing radiation produced by a given number of neutrons are not the same at various neutron energies. The instruments are able to detect neutrons of a single energy more accurately than when energies are mixed. A comprehensive study of the detection and measurement of neutrons is under way at the Commission's Mound Laboratory, Miamisburg, Ohio, where the object is to develop new counting methods that will be both rapid and accurate.

All told, much time and ingenuity have been expended on instruments and techniques that will give quantitative answers—that will actually count—because the nuclear sciences are based upon numbers. When an investigator trains a beam of particles upon a specimen

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A mirror that polarizes neutrons. The nuclear particle called the neutron is so small that it would have to be magnified about a hundred million times to be visible; yet it is like a tiny model of the Earth, in that it spins and possesses magnetism and has "north and south poles." Sometimes for experimental work, beams of neutrons are required that are polarized, with their axes pointed all the same way. This is accomplished at Argonne Laboratory with a highly polished and magnetized cobalt mirror, shown above reflecting the experimenter's hand. Neutrons emerging from the nuclear reactor (background) have their axes oriented in all directions, but those that are reflected from the mirror are 100 percent polarized.

to be tested, he needs to know how many were absorbed and how many got through.

A technique of measuring absorption of neutrons. Nearly all of the instruments built to answer this question depend upon counting the number of atoms struck and made radioactive by the neutrons. However, a technique developed at Oak Ridge and Argonne is entirely different in principle. The problem to be solved was to find out how many neutrons were being absorbed by a specimen of material placed in a reactor. It was found that this question could be answered quantitatively if the specimen were oscillated regularly in and out of the neutron field inside the reactor. This procedure affected the level of operation of the entire reactor. From the magnitude of this effect it was possible to compute how many neutrons the specimen had absorbed. Measurements of neutron absorption have been made on more than 70 different elements by this technique.

Parallel plate counter. Investigators also need to be able to measure accurately the angles of flight of neutrons when they are deflected

from their course by target materials. Brookhaven has devised a "parallel plate counter" to answer this need. The neutrons, having passed beyond the target, enter the space between two plates, one of which is of glass. They strike the other plate which has been coated with the rare metal indium. The indium emits beta particles for some time after being struck, producing tiny visible "sparks" which can be photographed. The result is a picture showing where the neutrons struck. From this, the angles of their flight are calculated.

NEUTRON CROSS SECTIONS

A variety of neutron energies is needed in the measurement of neutron cross sections: that is, the measurement of the probabilities that neutrons of any specific energy moving into any particular material will pass through unhindered, or be deviated from their course, or be bounced about, or be absorbed—and if the last, which one of the many possible resulting nuclear reactions will ensue.

To cover this field of investigation completely would require the measurement and tabulation of these various cross sections for every isotope of every element at every possible neutron velocity from the slowest to the fastest. The investigations actually being carried out concern themselves with the isotopes and the neutron velocities of most immediate practical interest in atomic energy development. The program again further divides itself in accordance with the different facilities available at the different laboratories. Uranium reactors are a tremendous source of slow neutrons, and programs for measuring slow neutron cross sections are under way at Oak Ridge and at Argonne. Measurements involving fast neutrons, on the other hand, are carried on where there are powerful particle accelerators, as at Berkeley and Columbia University.

Even when reduced to its essentials, the program for the determination of neutron cross sections engages a substantial part of the available manpower at every large AEC laboratory and accounts for a sizable share of the Nation's budget for atomic energy research and development. Typically in the past, the kind of background research involved here—the painstaking collection and tabulation of related measurements that are finally printed in the handbooks of the engineers—was the work of many decades. Today, it is being done systematically and rapidly. It is speeded by: (1) the development of better experimental techniques, (2) the advancement of nuclear theory, and (3) the promotion of basic research.

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Development of Instruments and Techniques

Such developments are continually lightening the task. The Argonne "neutron chopper," for example, now makes possible a close selection of neutron energies that would have saved much difficult and awkward experimentation for the wartime developers of atomic energy if it had been available to them. Again, the refined velocity spectrometers now in use in Columbia University's physics department have facilitated the study of certain fission reactions and brought the first success in measuring directly the scattering cross sections of a number of substances important in atomic energy development.

The Assistance of Theory

In the early stages of a scientific development the facts and figures collected by the workers in routine research may appear to be entirely random, bearing no relation to one another, but sooner or later they begin to form meaningful patterns. At this point theory comes into use and, by formulating the underlying principles which the patterns may reflect, saves much labor. For example, when work in various laboratories had compiled the cross sections of all the elements in the periodic table for the capture of neutrons of one selected energy, it became apparent that there were regular hills and valleys in the graph, and that the recurrent low points, standing for minimum absorption of neutrons, were occupied by isotopes containing certain definitely interrelated numbers of neutrons and protons. The builders of the wartime reactors that produced fissionable material have stated that knowledge of these "magic numbers" would have saved them many months of experimentation. The benefit to today's reactor designers is, of course, considerable.

Mathematics is the language of nuclear theory, and all of the National Laboratories have organized working teams of mathematicians. These teams develop the formulas that describe nuclear phenomena and translate them into numerical quantities which they check with the results of experiment. Once experimentally verified, the formulas are then used to predict future results and guide further experimentation. The so-called Monte Carlo system used in atomic energy laboratories is typical of the new mathematical techniques.

A statistical method. The Monte Carlo system is used, for example, to determine the effectiveness of the shielding structure planned for a particular reactor. To make the calculation, the mathematician traces the course of a single hypothetical neutron through the maze of atoms in the shield to its final destination. Sheer chance determines how often this neutron will collide with a shield atom and which way

it will rebound. In the mathematical solution, therefore, the distance between collisions and the direction of travel after collision are determined by means of "random numbers," like the numbers that could be obtained from repeated spinning of a perfectly balanced roulette wheel (hence the system's name). As the result of these chance collisions, the neutron may bounce about within the shield until it is captured by an atomic nucleus, or it may escape quickly to the outside, or it may follow any of an infinite number of courses between these two extremes. By following the behavior of a great many such hypothetical individual neutrons, the mathematician can determine the statistical behavior of the group—that is, all of the neutrons that will strike the shield. Any desired accuracy can be achieved by increasing the number of individual calculations.

Ever since the earliest days of the atomic energy project there has been a need to solve very complex computational problems, such as are involved in bomb design, pile construction, thermal diffusion, electromagnetic separation of isotopes, and problems in pure physics. Solving a single problem may involve some tens of thousands of individual operations, and in some instances the number is larger. To tackle such problems at Los Alamos, large groups of computers using desk machines were formed; in other cases, where simple and highly repetitive operations permitted, electromechanical computers were brought into use.

Electronic computers. One development carried on during the war at the Army's Aberdeen Proving Ground was the construction of an electronic digital computer, the so-called Eniac. Its success has provided considerable stimulation in this new field.

The Commission is supporting in part the development and construction by the Institute for Advanced Study at Princeton of an electronic computer which will be ideally suited to handle many of the theoretical problems arising in nuclear research. This device will be completed during 1950. Construction of computers based on this prototype is already under way at Los Alamos and Argonne. Thus these AEC laboratories will have at their disposal the most modern means of scientific computation and will be able to handle problems not possible with existing computers.

To further the development and utilization of mechanical computing devices, the Commission has assisted, through contract, in financing the 12-hour-a-day operation of Harvard University's Automatic Sequence Controlled Digital Calculator, more familiarly known as the Mark I Computer. The problems turned over to this computer are selected by a committee of Harvard scientists and have ranged in scope from the detailed investigation of the force constants necessary to bind the neutron and proton together to studies in heat radiation

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applicable to stellar (and also to atomic weapon) problems. Between these extremes of the small and the great, the machine has helped in solving engineering and medical research problems—having dealt, among other things, with the propagation of flames, the principles of streamlining, the electromagnetic radiation from systems immersed in conducting media, and the dimensions of asymmetrical molecules.

Basic Research With Neutrons

In the long run, the greatest assistance to technological development comes from the discovery of new truths about nature in the course of fundamental research.

Neutron-proton reactions. The reactions of neutrons with single protons are under study in a number of laboratories, including Argonne, Brookhaven, Oak Ridge, Berkeley, and Columbia University. At Berkeley, where very high energies are used, one of the results obtained has given further support to the meson theory of nuclear cohesion. It is observed that when the incident neutrons have a mean energy of 90 Mev, one feature of the neutron-proton collision is the frequent exchange of identity between the two particles. The particle which approached as a neutron leaves the scene of the collision as a proton, and the proton, which was a hydrogen nucleus in the target, recoils from the collision as a neutron. In effect, the two particles appear to be performing, upon collision, the "exchange" which the meson theory postulates as occurring within the tightly-packed confines of the atomic nucleus.

The forces between a neutron and a proton when locked together in the nucleus are most easily studied in deuterium (H 2) which contains one of each. Precise calculations concerning such a "two-body problem" are possible. In preparation for such computations, Columbia physicists have measured with a new accuracy the cross section of a proton for a low-energy neutron, and are now engaged in a second preparatory experiment.

Combined work at Brookhaven and Argonne has recently permitted an experiment—the measurement of the angle of reflection of incident neutrons from a "hydrogen mirror"—which has provided data for a new calculation of the limit of distance within which these elementary particles act upon each other. The figure obtained is about one ten thousand billionth of a centimeter.

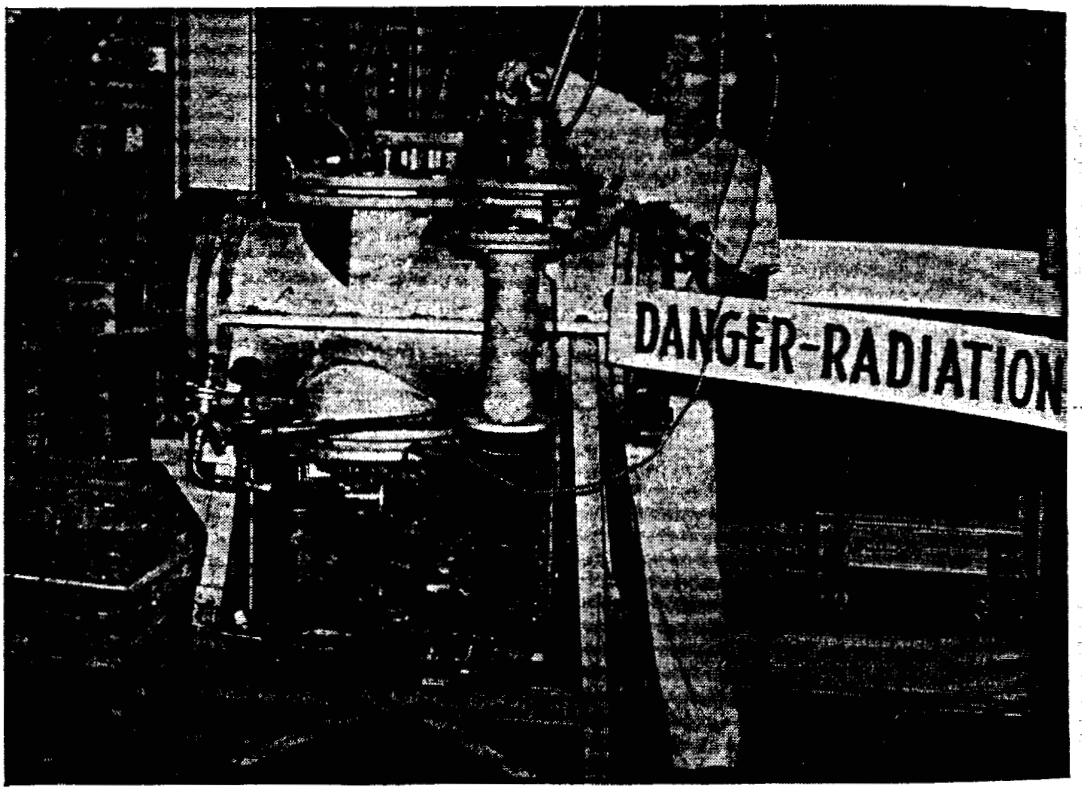
The scattering of neutrons. Neutrons that pass within this distance of atomic nuclei are either absorbed by them or deflected more or less from their original paths. This scattering gives useful information about nuclear dimensions, magnetism, spin, and other characteristics.

At Berkeley, extensive measurements have been made of the scattering cross sections of nuclei for neutrons of energies ranging from 40 Mev to 90 Mev. It appears that as energies increase nuclei of low atomic number display an increasing "transparency," allowing some of the neutrons to pass completely through the nucleus. This phenomenon is still under investigation.

NEUTRON DIFFRACTION

When a beam of slow neutrons strikes a crystal, the neutrons are scattered in certain preferred directions determined by the original angle of the neutron beam with respect to the crystal and by the arrangement of the atoms or molecules which compose the crystal. The pattern thus formed is characteristic of the structure of a given crystal.

Diffraction of X-rays and electrons has been used similarly for many years to study the structure of materials. But X-rays and electrons do not satisfactorily show the presence of lighter elements in the diffraction patterns that they form. Neutrons, on the other hand, do this very well.



Studying the radioactive decay of the neutron at Oak Ridge. A beam of neutrons from a hole in the concrete reactor shield at the left enters the horizontal vacuum tank. If a neutron decays at this point, the apparatus is designed to register the resulting particles—electron and proton—on two counters which are timed a millionth of a second apart. When the neutron beam emerges from the tank, it passes behind the warning sign and is absorbed in a heavy boron "beam catcher" 10 feet away.

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Oak Ridge Laboratory, because its nuclear reactor provides a plentiful source of slow neutrons, has developed an extensive program for the investigation of crystal structure through neutron diffraction. The technique has been found equally applicable to the problems of the nuclear physicist, the chemist (including the organic chemist), and the metallurgist. Neutron diffraction has been applied to the location of the hydrogen atoms in ice crystals and in the crystals of some of the heavy metal hydrides. It can also be applied to the location of relatively light atoms like oxygen in oxides of heavy metals. The gold-copper alloy system has also been extensively investigated.

STRUCTURE AND LIFE OF THE NEUTRON

About 15 years ago, when it was found that neutrons are a little heavier than protons, it was suggested that they should in fact be unstable and should "decay" spontaneously into protons. This process would involve the neutron emitting a beta particle (an electron). Upon ejecting the negatively charged electron, the neutron would become a particle of somewhat smaller mass which carried a positive charge, that is to say, a proton. From theoretical considerations, the half-life was predicted to be approximately a half hour. Present predictions are that it should be somewhat shorter.

Neutrons are so hard to handle that their radioactive decay has not been observed in the laboratory. However, at Oak Ridge evidence of neutron decay is now being sought in an apparatus which registers coincidences, as recorded by the simultaneous operation of two counters, between the emitted beta particles and the resultant protons.

In this experimental arrangement, when a neutron decays the emitted beta particle is registered at once on a proportional counter; the proton which remains, being positively charged, is accelerated by an electric field and after a time of flight of about one-millionth of a second it registers upon a second counter. Thus for both counts to be registered at the same instant it is necessary to delay the operation of the first counter by one-millionth of a second. By this means, the time required to accelerate the proton is used to identify it; a lighter particle than a proton would arrive at the secondary counter too soon to actuate it simultaneously with the first, and a heavier particle would arrive too late.

Results thus far of this experiment have been encouraging. Coincidences have been observed which seem to depend upon the presence of neutrons. Further work must be done, however, to make sure of the trustworthiness of the results and to deduce a fairly accurate value for the half-life of the neutron.

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Mesons and Neutrons

At Columbia University, experiments are being conducted to throw light upon the newer theory about neutron structure: the theory that pictures the neutron as being—at least part of the time—a positive proton with a negative meson attached to it. If this theory were valid, it would appear that the proton in the neutron should have an attraction for electrons even though the particle as a whole were electrically neutral.

A beam of slow (low energy) neutrons was projected through some liquid bismuth, and it was found that negative electrons apparently were attracted by neutrons. Although much remains to be done, this result gives support to the proton-meson idea of neutron structure.

Nuclear Excitations

Atomic nuclei that have captured neutrons, or that have been disrupted by high-energy charged particles, contain excess energy and are said to be in excited states. Some rid themselves of their excess energy almost immediately by emitting energetic radiation in the form of gamma rays; others remain in the unstable condition for widely varying periods of time and emit various combinations of beta or alpha particles and gamma rays when they decay into more stable states. These latter are the artificial radioactive isotopes that have become so important as sources of radiation for doing useful work in science, medicine, agriculture, and industry.

One of the most fruitful of all the sources of information about the nucleus is the observation of its behavior when in the excited state. Some of the kinds of facts obtained may be illustrated by studies under way at Berkeley of the nuclei that emit alpha particles.

Alpha-Radioactivity

A decade ago only 24 nuclear species were known that emitted alpha particles in their decay, and these were all among nature's radioactive families, starting from uranium, actinium, and thorium (radium being the most active and best-known member). Since that time, some four or five other natural species have been found. Today, however, there are more than 100 alpha-emitters, most of them man-made—some by neutron irradiation in reactors, the majority by accelerator bombardment of heavy nuclei with high-energy charged particles.

The information obtained at Berkeley through alpha-radioactivity, chiefly about the heavy elements, is varied and useful:

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a) The manner in which a nucleus emits alpha particles is related to the *energy* that it contains. By measuring the energies of emitted alphas, research workers are able to discover the relative energy content of the radioactive nuclei above lead and bismuth in the periodic table—and thus to arrange the successive members of these families on energy-content basis. Having done this, they find certain hills and valleys in energy-content trends, which give a picture of the relative stability or instability of the structures of the interrelated nuclei. Mapping out these regions, they are able to predict the radioactive behavior and properties of isotopes for which they may be searching and also of istopes that will be formed in nuclear reactors not yet constructed. The reactor designer is vitally interested in this information.

b) The manner in which a nucleus emits alphas is related to its *structure.* For heavy nuclei that contain even numbers of both protons and neutrons, the theory expressing this relationship is well substantiated and has been used to calculate the sizes of these nuclei.

c) The phenomena of alpha-radioactivity and the theories built around them have been used as guides for finding *new isotopes* and "extinct" istopes of elements that once existed upon earth. Many new alpha-emitters have been found in the region of the artificial elements above uranium, and seven other isotopes of plutonium besides Pu 239 have been identified.

Beta-Radioactivity

Most radioactive isotopes decay to a less excited state by emitting a beta particle, either a negative electron or a positive positron. The radioactive nuclei of carbon 14 and oxygen 15, both end as stable isotopes of nitrogen:

Carbon 14, the radioisotope with 6 protons and 8 neutrons in its nucleus, emits a beta particle, an electron with one unit of negative charge. The consequence is that one of the neutrons in the nucleus has now become a proton. Now, with 7 protons in its nucleus—7 positive unit charges—the nucleus no longer is carbon; it has become nitrogen. Its weight is the same as before: 14 nucleons in all, but its positive charge has increased from 6 to 7.

Oxygen 15, a radioisotope with 8 protons and 7 neutrons in its nucleus emits a positron, with one unit of positive charge. The effect is the reverse of the above: one of its protons has become a neutron. Its weight is the same as before (15) but its positive charge has been reduced from 8 to 7, so it is now nitrogen 15, a stable isotope.

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One of the conclusions that seem to follow from these observed facts is that a neutron is a combination of proton (positive charge) and electron (negative charge) and that it transforms itself into a proton by getting rid of the electron. But as soon as the energies involved in the reaction were measured this theory ran into trouble. In transforming from an excited to a stable state, the nucleus reduces its energy-content, and this reduction can be measured. Theoretically, the emitted electron should carry just this amount of energy. But, usually, it carries less.

The neutrino. To account for this discrepancy, there has been postulated an uncharged particle, the neutrino, assumed to be emitted by the neutron along with the electron and to carry the missing energy. This particle has never been observed: and, in fact, its postulated properties—close to zero mass and no electrical charge—make its observation next to impossible.

Nuclear physicists today are continually making more precise observations of beta decay and keeping a lookout for the neutrino. In experiments conducted over the past year, serious errors in the measurement of the energies of emitted beta particles have been corrected. It has been found that the samples of material used as beta-particle sources in many previous experiments were too thick, with the consequence that many of the emitted particles lost part of their energy by absorption in the sample before they could emerge from it.

By using thin enough source materials in a solenoid spectrometer, energy measurements have been obtained at Columbia University that agree closely with the electron-neutrino theory of neutron structure. Equipment is now being prepared at Columbia to conduct an experiment on the beta decay of helium 6, with the expectation of throwing more light on the problem.

Half-life measurement. The two radioisotopes mentioned above provide examples of long and short half-lives. Half of the atoms in a given sample of oxygen 15 will transform themselves into nitrogen in 126 seconds, but the carbon 14 will need 5,100 years for the same change. Most radioisotopes have half-lives somewhere in between.

For many reasons, it is important to know half-lives accurately. Those ranging from a few seconds to a few thousand years can be measured fairly easily, but there is difficulty in measuring the very short half-lives. Brookhaven Laboratory has constructed an instrument to measure those that are extremely short. The sample of material is placed on the rim of a rapidly rotating disc. As the sample rotates through a strong beam of neutrons, a small amount of radioactivity is induced in it. It next whirls past two Geiger counters. If the induced radio-activity has a very short half-life the second counter will show a lower count than the first, since some of the isotopes will

have disintegrated in the time that it takes the disc to turn from one counter to the other. It is then possible, knowing the speed of rotation of the disc, the distance between the two counters, and the number of counts registered respectively on the counters, to calculate the half-life of the radioactive material. The more accurate determination of the half-life of carbon 14 is the object of another series of Brookhaven studies being carried out in collaboration with the Massachusetts Institute of Technology and the University of Minnesota.

Other Particles from Bombarded Nuclei

A single bombardment experiment sometimes can throw considerable light upon the nuclear structure of target atoms. At Berkeley, for example, deuterons were discovered coming out of a bombarded target. This was surprising, because the bond between the proton and neutron in a deuteron is relatively weak and the experimenters at first had difficulty in understanding how it could withstand the violent disruptive forces of the bombardment.

Theoretical explanation was soon forthcoming in terms of a "pick-up" process within the nucleus. The internal energy of a nucleus in its normal state causes some nuclear particles to move within the nucleus at high speeds. When an incident high-energy neutron passes into and through a nucleus there will be a possibility of its joining with a proton moving with comparable speed and direction, and the two may thus emerge as a deuteron.

Deductions like this are made by calculating such quantities as the "yield"—that is, how many product particles are actually emitted from the nucleus for a given number of incident particles—and the "angular distribution," or the direction of emission of the particles. Sometimes, again, two distinct product particles are emitted, one after the other, and it is important to observe whether the direction taken by one of them is related to the direction taken by the other.

At Johns Hopkins University, this kind of information is being obtained about three light nuclei.

Lithium 7. When a target of lithium 6 is bombarded by deuterons, it is transmuted into lithium 7, with the yield of protons plus gamma radiation. At Johns Hopkins the angular distribution of the emitted protons has been measured and certain conclusions drawn about the nucleus. Confirmation is being sought by performing the same kind of measurements upon the emitted gamma rays. The preparation of lithium 6, the target required for this experiment, has peculiar difficulties. Li 6 is a rare isotope of natural lithium, and the experimenters had to build a special isotope separator to obtain it. Further-

more, Li 6 is extremely reactive with the oxygen in the air, and therefore the target must be prepared and used in a vacuum.

Beryllium 7. The Johns Hopkins investigators have been able to show that beryllium 7 has an excited state very similar to that of lithium 7. They produced the beryllium 7 by bombarding boron 10 with protons, causing the emission of alpha particles. They found that these alphas are emitted in two groups of differing energies, and are now preparing to measure this difference.

Oxygen 16. Also at Johns Hopkins instruments are being prepared to study the excited state of oxygen 16 because observations made elsewhere have given rise to two alternative hypotheses about the behavior of this nucleus. It is hoped to determine which is correct.

Separation of Isotopes

One of the original approaches to the study of the atomic nucleus, early in this century, was through the use of the mass spectrograph to separate, weigh, and observe isotopes.

With the discovery in 1939 that uranium 235 was fissionable, the separation of this isotope from the other isotopes of uranium became a practical problem on a large scale. It was solved at Oak Ridge as the result of a major wartime investment of money and manpower.

But the separation and production of the natural isotopes of the elements has other important practical aspects. Tracer isotopes as tools of research are the most valuable contribution of atomic science to human welfare yet realized. Although the artificial radioactive isotopes are more widely used, the stable isotopes—the ones that occur in nature—have an important place among scientists' research tools. They can be used where emissions from radioactive isotopes would injure living tissues, and also where a suitable radioisotope of the required element does not exist.

To study the fundamental properties of individual isotopes of an element, the isotopes must be separated from each other. In general, chemical methods for doing this are extremely difficult. Isotope separation can be done only by techniques that make use of the tiny differences in weight between different isotopes of an element. Since the Commission possesses equipment uniquely suitable for this work, it has actively supported both the separation of stable isotopes and research directed toward improving methods of separation. The three methods scaled up to production-plant dimensions during the war for separating uranium 235 from natural uranium were gaseous diffusion (used at K–25), electromagnetic separation (used at Y–12), and thermal diffusion. Research designed to improve these methods

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and to develop new ones is under way at AEC laboratories and in university laboratories under AEC contracts.

Electromagnetic Separation

The instrument developed for electromagnetic separation work at Y-12 in Oak Ridge is the *calutron.* It is basically like the mass spectrograph only much larger. The mass spectrograph separates only the minutest quantities and is used to measure the mass of the separated isotopes; the calutron can separate usable quantities.

Y-12 laboratory at the Oak Ridge National Laboratory began a research project in November 1945 to improve the electromagnetic process of separating uranium isotopes. This program has improved the flexibility and efficiency of the separation process, and has been expanded to supply separated stable isotopes of many elements for other AEC research installations and for universities and other qualified users throughout the country. The isotopes of 37 chemical elements have been successfully concentrated and are being used as research tools in ever-increasing number.

Between January 1947 and September 30, 1949, 190 shipments to users outside AEC installations resulted in 40 reports of research work published in the "Physical Review," and new reports were appearing every month. The 459 shipments to AEC installations made possible investigations that led to a large number of reports.

Research is in progress at Wesleyan University, Middletown, Connecticut, on several special problems involving electromagnetic separation methods. One problem is the attempt to isolate certain stable isotopes that have never been found. This search led to discovery of platinum 190, and demonstrated that three other isotopes sought—lead 202, tungsten 178 and palladium 100—either do not exist or are extremely rare. The work at Wesleyan also includes research on new ion sources for electromagnetic separation work and very precise measurements of the atomic weights of several heavy isotopes.

Thermal Diffusion

The thermal diffusion method of isotope separation has its limitations, but it is the preferred method for a few of the lighter elements that exist as gases or that have stable gaseous compounds over a suitable temperature range.

Yale University is conducting research work on the separation of the rare isotope helium 3 from ordinary helium by the use of thermal diffusion columns with helium gas under pressure. This method is expected to produce helium 3 that is 1000 or more times as concentrated as in the natural gas. In research on neon isotopes, the Yale laboratory

recently produced a sample of neon gas enriched in neon 22 to 93.4 percent as compared with a normal of 10 percent. Work is also in progress to separate the light argon isotope argon 36.

At Columbia University, a new separation method has been devised that uses chemical exchange in thermal diffusion columns to concentrate the isotopes of some of the lighter elements. The method has thus far been applied to carbon and nitrogen isotopes, and will be extended to others.

New Separation Methods

Research is under way at the Oak Ridge Y–12 laboratory, Los Alamos, Oregon State College, and elsewhere on new methods of separating stable isotopes. In most cases, these methods are directed specifically at certain isotopes that are exceptionally difficult to separate by the more widely used techniques.

RESEARCH IN CHEMISTRY

To begin with, there would have been no plutonium in the early 1940's—nor, indeed, any exploitation of nuclear fission—if physicists and chemists had not for years been seeking knowledge for its own sake about the transuranium elements. With the new techniques of nuclear bombardment, they had been attempting to produce atoms heavier than uranium, elements that did not exist in nature. They had developed theories about what these elements, including plutonium, should be like—their physical and chemical properties.

Of course, they had no practical knowledge of plutonium's properties. In the then recently invented cyclotron at the Berkeley Radiation Laboratory, they produced an isotope of plutonium and, using both theory and empirical methods, were able to extract chemically a small amount of this new element from the large quantities of other radioactive substances with which it was intermixed. By using this isotope of plutonium, observable only by "tracer" techniques dependent on its radioactivity, they were able to determine more definitely some of its chemical properties. Using this knowledge, they then were able to extract it more efficiently, obtain larger quantities, and determine its chemical properties more rigorously. With this information they were at last able to undertake the much more difficult job of preparing and isolating a small amount of the isotope of interest, Pu 239, and to demonstrate that it actually was fissionable.

This accomplished, the second stage of the task began. It was necessary to study plutonium chemistry again in much greater detail in order to carry out the enormously more complex job of separating it on an industrial scale from the uranium and intensely radioactive fission products.

It is characteristic of the function of basic research that some of the chemistry worked out at this stage was not used for the plutonium separation process but later became extremely important for the solution of problems not foreseen at that time. Such problems will continue to arise. A broad program in nuclear chemistry therefore includes not only basic research for which there is a foreseeable objective, but also much in which the discovery of new phenomena and gathering of new information is the only immediate goal.

Chemical Separation

The job that the chemist is most often called upon to do in atomic energy is to separate, or extract, one material from another, or more often, from a mixture of others. Chemists have many ways of doing this—selective solvent extraction, distillation, precipitation, ion-exchange, and liquid-liquid extraction, for example.

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The Transition Elements

The differing chemical properties of the elements, the basis for all of these separation methods, are intimately related to the differing arrangements of the electrons of their atoms. Hydrogen has 1 such electron outside the nucleus, helium 2, lithium 3, carbon 6, iron 26, gold 79, and so on, up to uranium, the heaviest natural element, with 92. These electrons are arranged in layers or shells; and the elements' chemical properties depend almost entirely upon the number of electrons in the outermost shell. When successive elements are built up by addition of outer electrons, there are fairly sharp changes in chemical properties from element to element.

But there are two areas in the periodic table where successive elements are built up, not by additions to the outer shell, but rather by various additions and adjustments to the inner shells. One of these areas is occupied by the "rare earth" elements, beginning with lanthanum, number 57, and ending with lutecium, number 71. The other such area comprises actinium (number 89), thorium (90), protactinium (91), uranium (92), neptunium (93), plutonium (94), americium (95), and curium (96)—all of these being radioactive and the last four, of course, man-made.

In these two families of elements, the members are so much alike chemically that there is some difficulty in separating them one from another in pure form. The elements in both of these families, particularly the latter, are of importance to atomic energy development. The chemical work involved in the program has been from the start very difficult.

Chemistry of the Heavy Elements

Greater understanding of the chemical characteristics of the heavy-element transition series is a prime objective of the chemical research program. Knowledge gained about actinium, protactinium, neptunium, americium, and curium assists in dealing with the chemistry of thorium, uranium, and plutonium. In fact, the main impetus that led to the isolation of curium, achieved by the Radiation Laboratory, Berkeley, was the desire to study its properties and thus help establish

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In 1869, the known chemical elements were first arranged in the above rows and columns, a pattern which is descriptive of their characteristics and enables prediction of their essential properties. At that time only about 75 of the elements were known. Since then science has been isolating, identifying, and studying the missing elements, one after another. Circled in black are the final two gaps to be filled. Promethium (Pm) was discovered at Oak Ridge Laboratory among the fission products from nuclear reactors. Technecium (Tc) also was produced for the first time in any quantity at Oak Ridge (opposite page).

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PERIODIC CHART OF THE ATOMS
The Atoms Grouped According to the Number of Outer (Valence) Electrons
Electronic Structure
Planetary Electrons in the completed shells
Total Atomic No.
End of the 1st Period
End of the 2nd Period
End of the 3rd Period
End of the 4th Period
End of the 5th Period
End of the 6th Period
Final Quota in red
Rare Earths Type
Rare Earths Type
I
II
III
IV
V
VI
VII
VIII
1 H 1.0080
2 He 4.003
3 Li 6.940
4 Be 9.02
5 B 10.82
6 C 12.010
7 N 14.008
8 O 16.000
9 F 19.00
10 Ne 20.183
11 Na 22.997
12 Mg 24.32
13 Al 26.97
14 Si 28.06
15 P 30.98
16 S 32.066
17 Cl 35.457
18 A 39.944
19 K 39.096
20 Ca 40.08
21 Sc 45.10
22 Ti 47.90
23 V 50.95
24 Cr 52.01
25 Mn 54.93
26 Fe 55.85
27 Co 58.94
28 Ni 58.69
29 Cu 63.54
30 Zn 65.38
31 Ga 69.72
32 Ge 72.60
33 As 74.91
34 Se 78.96
35 Br 79.916
36 Kr 83.7
37 Rb 85.48
38 Sr 87.63
39 Y 88.92
40 Zr 91.22
41 Cb 92.91
42 Mo 95.95
43 Tc 99.
44 Ru 101.7
45 Rh 102.91
46 Pd 106.7
47 Ag 107.880
48 Cd 112.41
49 In 114.76
50 Sn 118.70
51 Sb 121.76
52 Te 127.61
53 I 126.92
54 Xe 131.3
55 Cs 132.91
56 Ba 137.36
57 La 138.92
72 Hf 178.6
73 Ta 180.88
74 W 183.92
75 Re 186.31
76 Os 190.2
77 Ir 193.1
78 Pt 195.23
79 Au 197.2
80 Hg 200.61
81 Tl 204.39
82 Pb 207.21
83 Bi 209.00
84 Po 210
85 At 211
86 Rn 222
87 Fa ~223
88 Ra 226.05
89 Ac 227
58 Ce 140.13
59 Pr 140.92
60 Nd 144.27
61 Pm 147.
62 Sm 150.43
63 Eu 152.0
64 Gd 156.9
65 Tb 159.2
66 Dy 162.46
67 Ho 164.94
68 Er 167.2
69 Tm 169.4
70 Yb 173.04
71 Lu 174.99
90 Th 232.12
91 Pa 231.
92 U 238.07
93 Np 237.
94 Pu 238.
95 Am 241.
96 Cm 242
97
98
99
100
101
102
103
2 8 18 32 18 8
2 8 18 32 32 18 8
2 8 18 32 18 8
2 8 18 18 8
2 8 18 8
2 8 8
2 = 2
10 = 2 8
18 = 2 8 8
36 = 2 8 18 8
54 = 2 8 18 18 8
86 = 2 8 18 32 18 8
0 n Neut. 1.0086
2 He
10 Ne
18 A
36 Kr
54 Xe
86 Rn
58–71
90–103

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the common properties of the whole series. Leaders in these studies have been Argonne, Los Alamos, and Berkeley. Brookhaven has recently undertaken a program of study of the magnetic properties of the heavy elements.

Since available samples are often as small as a few millionths of a gram, their chemical properties must often be studied by tracer methods based on their radioactivity. AEC laboratories have succeeded, during the last year, in preparing protactinium and americium in metallic form, although the tiny quantities available and their intense radioactivity made this a very difficult task. The work with the heavy elements, particularly americium and curium, has involved detailed studies of methods of separating them from each other and from rare earth fission products, and has resulted in some marked advances in the technique of ion exchange.

Los Alamos chemists have succeeded in separating a small quantity of americium (atomic number 95; atomic weight 241). The material has about three times as much alpha activity as an equivalent weight of radium; and although its gamma radiation is not as penetrating, the work still calls for lead shielding. Chemists must handle this substance through gloves in enclosed boxes through which streams of air are constantly being drawn. Some of the Los Alamos americium is being converted by neutron bombardment into curium to provide samples of that element for study.

Plutonium Separation

Everything learned about the chemical properties of the heavy-element transition series helps in solving one of the most pressing problems of atomic energy development: the improvement of the processes used for extracting plutonium from the uranium slugs from the production reactors at Hanford and the development of the processes that will be used in connection with future reactors. The processes originally installed were hurriedly developed; improvements will increase the efficiency of the production of fissionable material.

Plutonium separation constitutes probably the most difficult chemical problem ever undertaken on a large scale. The plutonium in the uranium slugs is extremely dilute. Created along with it during reactor irradiation are a multitude of other elements, the fission products. Therefore, the chemist is faced with the job of separating and isolating a small amount of a single chemical element from over 40 other elements.

The plants and laboratories of the Commission accordingly are engaged in constant study of the changes which plutonium undergoes under various treatments—how plutonium can be dissolved, how it

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can be precipitated from dilute solution, how solutions of plutonium and uranium compounds in water can be extracted into solvents other than water, and how plutonium metal can be made economically and efficiently from plutonium salts.

Not only must the chemist study the chemical actions of plutonium but also he must know exactly what iron, aluminum, iodine, lanthanum, cerium, neodymium, samarium, calcium, barium, tin, and some 40 or 50 other elements will do when treated by the method being studied.

If there were available collections of data listing precisely what each element and its many compounds do when treated in a particular manner, there would still be great difficulty in selecting processes for the separation of plutonium. The reason is that the material does not always behave the same in the presence of other substances as it does when alone, nor is its interaction always predictable.

Chemistry of the Rare Earths

The other family of "transition elements," the 14 rare earth elements between lanthanum (57) and lutecium (71), are important in the atomic energy program because they are prominent among the fission products created in uranium slugs along with plutonium in a production reactor. Most chemists knew very little about these rare earths in 1940. They occur together in nature, and—because they were so hard to separate and had not been of any great practical importance in the past—their chemical properties were little understood. The developers of atomic energy had to get the facts about these rare earths; the work to be done fell within the field of fundamental, experimental, and theoretical chemistry.

Ames and Oak Ridge laboratories have pioneered the basic studies of, and the development of separation methods for, the rare earths. Their most successful method has been a refinement of the ion-exchange process. In this process, a solution containing rare-earth elements is allowed to flow downward through a long thin vertical tube which is packed with resin. This solid resin removes the various elements from solution by the process of ion exchange. After the rare earths are absorbed on the resin, a weakly acid sodium citrate solution is poured through the column. Under the action of this solution, the grip of the resin upon the rare earths seems to be loosened, but to a slightly different degree for each rare earth element present. As the solution passes down the tube the rare earths begin to be carried with it, but at different rates, so that the solution as it emerges from the bottom of the column is found to carry one rare earth for a time, and then another for a time, then a third for a time, and so on. By collect-

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ing these fractions in different vessels, chemists achieve a separation of the component rare earth elements.

Remote-control chemistry. The material that is put through this process, being the product of a nuclear reactor, is strongly radioactive. The chemist, therefore, cannot get close to his work; he must be separated from it by several feet of concrete. The thin glass column just mentioned, together with the containers of fluid, pipes, valves, and all the other necessary apparatus, is sequestered within massive concrete walls of a "hot cell." The operator works by remote control and views his work through mirrors and periscopes, even though the quantities of material that he handles and the pieces of equipment that he uses may be tiny.

Last of the missing elements. From the point of view of pure science, the exploration of the rare earth fission products has been an exciting advance. In some cases, the radioactive varieties that come out of reactors are the only samples of the elements that have ever been available for study. Oak Ridge Laboratory has been internationally accredited with the discovery of element 61, promethium, isolated by the ion-exchange process from reactor products. This laboratory, also, is the first producer in any quantity of technecium (43), the other of the final two missing elements to be discovered (see chart p. 99).

The successful application of the ion-exchange method to the separation of rare earths has led to its use in other fields, notably the separation of certain biological compounds known as nucleic acids and the separation of other very similar compounds or elements, the purification of which by other means is extremely difficult.

Spectroscopy of Hydrogen Isotopes

One of the most important problems regarding atomic and molecular forces, one which interests physicists and chemists alike, is how atoms interact to form molecules.

Because of the many electrons which usually form part of an atom's shell, the interaction between atoms presents a problem which so far has been solved only partially. Much of the experimental evidence comes from a detailed study of the absorption spectra obtained when molecules absorb light. The information thus obtained has made it possible to unravel many general features of the structure of molecules, and to obtain a knowledge of the forces acting between atoms.

In most cases, the experimental difficulties and the complete impossibility of making basic theoretical calculations put a limit to the knowledge that can be obtained. Only for the simplest of molecules is it likely to be possible to get a fairly complete and accurate picture of the structure and the interatomic forces involved.

The simplest of all molecules is that of hydrogen, which contains only two electrons. By studying this molecule, knowledge may be gained that will help to understand by analogy features in the structure of more complicated molecules.

In the study of the hydrogen molecules, a complete theoretical treatment, though difficult, is possible if there are enough experimental data to guide the theory. The molecular spectrum of hydrogen contains more than 10,000 lines from which data may be secured.

Three Isotopes Give Assistance

The interpretation of the meaning of these lines is in many cases very difficult and might be hopeless were it not for the fact that hydrogen exists in three isotopic forms, ordinary hydrogen (H), deuterium (D), and the radioactive form, tritium (T).

The interatomic forces among the three isotopes are practically identical, but their masses are different—deuterium being twice and tritium three times as heavy as ordinary hydrogen. A combination of the three isotopes makes it possible to obtain six different kinds of hydrogen molecules (H2, D2, T2, DH, TH, TD), and the spectra of all six molecules may be studied. Because of the differences in mass, these molecules vibrate and rotate in different ways. Each state of vibration and rotation, combined with a particular motion of the electrons, gives rise to a line in the spectrum. The spectra are, therefore, different for the six molecules, and the differences can theoretically be predicted from a knowledge of the masses and of the type of electron motions.

The actual procedure is to produce the spectra of the six molecules and study the differences between comparable lines. From this, the type of electron motion can be deduced. The electronic structure is responsible for the interatomic forces.

Success with Photographic Technique

Tritium has become available only recently. Fortunately, only very small quantities are necessary for this work. The first step—photographing the spectra of the hydrogen molecules containing tritium and measuring them—has been largely successful. The work has been a cooperative effort of Argonne Laboratory and the Johns Hopkins University. The former has facilities for handling and purifying the radioactive tritium, the latter the necessary spectroscopic facilities as well as experience with the analogous molecules containing deuterium.

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High and Low Temperature Research

If a powder consisting of tiny insoluble particles is dropped into a glass of water, the particles may be seen, under high magnification, to be dancing about as though they were being kicked or pushed. As a matter of fact they are, by the motion of molecules (H_2O) of the water. The incessant motion of atoms and molecules constitutes the phenomenon we know as *heat.*

Absolute zero (460 degrees below zero, Fahrenheit) is the temperature at which constituent atoms or molecules of all substances are in a state of frozen immobility. As the temperature rises, motion starts; but for a long distance up the thermal scale, the energies possessed by the primary particles of most substances are too weak to break the cohesive forces binding them together, and the substance remains solid. At different temperatures, depending upon the strength of the cohesive forces peculiar to each substance, the atoms or molecules get enough heat energy to loosen the cohesive bonds and obtain enough freedom to slide by one another. The substance "melts" and assumes the liquid state. At still higher temperatures, the cohesive forces are no longer able to hold the primary particles together at all; the substances "evaporate" and assume the gaseous state. At even higher temperatures—say those of the sun or of an atomic bomb—the cohesive forces of the molecules themselves are broken; only separate atoms can exist, and even the atoms may be stripped of their electrons and reduced to bare nuclei.

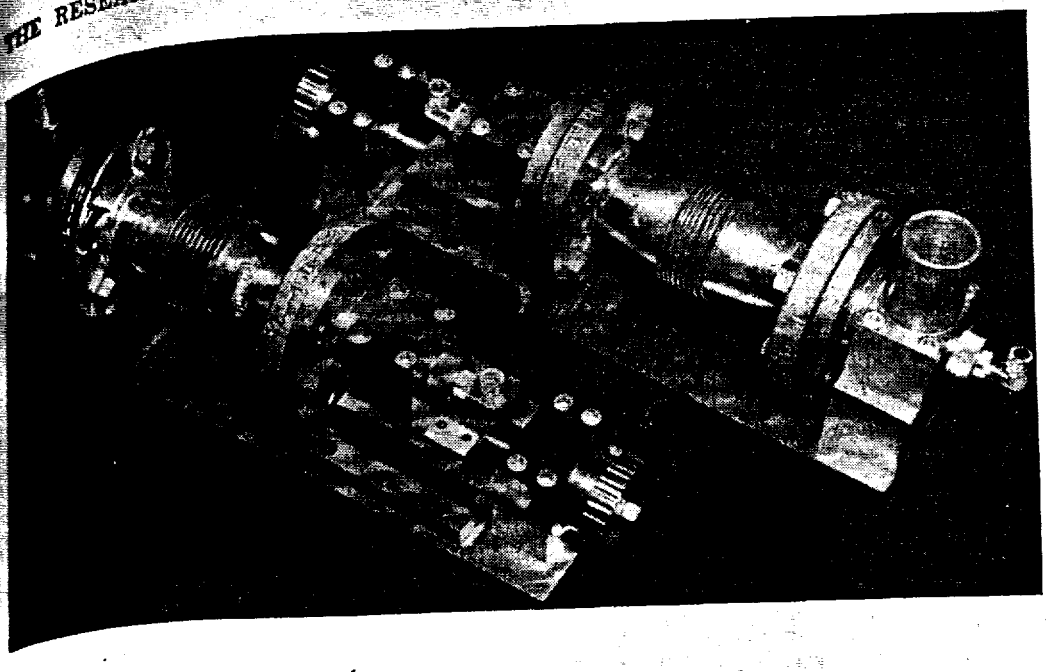
Temperature Extremes in Atomic Energy Work

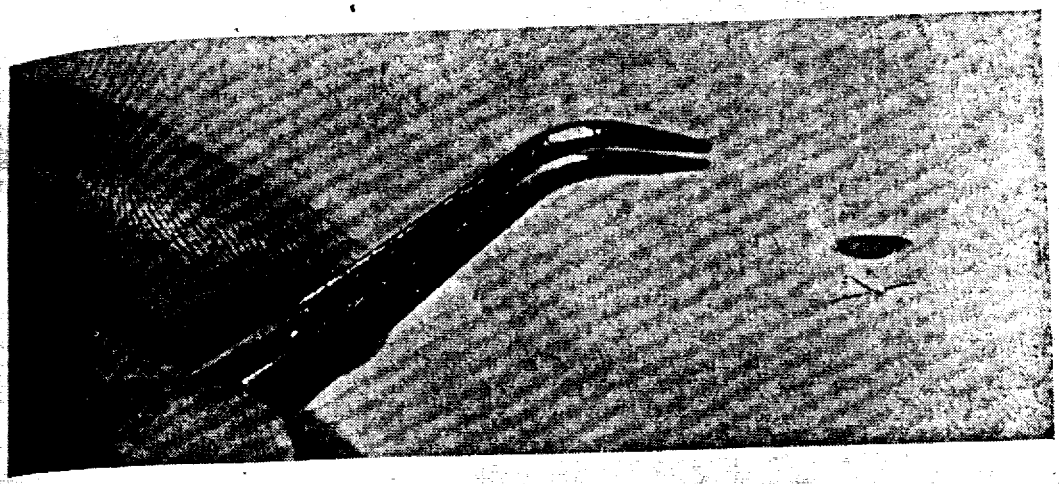
Chemists and physicists in the atomic energy program sometimes need to know the behavior of elements and materials at both of these extremes. The chemists who are laying the groundwork for the design of new nuclear reactors—which will use higher temperatures than ever before employed in a machine—and the physicists who must calculate the behavior of an atomic weapon—where the temperatures are comparable only to those found in the centers of the stars—must seek the highest experimental temperatures attainable. At the other end of the scale, both physicists and chemists find, at temper-

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The chemistry of atomic energy calls for extremely small measurements—of time, weights, quantities. The mercury device, top, opposite page, developed at Columbia University records time intervals in billionths of a second for measurements of radioactivity. The Argonne quartz fiber balance, center, will show weight differences of a billionth of an ounce (an elaboration of this instrument, developed at Mound Laboratory is described on page 108). The fluorophotometer, below, at Battelle Memorial Institute, is able to measure quantities of uranium smaller than a trillionth of an ounce in minerals and other materials.

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atures close to absolute zero, elementary information about materials close to their "rest" state.

High-Temperature Work

The United States has been behind other countries, notably Germany, in the study of high-temperature chemical reactions. Lack of experience in this field was a serious handicap during the wartime atomic energy work, and studies were initiated in 1943 by the University of California.

One of the greatest problems of high-temperature work is finding materials which can be used to contain the chemical process—materials known as refractories. Most molten metals are very corrosive at high temperatures, and few containers are known which can withstand the attack.

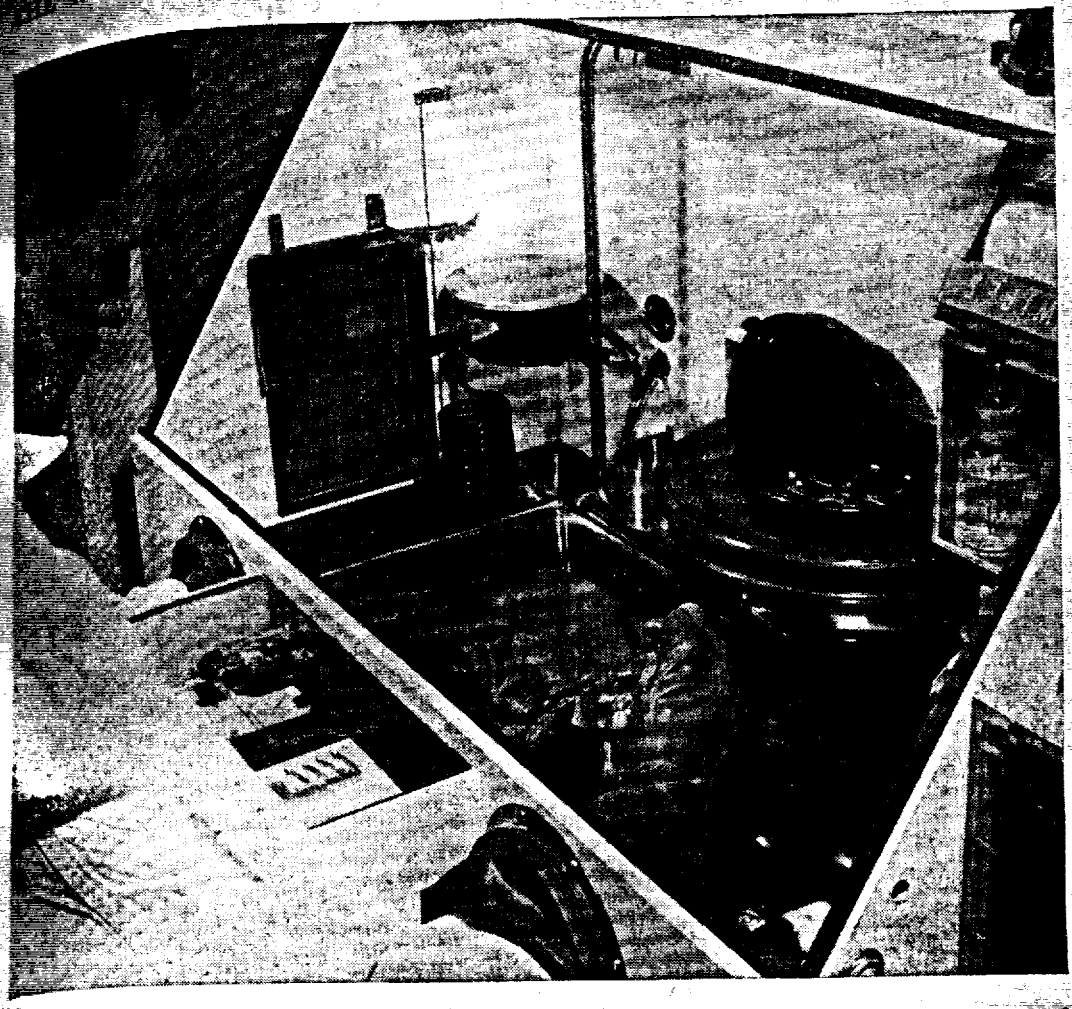
The wartime search for satisfactory new refractories culminated in the discovery of some cerium sulfides which had been previously unknown. Methods were developed for fabricating crucibles of this material and of various other metal sulfides found to have desirable properties for use as high temperature containers and construction materials.

Chemists have made extensive use of thermodynamics in solving high-temperature problems. Using thermodynamic principles, they take the results of experiments at room temperature, and even at temperatures approaching absolute zero, and use those results to predict behavior of chemical systems at very high temperatures.

Information gained through such application of thermodynamics is combined with such data as that gained from observation of the behavior of materials on the surface of the sun and the stars, and with observations on earth of the geological processes which have taken place at high temperatures. This consolidation of knowledge permits predictions of the behavior of materials under yet untried conditions, such as those that will prevail in the interior of high-temperature nuclear reactors.

Protection for radiochemists—Materials that have been bombarded by neutrons inside a nuclear reactor, or by charged particles in an accelerator, become radioactive, emitting *alpha*, and *beta* particles and *gamma* rays. Alpha particles cannot penetrate the skin but alpha-emitting substances are highly damaging if they get inside the body. The rubber-glove box at the top, opposite page, is designed to prevent this, being tightly sealed and ventilated by a strong current of air. Beta particles are moderately penetrating, gamma radiation highly so. Different degrees of radiation protection are represented by the Argonne "cave" and the Hanford "junior cave," illustrated below. Some "hot cells" use thick concrete shielding, with periscopes as the only means of viewing the work.

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Low-Temperature Work

Among the most interesting experiments performed with materials at low temperature have been those at Los Alamos and Argonne dealing with isotopes of helium. Helium 4 and helium 3 have been found to have very different properties at temperatures close to absolute zero.

The rate of flow of liquid helium 4 through a small opening decreases as the temperature is lowered—until the temperature reaches within a few degrees of absolute zero. But below this temperature its behavior abruptly changes. Instead of becoming more sluggish, helium 4 enters the so-called fourth state of matter in which the element becomes a super heat conductor and a super fluid. It is able to leak through openings so small as to hinder the movement of gaseous particles, and actually creeps up and over the walls of its container.

Helium 3, the rare isotope of helium, is chemically almost the same as He 4, but scientists wondered if the fact that it had only one neutron, instead of two, would make a difference in its behavior at low temperatures. Recent investigations have indicated that, even within one degree of absolute zero, He 3 displays no signs of superfluidity.

In order to make these tests, Argonne scientists produced He 3 that was isotopically pure to a degree of 99.9 percent or better. Previous experimenters were attempting the same type of study with dilute solutions of He 3 in He 4. Argonne manufactured the pure He 3 as a decay product of hydrogen 3, which is created in nuclear reactors by neutron bombardment of lithium. When lithium captures a neutron, it breaks down at once into a mixture of helium 4 and hydrogen 3. These can be readily separated since tritium will combine with oxygen to form a kind of water in which the common hydrogen atom is replaced by a tritium atom, while helium remains as a gas. Tritium emits a negative beta particle and thus changes into helium 3.

Refrigeration. Obtaining temperatures near absolute zero is not an easy or a safe process. Liquid hydrogen is the most frequently used refrigerant for studying temperatures from 16 to 36 degrees (Fahrenheit) above absolute zero. However, when liquid hydrogen becomes contaminated with oxygen or air, an explosion may result. In recent work, neon has been used instead. Liquid and solid neon can provide refrigeration in about the same temperature range as liquid and solid hydrogen and is considerably safer, since neon is an inert gas which does not combine chemically with other elements.

Instrument Development—The Microbalance

The most-used analytical tool in chemistry is the balance, the delicate instrument that weighs samples of material and provides quanti-

itative results. Atomic energy work with radioisotopes has made new demands on the art of weighing. Quantities as small as one microgram—one twenty-eight millionth of an ounce—need to be determined accurately. The material to be weighed is often dangerously radioactive. And, to add to the complications, the material sometimes must be guarded from exposure to air.

The Mound Laboratory, operated by the Monsanto Chemical Company, AEC contractor, undertook some time ago the development of a balance that would answer all these needs. During the war a balance had been developed at the Metallurgical Laboratory, University of Chicago, which depended upon the torsion of quartz fibers. The twisting of these fibers would register the weight of samples so small as to be virtually invisible. This principle was adopted and improved upon at Mound.

The torsion fiber, beam assembly, and pans of the new balance are made of fused quartz, containing fibers as small as one twenty-five thousandth of an inch in diameter. The weight of the whole quartz system is only about one fourteenth-hundredth of an ounce, and the load placed on either pan may not be much greater than this quantity. Major improvements in the quartz-fiber system were made possible by the development of improved methods of making the fibers and fusing them into more uniform beam assemblies than had been made before. The twist of the torsion fiber that balances the load is measured to one part in a twenty-thousandth of a revolution. An air-tight shield permits maintenance of a vacuum or inert gas atmosphere around the balance during the loading, weighing, and unloading of any number of samples.

These improvements in the quartz-fiber torsion balance have made it useful for microchemical investigations involving frequent weighings and have made the work safer for personnel. The principles developed for operating the apparatus inside the air-tight radiation shield give promise of proving useful in the future for other work requiring remote control and radiation protection of operators.

METALLURGY IN THE FUNDAMENTAL SCIENCES

Metallurgy, the science of metals, has become a field of vital import in the atomic energy program. Particularly in reactor development, intensive research has been necessary to perfect metals and alloys of metals that can perform adequately under the temperatures, pressures, and radiation to which they are exposed. Success of development at nearly every point depends on improvements in available metals.

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Thus the Commission's program in metallurgical research is necessarily aimed at urgent practical goals. But, as in any field of technical development, the most direct path to achievement of desired results may not always be through applied research and development. Fundamental facts about the nature and behavior of metals must be investigated first. Then technological development and improvement in the use of metals will follow more surely and more swiftly.

The Commission's program of basic research in metallurgy includes the following: strength of metals, diffusion in solid metals, thermodynamic research, corrosion, and effects of radiation.

Where the nuclear physicist deals with the subatomic particles of matter such as neutrons and protons, the metallurgist, like the chemist, deals largely with the behavior of whole atoms. The boundary between the fields of chemistry and metallurgy is less easily defined. Both sciences deal with the methods by which atoms combine to form larger aggregates. Chemistry deals with molecules in which two or more atoms combine in definite numerical ratios.

STRUCTURE AND NATURE OF METALS

The concept of the molecule is not needed, nor in most cases can it be used, by the metallurgist. Atoms of metallic elements combine in a much broader linkage pattern, regular and symmetrical to be sure, but without close-knit molecular units. In the simplest crystal lattice of a metal crystal, the basic pattern is that of a cube with an atom at each of the eight corner positions, and this relative spacing continues in all directions. The commonest forms of combinations of metal atoms are simple modifications of this cubic pattern.

In a molten metal no such regular lattice system exists. The atoms occupy essentially random positions. When cooling causes solidification, the ordered lattice begins to form at many points simultaneously like ice crystals forming in water. From each of these points, growth proceeds in the pattern characteristic of the metal until further expansion is stopped by contact with other growing clumps or the walls of the containing vessel. The final solid, therefore, will be composed of many small crystallites or grains, each with the characteristic lattice pattern; but the lattice pattern of separate grains will be differently oriented with relation to each other.

The main distinguishing properties of metals are their ability to undergo a plastic alteration in shape without cracking or breaking—the quality called malleability—and their high electrical and heat conductivity. Electrical and heat conductivity are high because in the type of atomic binding peculiar to metals, electrons are free to move through the atomic lattice carrying electrical current and heat.

Strength of Metals

Strength and plasticity are related in a more complex way both to the atomic lattice binding and the more gross characteristics of grain or crystallite structure. In theory, metallic structure should provide considerably greater strength than is actually the case. Many attempts have been made to explain this discrepancy, but the answer is still not clear. Currently the most acceptable explanation is that actual strength is less than theory indicates because of imperfections known as dislocations believed to be present within the metal lattice.

A group under AEC sponsorship at the University of California is attacking this problem by controlled experiments on "creep" of high purity nickel. The term "creep" signifies very slow extension or stretching of a metal under stress at elevated temperatures.

To measure this property, a carefully machined specimen is suspended vertically in a furnace and subjected to a load tending to stretch it. The actual total stretch may only be a few thousandths of an inch, and measurements are usually made to an accuracy of at least one ten-thousandth of an inch. The commonest method of measurement is by sighting inside the furnace with an optical telescope and measuring and comparing the motion of two reference points on the specimen. Furnace temperatures must not vary more than one-half of one degree from the control point, since temperature fluctuation strongly affects creep rates. Creep rates also depend on metal grain size, the prior heat treatment of the specimens, the rate of hardening produced by the stretching, and other factors.

Creep occurs generally in three stages, all of which are accelerated by high temperatures and heavy loads:

a) A rapid stretching or elongation which continues for a short time (minutes or hours).

b) A slow, steady extension which may continue for years.

c) Finally, a rapidly increasing rate of stretching until failure occurs.

The mechanism by which creep occurs is still a subject of controversy. Creep occurs in single crystals and also in material made up of many crystals or grains. Theories of dislocations (specific lattice discontinuities), theories concerning so-called viscous flow at grain boundaries, and theories involving a subcrystalline unit labelled a "mosaic block" are all prevalent today. It is hoped that data resulting from this work will aid in developing a more satisfactory theory of plastic flow in metals. This is potentially of great importance to the nuclear reactor engineer.

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Diffusion in Solid Metals

A fundamental fact in metallurgy, perhaps hard to visualize, that considerable movement of atoms is possible within a metal latti Some of the most important properties of metals, such as gra growth, recrystallization, and age-hardening are affected by th through-the-lattice movement of atoms known as *diffusion*. For e ample, if a smooth flat block of copper is placed on a similar smoo flat block of silver, and the pair are heated to a fairly high tempe ture but still below the metals' melting points, silver atoms will mo into the copper block and copper atoms into the silver block. A this net interchange, or diffusion, of silver and copper atoms bon the metal blocks solidly together. This technique, actually used fasten metals together, is known as diffusion bonding or diffusi welding. Heat is necessary since the rate of diffusion of atoms greatly accelerated by increasing temperatures.

If two similarly prepared blocks of copper are placed together a heated, similar bonding occurs. This indicates that copper ato move across the interface (boundary) between the blocks to fo atomic linkages and hold the blocks together. This movement atoms in a single metal is know as *self-diffusion*. It explains w strong, coherent metal bodies can be formed by powder metallur processes in which finely powdered metals are first compressed un high pressures and then heated to high temperatures for "sinterin In sintering, metal atoms simply diffuse across the compacted parti boundaries and establish a continuous solid body. In none of th operations is the melting point of the material ever reached, and bonding reactions occur between solid particles.

Hardening of steel takes place largely because of a change in t organization of the iron lattice as the metal is cooled from high temp atures. This so-called phase change is made possible by the diffusi of atoms to new sites in the lattice. The hardening process in stee a key industrial phenomenon, and much of our present knowledge diffusion grew out of extensive research in steel technology.

Research on Diffusion

The mechanism by which diffusion occurs is not yet fully und stood. Three different AEC-sponsored projects are now work on this problem.

Relative diffusion rates. At the General Electric Company's search Laboratory, studies are under way to determine the relat rates of diffusion at metal surfaces, through grain boundaries, a through the grains themselves. Certain information on the rates diffusion along these three paths was gained some 20 years ago,

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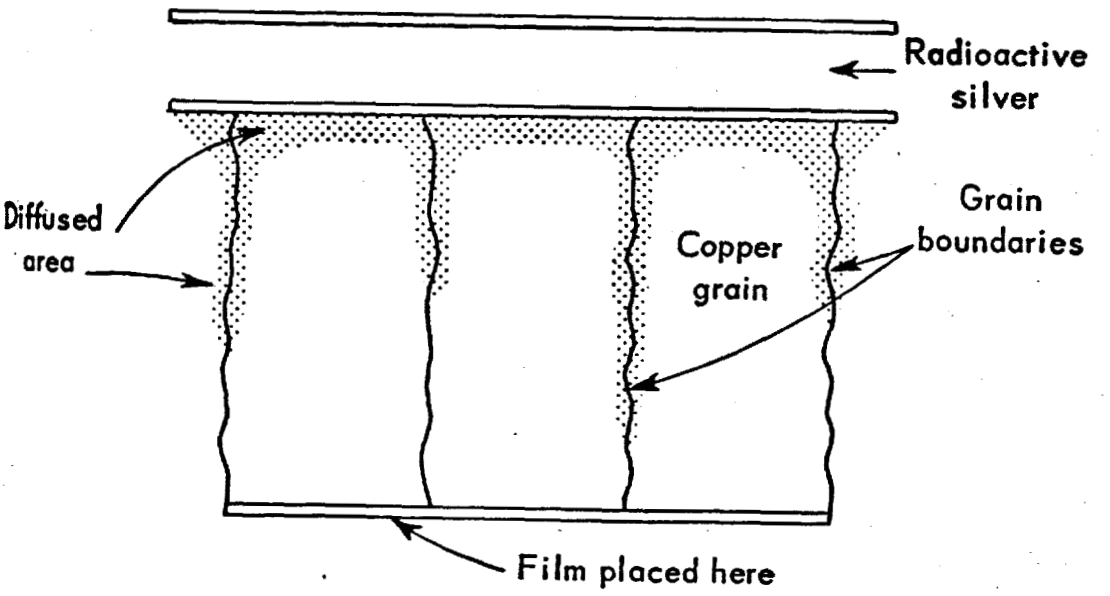
only for the diffusion of thorium in tungsten. At that time, metallurgists lacked certain high precision techniques such as radioisotope tracer methods, which now can be used to advantage. The General Electric group is now measuring the rates of self-diffusion in silver by using radioactive silver atoms. They have found that the rate of diffusion along grain boundaries is at least one million times greater than through the grains themselves. Since a metal sample with many fine grains has far more grain boundary area than one with fewer, larger grains, the total rate of diffusion may therefore be expected to be faster in a fine-grained sample than in a coarse-grained one.

Self-diffusion rates. The Research Laboratory of the Sylvania Electric Products Company at Bayside, Long Island, is also studying diffusion phenomena as part of its fundamental program supported by the Commission. This group has developed a new method for measuring the rate of self-diffusion of atoms. Certain metals do not have suitable radioactive isotopes to use in measuring self-diffusion rates. In the Sylvania method a fine wire, of copper, for example, is placed on a copper block and the two pieces are heated to a temperature at which diffusion, and therefore bonding, occurs.

As diffusion occurs, a neck is formed at the junction of the wire and the block. By measuring the thickness of this neck after various heating times, the rate of diffusion can be calculated.

Effect of grain orientation. Carnegie Institute of Technology, also working on diffusion at grain boundaries, is trying to determine

DIFFUSION OF SILVER THROUGH COPPER



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whether the orientation of adjoining grains has any effect on the rat of diffusion at the boundary between the grains. The experimenta technique is to measure the rate of diffusion of silver atoms into th boundary regions between large column-like grains of copper in whic the exact orientation in space of the lattice pattern has been mea ured. Several methods are being used to trace the course of diffusio In one method, a thin layer of a radioactive silver isotope is electr plated directly on one surface of a cast piece of copper prepared i the form of foil five-thousandths of an inch thick. The plated spec men is then heated to a temperature at which diffusion will occu When the specimen has cooled, a photographic film is placed again the unplated side of the specimen. As is shown in the diagra (p. 113), radioactive silver will penetrate down the columnar grai boundary and will be closer to the film at these regions. The fil exposed to the radiations from the radioactive silver, will be darke where the silver is closest to the film. The relative amount of diffusio at the grain boundaries and through the grains can thus be measure

The Heat-Energy Approach

Stepping almost directly into the chemist's field, metallurgists ha recently begun more extensive use of the so-called thermodynamic a proach to find answers to unsolved fundamental problems. In th approach, attention is focussed on the varying heat-energy conte of metals under different conditions. For example, heating a on pound sample of iron up to its melting point (about 2,800 degre Fahrenheit) from room temperature (say 70 degrees Fahrenheit requires about 86,000 calories of heat energy. At this point, to m the iron, without any further change in temperature, requires near 30,000 calories. Melting is called a "change in state." Other chang in state are known—vaporizing, condensing, solidification—and ea one requires a transfer of heat energy.

This change in heat energy works in both directions. In so changes of state, heat energy is given off. When steam condenses in liquid water, a large amount of heat is liberated—268,000 calories p pound—and this takes place at 212 degrees Fahrenheit without a change in temperature. Similarly, heat energy must be taken fr water at the freezing point to change water to ice.

Chemists have known for a long time that heat-energy changes along with chemical reactions. And the chemical reactions that occ in processes of refining and alloying metals are no exception. Th is the point where the metallurgist borrows techniques from the che ist. Reactions which occur in liquid alloys or liquid metallic solutio can be studied by methods similar to those which the chemist has us for many years in studying solutions in water and other liquids

lower temperatures. While the same thermodynamic principles apply to liquid metallic solutions, experimental methods must be developed to meet the problems imposed by higher temperatures.

Three Attacks on the Problem

At the Massachusetts Institute of Technology, three different methods of attack are being directed at this general problem. One method (also being used at the Carnegie Institute of Technology) involves the measurement of electromotive force in an electrolytic cell. One might say that this means measuring voltages in a series of batteries, the elements of which instead of being those of a normal storage battery (lead, lead oxide, and sulfuric acid solution) are the liquid metals or alloys to be studied and a mixture of fused melted salts. The techniques in use at MIT have been extended to study three-metal systems such as cadmium-lead-tin, cadmium-lead-bismuth, and cadmium-lead-antimony. Previous studies have been largely limited to two-component systems.

A second method involves measuring the vapor pressures of metals over their liquid alloys. Here alloys of cadmium and zinc are being studied.

The third approach, which uses liquid alloys of iron and sulfur, utilizes the reaction of sulfur with hydrogen to produce hydrogen sulfide (H_2S).

Heat-of-Formation Studies

At the University of Pittsburgh work is concentrated primarily on developing methods and designing and building equipment for studying various heat-energy transfers involved in metallic alloy formation. A special calorimeter has been built to determine the heats of formation of magnesium-cadmium alloys and sodium-potassium alloys. Other special equipment is virtually complete for measuring low temperature heat-of-formation effects of magnesium-cadium alloys. In connection with this work, facilities for experimenting at the extreme cold of liquid helium (approximately 4 degrees Centigrade above absolute zero, or 452 degrees below zero, Fahrenheit) had to be provided.

Metallurgy of Solids

The thermodynamic approach may also be applied to metallurgy of solids. A research group at General Electric is working on measurements of the energies contained in metallic grain boundaries. For the first time, the energies required to form a boundary between two

crystals of the same metal have been measured. This quantity determines in part the rate at which these boundaries move when grains grow under the influence of high temperatures and, combined with the diffusion data previously discussed, should contribute much to our understanding both of metal surfaces and of the boundary interfaces between metals.

Scientists at MIT are using somewhat different techniques to attack this same problem. Their objective is to measure the degree of order, that is, the regularity, in the metal lattice at the grain boundaries.

X-ray Studies

The question of order or degree of lattice perfection is also being studied at Carnegie Institute of Technology by advanced X-ray methods.

The research programs at MIT and the Carnegie Institute of Technology are examples of the growing use of X-rays in studying the atomic structure of metals. If we recall that normal sunlight can be separated into its spectrum of wave lengths by means of finely-ruled gratings, it is somewhat easier to understand the use of X-rays in crystal structure work. Here the lattice planes in the crystal take the place of the grating lines and reflect the X-rays. The angles of reflection depend on such things as lattice spacing and regularity. In a typical experimental setup, a beam of X-rays strikes a crystal at a known angle. Within the crystal, the rays are reflected (at the same angle) onto a photographic film. X-ray pictures on film can then be interpreted to reveal information on the atom arrangement of the crystals through which the X-rays pass.

Research on Corrosion

Corrosion is a general problem in use of metals. Its severity varies with the environment to which the metals are exposed. Since corrosion is generally accentuated by high temperatures, it is of prime concern to atomic energy metallurgists.

Two paths of solution are open. The first approach is through specific experiments on one material under a specific set of conditions. This type of development research is needed to obtain quick answers to the most pressing problems. But then, more frequently than not, if conditions are altered slightly, these answers no longer apply, and the work must be repeated.

The second, more fundamental, approach is through a long-range research program which will reveal the basic nature and underlying causes of corrosion in metals. The principles thus learned can then be applied to the specific problems at hand.

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Since the Office of Naval Research already has under way a well organized, comprehensive program on corrosion fundamentals, AEC has not entered into extensive work in this field but has tried to select limited areas which appear most relevant to direct corrosion problems of the atomic energy program.

Certain types of corrosion are accompanied by a flow of electric current and are characterized by voltages known as "electrode potentials" which exist between metals placed in current-carrying solutions. For instance, if a number of metal strips such as copper, silver, nickel, and zinc are immersed in a salt solution, and a voltmeter put in contact with any two dissimilar strips, a voltage will be shown on the voltmeter. These electrode potentials vary with the metals and solutions involved, the temperature, and other factors.

Corrosion of Zinc

The work now being done at Carnegie Institute of Technology on the corrosion of zinc is a good illustration of the need for the complete understanding of this corrosion process. Historically, coatings of zinc on steel, commonly called galvanized steel, have been used for many years to minimize the reaction of the steel with water and prevent the formation of rust. The traditional explanation for the protective action of the zinc is that zinc, being more active chemically than steel, has a greater tendency to go into solution; hence, the steel is protected at the expense or sacrifice of the zinc coating.

The common use of galvanized articles over many years might lead one to believe that the corrosion behavior of zinc had been accurately evaluated. However, only recently it has been noticed that galvanized steel when exposed at high temperatures to certain types of water, as in water heaters, is no longer protected by the zinc coating. Under these special conditions, the zinc coating appears to have lower activity than steel and it is the steel that corrodes. Full-scale basic investigations of this type of phenomenon will give information which will lead to a more complete understanding not only of the corrosion characteristics of zinc but also of the corrosion process in general.

Along with the work on zinc, the corrosion characteristics of titanium metal are also being evaluated. Titanium metal is the basis of an intensive industrial development at the present time, because its solutions or alloys with other metals have high strength and light weight. The future uses of titanium and titanium alloys depend on better understanding of their reactions with water or water solutions. The present study will furnish such information and also assist in developing a general theory of corrosion.

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Effects of Radiation

Another topic of major concern to the Commission's materials engineers is the effect of radiation on metals. Again a double-barreled approach is being taken to obtain answers to the problems.

In the first place, samples of many different materials are being put into operating reactors to determine the effects of radiation on their hardness, electrical resistance, dimensions, strength, and other properties. This empirical cut-and-try approach is being supplemented by basic investigations into how radiations induce changes. Part of this basic work is being done in universities and other cooperating institutions by the use of cyclotrons or other nuclear particle accelerators to irradiate metal samples.

Atom Displacement

Since the displacement of atoms or distortions of the atomic lattice are the basis for many property changes in metals, radiations which cause such displacements can be used to investigate metal structure. For example, when a neutron from a reactor penetrates a metal lattice it may strike the nucleus of one of the metal atoms and displace this atom from its normal position. The lattice is thus distorted. When many thousands of neutrons per second enter a small area of metal, considerable disruption of the lattice is possible. In some cases the displaced atoms may lodge in between normally located atoms and create high stresses. This will show up in greater hardness, less heat conductivity, less ductility, and perhaps even in changes in size of the material affected.

Similar changes are produced in metals by such operations as rolling or hammering at low temperature, and it may be possible to establish a relationship between neutron-induced changes and those produced by mechanical effects.

Numerous other miscellaneous topics of fundamental interest to metallurgists are being studied under AEC auspices. Studies in heat transfer to molten metals, methods of measuring heat conductivities in ceramics, and studies in mineral engineering involving radioactive tracers are examples.

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IV

APPLYING THE RESULTS OF RESEARCH

The foregoing sections have presented in broad outline the Atomic Energy Commission's program of research in the physical sciences. Throughout this program, a balance is maintained between basic research, and developmental and applied research. The national interest clearly requires strong concentration on directed research that will develop needed material and equipment in the fastest, surest way. But it is equally clear that it takes pure research to penetrate beyond the frontiers of our present knowledge and allow us to open new fields for development.

Much of the knowledge that has been gained in basic research has been channeled directly into process and development work. This work is, of necessity, largely classified. As far as is possible, within the limits of security, the following sections report some of the progress in putting research results to use, including examples from major operations areas: reactor development, production of fissionable materials, and military application.

RESEARCH AND REACTOR DEVELOPMENT

Nuclear reactors are the machines in which atomic energy is put to work, and their development—for the better production of fissionable materials, for the production of useful power, and for use in research—is a major effort of the program being forwarded by the Commission. Because the field of effort is so new, the design of a new reactor always calls for facts which have not yet been obtained. The reactor designers and those working with them, before setting up projects in applied research aimed at answering essential questions, survey the store of current knowledge and research to find what is available for their use.

Although there is necessarily much overlapping, research for reactors may be grouped into three broad fields—nuclear physics, metallurgy, and chemistry. This is the work the scientists do. Engineers also have three fields—chemical, mechanical, and heat-transfer engineering. The work of all the investigators is almost exclusively programmatic, for it is aimed at the one objective of building reactors.

The experimenters seek more basic knowledge in the still relatively unexplored field of nuclear physics; they determine properties of rare

elements that hold promise in reactor design; they open up a new branch of chemistry and chemical engineering in separating valuable materials from the mixed output of reactors. Engineers devise control systems that meet the new requirements of reactor operation, and heat-transfer specialists work in a new realm of more rapid rates of transfer at higher temperatures.

Control of Neutrons

The Nation-wide program for the measurement of the neutron and other cross sections of materials, already described, is basic to reactor development.

An important application of these data lies in the choice of shielding for reactors. The material of the shield must have a *high* capture cross section because the purpose of the shield is to absorb neutrons, and thus keep them from escaping to injure people and contaminate equipment. Shields must also stop both the gamma rays originating in the reactor, and secondary gamma radiation induced in the shield as a result of the neutron bombardment. Hence, in this case gamma-ray-absorption cross sections as well as neutron cross sections are measured.

All the other components of a reactor—the moderator, coolant, structural materials, and reflector—must have *low* capture cross sections so that the neutron losses inside the chain-reacting core will be small.

Applications of Fundamental Physics, Chemistry, Metallurgy

Nearly all of the research work in nuclear physics, chemistry, and metallurgy, reported in the foregoing pages, contributes in one way or another to answering the questions faced by the designer and builder of nuclear reactors. The reactor designer must have information, as exact as possible, concerning:

Nuclear reactions. For example, the behavior of neutrons; the fissions they cause and the nature of the fission products; the transmutations that neutrons and other bombarding particles bring about in materials; the radiations emitted by the great variety of radioactive isotopes produced in these nuclear events.

Chemical reactions. For example, the effects of intense radioactivity upon all the kinds of elements included in the original components of the reactor, and also the secondary elements produced therein; the influence of intense heat upon the chemical reactions that occur; the changes that occur in the properties of the chemical elements under reactor conditions—their corrosion, electrical conductivity, heat conductivity, and reactivity with other elements.

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Properties of metals and other materials. The materials used for the structure, coolants, moderators, fuels, and the rest—how they will behave, what changes of state they will undergo, and how their structure will be affected by the nuclear and chemical reactions involved. It is even necessary to determine "conventional" properties—weight, strength, melting point, hardness, conductivity, etc.—of many materials not in common use or of everyday materials in ranges beyond conventional applications. These newly determined nuclear, physical, and chemical properties constitute new material to be added to engineers' handbooks.

Research on Fissionable Materials

Nuclear physicists are working in Commission laboratories to find the best methods and techniques of using uranium 235, uranium 233, and plutonium as fuels. At the same time, they are studying the possibilities of breeding U 233 from thorium and plutonium from U 238.

Breeding is the production in a reactor of more fissionable material, by conversion of nonfissionable materials, than is consumed as fuel. Obviously, success in producing and using new fuels will make possible much wider use of reactors than can be achieved with the present limited supply of U 235. These investigations range from trial of new processes using neutrons of energies between 0.025 of an electron volt and hundreds of thousands of electron volts to the actual building of an experimental breeder reactor at the new Reactor Testing Station in Idaho.

Metallurgy of uranium. Research on the metallurgy of uranium has advanced to the point where it has been possible, for some years, to produce highly purified uranium fabricated into the various exacting sizes and shapes required for the fuel elements of reactors. During the last 2 or 3 years, much has been learned from work at Argonne, Oak Ridge, Massachusetts Institute of Technology, and laboratories of the Department of Defense about the effects of small amounts of alloying agents on the properties of uranium. This basic information has shown the way toward new and improved reactor fuel elements. More detail concerning uranium metallurgy in AEC operations is given on page 126.

Metallurgy of Beryllium

Progress with beryllium is another typical example of results from metallurgical research. In the fall of 1941, it was difficult to obtain enough beryllium to make the significant experiments which showed

that beryllium was a possible moderator comparable to graphite. Early beryllium work was carried out at the University of Chicago and later by a group at MIT.

The status of beryllium is now far different from that in 1941. Although the metal remains difficult to work because it is exceedingly brittle, special techniques of casting followed by extrusion produce fairly large bars which are successfully machined to intricate shapes. Powder metallurgy techniques have also been developed for production of many shapes of large size, and information has been obtained on the physical properties of the metal under many varied conditions.

In general, beryllium can now be considered of engineering usefulness. Research continues, however, to improve even further the characteristics of the metal and to produce it more cheaply.

Research on Heat Transfer

The problem of removing heat from a reactor is particularly difficult for mobile units because of the necessity for small size and high power. The heat-removing mechanism must be extremely effective. When heat removal is mentioned, most people think of water, which has worked so well in conventional applications. Not so well known is the fact that molten metals such as sodium, potassium, lead, bismuth, tin, and possibly magnesium, are much more effective than water in removing heat from a concentrated source. It is, of course, desirable to use a metal or alloy with as low a melting point as possible. The best coolant should be fairly light, have the proper nuclear characteristics, be suitable for circulation at high temperatures in a piping system, and be as cheap as possible. All this must be over and above the basic requirement of good heat-transfer characteristics.

Study of liquid metal coolants is one of the major metallurgical problems faced by reactor development workers in the atomic energy program. A number of liquid metals looked promising until continuing investigation revealed properties that made them unsuitable.

Some liquid metal systems do have definite promise, however, and at least two new reactors will use molten metals to carry off and transfer heat. Continuing research will shed more light on such problems as corrosion, purification, and alloying in the production of new materials that will remain in the liquid state over a wide range of temperatures between a low melting point and a high boiling point.

Research on Reactor Materials

The common structural materials are not satisfactory from a nuclear point of view. Iron absorbs, atom for atom, nearly 10 times as many neutrons as aluminum. The problem, therefore, has been to develop

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Metallurgical research at Oak Ridge National Laboratory. Here, a red-hot billet just out of the furnace is being placed in the press which will extrude it as a long rod, one inch in diameter.

materials which have structural properties at least equivalent to standard materials and which are also satisfactory from the nuclear standpoint. Studies of several reactor materials are being carried out by the Atomic Power Division of the Westinghouse Electric Corporation, under contract with the Commission. The work includes investigation of corrosion, fabrication, and radiation effects.

Such metallurgical investigations are programmatic, aimed at solving specific reactor problems. Underlying them is a broad base of AEC-supported fundamental research into such areas as rates of diffusion of one metal into another, thermodynamics in metallurgy, use of radioactive tracers in minerals engineering, and development of new methods for measuring thermal conductivities of ceramics. Programs of this sort are generally carried out at MIT, Battelle, and other universities and research institutions throughout the country.

Processing of Fuel Elements

During the operation of a nuclear reactor, fission products are created within the machine. These radioactive materials are the ashes of the reaction, but unfortunately they do not drop out at the bottom; they are intimately mixed with the fuel. The fuel has to be removed from the reactor and valuable materials separated from the fission products by chemical processing, a procedure in which successful development and improvement is of utmost importance to the future of reactors.

Fuel elements have to be processed and refabricated after only a

small percentage of fuel is consumed. Accumulation of fission products wastefully absorbs neutrons needed to sustain the reaction.

A small portion of the fuel in use by an operating reactor is being processed and refabricated practically all the time. Partly used fuel is constantly being withdrawn and replaced by reprocessed fuel, and the very small amounts of fuel actually consumed are restored from a fresh supply.

There are two major processing difficulties. First, the processing, even the repairing of processing equipment, must be controlled remotely by men protected against radiation behind concrete walls as much as seven feet thick. Second, it is necessary to purify large volumes of materials to a degree far beyond standards of industrial processing.

There are additional difficulties involving the containers used for these processes. They must be small enough so that there is no possibility of accumulating critical masses of fissionable material and setting off chain reactions. Again, they cannot be allowed to become contaminated with radioactive reactor products to the point where their radiation would alter the chemistry of the processing.

At Hanford, only plutonium has been separated. Uranium 238 and nonvolatile products of fission are stored. Disposal of waste byproducts without contamination of streams and underground waters is the object of considerable study and investigation.

Research workers at Oak Ridge and Argonne worked on waste handling and processing late in the war. Their early investigations were expanded into a program of basic research into the chemistry and reactions of the materials used in the construction of fuel elements. Also, it was necessary to obtain basic information about the little known elements included among the fission products. Some of these elements lose their dangerous radioactivity in a few hours or days; the half-lives of others are measured in years and tens of years. The more lasting of these elements include strontium with an atomic weight of 90, ruthenium 106, cesium 137, cerium 144, and promethium 147.

Applied research to develop methods to separate fuel from fission products followed. Basic and applied research continued through the pilot plant stage in AEC laboratories, and valuable contributions have been made elsewhere. The first full-scale new process fuel plant for reactors will be built at the new Reactor Testing Station in Idaho during the coming year.

Handling Radioactive Wastes

The safe disposal of radioactive wastes is a problem throughout the atomic energy enterprise, and all of the major laboratories and production installations of the AEC are studying one or more of its

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aspects. The Mound Laboratory at Miamisburg, Ohio, has undertaken an overall study of the entire subject, dealing with methods of handling wastes of all degrees of radioactivity. The Commission is being assisted in its work by the U. S. Geological Survey, the U. S. Public Health Service, and the U. S. Bureau of Mines, and also by the University of Tennessee under contract. In October 1949 the Commission issued a special report, "Handling Radioactive Wastes in the Atomic Energy Program." *

RESEARCH AND PRODUCTION

The production of fissionable materials—the fuels of atomic energy—is a large and diversified industry. It is also a new industry, and nearly all of its key processes are in an early stage of development. Throughout the production chain, from the acquisition and treatment of raw materials to the fabrication of finished uranium 235 and plutonium, the variegated manufacturing operations are continually improved by the knowledge gained in fundamental research.

The application of research to production is an aggressive and continuous effort. All of the key installations—the raw materials offices in Washington and Colorado, the feed materials processing headquarters in New York, the Hanford plutonium works, and the K–25 uranium separation plant at Oak Ridge—maintain teams of technicians who operate as liaison agents between the manufacturing plants and the research laboratories. These specially assigned scientists and engineers are expected, not only to find the answers to production problems that are giving trouble, but also to critically study production processes and operations, develop original ideas for their improvement or replacement, and find the best sources of the needed fundamental facts in science laboratories and research publications.

Year by year, the resulting production improvements are increasing the health of the fissionable materials industry—saving money and manpower, making better use of available uranium. The details of these improvements cannot be told to the general public, for security reasons. Often, in fact, their very existence must be kept secret. A few examples, however, from the various major operations, will show the kind of work being done.

Production of Plutonium

The Commission has carried through a 3-year program for the rehabilitation of the war-built plutonium-producing reactors at Hanford and, at the same time, has built new and improved facilities, both as

*Superintendent of Documents, Washington 25, D. C., 15 cents.

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replacements and for increase of output. Today's program of development (see Part I), includes additions to present facilities and a long-range effort to perfect designs for new-type reactors to operate at new high levels of efficiency and productiveness.

URANIUM AND PLUTONIUM

The transmutation of uranium into plutonium involves some of the most complex chemical and metallurgical problems ever solved on an industrial scale. Present knowledge is far from complete.

Uranium

Uranium production in the atomic energy program is a long, complex chain of manufacturing processes that starts with uranium-bearing ore and ends with cylindrical rods of the purest uranium metal ever prepared in quantity. Impurities that would capture neutrons are intolerable. After the processes of ore treatment, purification, and reduction to metal, which are difficult enough, comes the problem of jacketing the uranium slugs to protect the metal from corrosion by water and air in the plutonium-producing reactor.

Uranium, at the start of the nuclear energy program, was a relatively unknown and little used element. While considerable quantities of uranium-bearing ores had been mined, they had been processed for their radium and vanadium content; the uranium was generally discarded as waste material.

Even after the war the metallurgy of uranium was in about the same state of knowledge that characterized the metallurgy of iron and steel in 1870. Techniques for extracting and fabricating relatively impure uranium were developed during the war, and some knowledge was gained of the properties of impure uranium. But nearly the only purification attempted was for the removal of neutron-absorbing materials. The properties of the high-purity metal and the possibility of alloying it for developing desired mechanical and chemical properties are still unknown today.

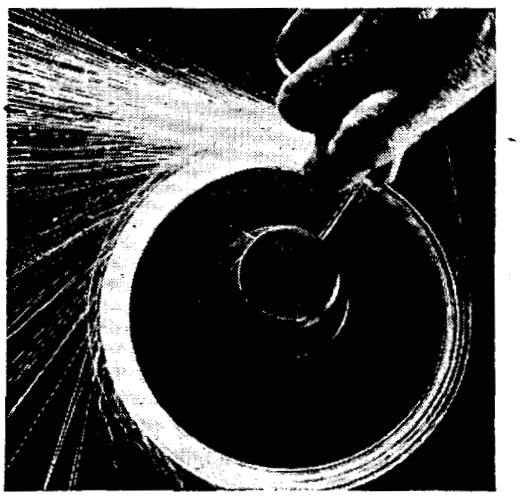
Purer uranium needed. The impurities in present-day uranium presumably affect its properties very markedly, but until purer uranium is available in some quantity, designers of reactors for production and other purposes cannot know what these effects are. Metallurgists of AEC laboratories and contractors are studying the problem and have succeeded in preparing small quantities of metal that is exceedingly pure insofar as the 20 to 30 elements normally found in uranium are concerned.

This will for the first time permit study of the chemical and

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physical properties of uranium and the effects of impurities and alloys on these properties.

Alloying uranium. Future development of reactors will require uranium alloys with certain specific properties. Uranium offers greater heat-treating possibilities than do most metals. It has two transformation points at which a rearrangement of the atoms takes place. By comparison, iron has but one usable transformation point, and copper has none. The uranium transformation points are consid-



Preparing the surface of a piece of uranium for microscopic examination at the Battelle Memorial Institute. Uranium, before atomic energy development, was a little used and little known element. Even after the war, knowledge of its metallurgy was no better than that concerning iron and steel in 1870. And today, the qualities of the high-purity metal are still not well understood.

erably below the melting point, and thus allow for full development of the heat-treating potentialities of the metal.

However, the physical and chemical properties of uranium present many difficult problems, which have tended to impede advancement in uranium metallurgy. The noncubic arrangement of the atoms causes the metal to have different physical properties in different directions—to expand more rapidly in one dimension than in another with increasing temperature, for example. Similarly, the two rearrangements of atoms (transformations), while offering heat-treating possibilities, give uranium three structural variations while iron has only two and copper only one.

Corrosion problems. Uranium possesses great affinity for oxygen; hence, to avoid trouble and prevent loss due to oxidation, special precautions must be taken when processing or studying the metal. All melting and casting, therefore, is done in a vacuum. Fabrication work, when possible, is done at low temperatures to avoid rapid oxidation. Other precautions involve working the metal in an inert atmosphere, or rapid manipulations or jacketing of the metal to reduce the oxidation period.

Better slugs for reactors. Research performed at MIT, Battelle, Argonne, Schenectady, and Hanford is primarily responsible for the

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better understanding that exists today about the behavior of uranium rods (or slugs) under conditions of controlled fission of the U 235 isotope. This information has contributed vastly to our better utilization of this scarce metal, and has resulted in higher yields of plutonium per unit of uranium, with consequent large dollar savings. Much research remains to be done to attain the fuller understanding that will be prerequisite to the attainment of conversion efficiencies common to non-nuclear reactions, and short of which atomic fuel cannot compete economically in the field of power generation with conventional fuels.

Graphite research. Graphite is the neutron-moderating material used in the Hanford reactors and also the material forming the matrix into which the uranium slugs are inserted. As a consequence of research into the chemical and physical properties of graphite, thermal energy reactors of greatly improved design and performance characteristics have been made possible. This work has also led to a better understanding of reactor operation. It has been found that there is a close correlation between the behavior of graphite and uranium when subjected to conditions resultant from the controlled fission reaction that takes place in nuclear reactors. This knowledge has led to the adoption of technical and operating procedures that have made possible higher rates of production, longer life of existing piles, and improved design of new piles.

Plutonium

A brief sketch of the process of making and separating plutonium indicates the complexity of the chemical processes involved. The process starts when slugs which have been in the reactor for a considerable time are removed. Their radioactivity at this point is so intense that they have a blue-white glow.

Inside the aluminum jacket, the irradiated slug is no longer uranium alone. It is still more uranium than anything else, but it also contains small amounts of neptunium and plutonium and somewhat larger quantities of other "impurities"—radioactive forms of more than forty elements, such as barium, iodine, cerium, arsenic, silver, tin, and cadmium.

Remote-control operation. Extracting plutonium from this slug is a far more difficult undertaking than separating, say, a magnesium-aluminum alloy. The first step is comparatively easy, though somewhat complicated by the fact that the chemist must do everything by remote control if he wishes to live to run another batch. The jacketed uranium slugs are dumped into a tank, and a solution is added which

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will dissolve the jacket but not the uranium. After it has done its work, the solution is drained off and the uranium, along with all its impurities, is dissolved with another reagent.

In the separations plant, longer than a football field, concrete walls protect operators from the radioactivity of the chemical processes going on. The corridor beside the process equipment contains banks of control panels, gauges, recording instruments, levers, and switches, but the entire process is actually completely out of sight of the operator.

Further along in the separations process is a glass-fronted cabinet containing a fair-sized glass vessel filled with what looks like pea soup. The greenish solid swirling about in the liquid is a compound of plutonium in a final precipitation process. This is the solid that can be filtered off and converted into metal by "conventional" metallurgical processes.

Plutonium a poison. The highly radioactive fission products have been so thoroughly removed that a glass window is now more than ample protection, because plutonium itself emits only alpha particles, which cannot penetrate the skin. Outside the body it is perfectly harmless. But let some plutonium enter the body—through the lungs or mouth, for example—and a very small quantity can be a deadly, slow-acting poison. This is the reason for the glass-fronted cabinet, and the elaborate ventilation system that causes an intense inward draft when the front is opened.

Research on separations problems. Development of separations processes in industry has traditionally been costly, requiring the coordinated efforts of highly trained personnel and specialized equipment. Until the war, development work in chemical industry proceeded at a good pace, consistent with economical use of manpower and materials. When separation of plutonium and uranium became a factor in the national security, it was imperative that extraordinary measures be taken to solve the problem quickly. The decision was made to pursue a single avenue of approach with all effort concentrated on solving immediate problems only. In contrast, under peacetime conditions, the decision to "freeze" upon one process would have been made only after years of basic research in the sciences, engineering studies, development work, and cost analysis.

Thus one significant aftermath to the rush of wartime development work is the continuing operation of a more costly process than would have been instituted under easier circumstances. As reported in Chapter III, the Commission has made every effort to assemble the body of scientific information in chemistry, physics, metallurgy, mathematics, and engineering necessary to develop a better process.

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Today's problems. At the end of hostilities in 1945, it was recognized that the wartime separation process was not only high in cost, but that it was inadequate in these respects:

a) Large volumes of highly radioactive liquid wastes were being accumulated. The construction and maintenance cost of additional storage space, ever increasing, demanded that steps be taken to concentrate the wastes more economically and recover for beneficial use many rare radioactive fission products.

b) The process did not recover valuable amounts of uranium contained in the wastes.

At the present time, with gradually increasing knowledge of the chemistry of plutonium, uranium, and the fission products, and with the development of new process and equipment techniques, the Commission is making important decisions which will completely alter the methods of separating plutonium and uranium. Important contributions besides those of the program at Hanford itself have been made by the Argonne National Laboratory, the Oak Ridge National Laboratory, the Knolls Atomic Power Laboratory, the University of California Radiation Laboratory, and several other AEC installations.

Production of Uranium 235

Of all the methods of isotope separation developed by science, the process of gaseous diffusion has proved the most successful for the extraction of fissionable U 235 from natural uranium. Ever since it went into successful operation in the war days, the efficiency of K–25 plant at Oak Ridge has been improved, until today a given quantity of U 235 costs the Nation something less than half of what it did originally. The Commission has enlarged the original plant and today is building and designing additional plants to use the gaseous diffusion process.

Research and development have been primary factors in these accomplishments. The nature of the process, the immensity of the operation, and the unusual character of the materials handled, have necessitated solving a multitude of problems unique in large-scale industrial practice. For this reason, a continuous program of research and development on the technology of gaseous diffusion systems has been necessary.

DEVELOPMENT AT K–25

The K–25 plant covers 60 acres of ground. Within it, uranium hexafluoride gas, an intensely corrosive material, is pumped by thousands of pumps through thousands of miles of pipe, and caused to

diffuse through tens of thousands of specially developed porous barriers, the total area of which is measured in square miles. Control of the process is largely automatic, involving a myriad of electrical and electronic mechanisms.

Operating Improvements

Determining the optimum operating conditions in a plant where there are dozens of ways in which the equipment can be interconnected, and where there are thousands of controlled temperatures, gas pressures, and flows, is exceedingly complex. Computational methods, employing the most advanced statistical and mathematical techniques, have now been developed to the point where it is possible to specify quickly the optimum operating conditions for projected production plans or equipment replacement and improvement programs.

The practical application of this work has yielded important increased production at lower costs. A recent example is a new piping system for interconnecting two of the diffusion units, K–25 and K–27, in such a way that an installation costing $500,000 is now increasing plant output by an amount equivalent to $1,000,000 per year.

Study of new diffusion cascades has recently led to the process design for a completely new plant addition (designated as K–29). This new addition, now under construction, will incorporate greatly improved equipment, and will place the separation of uranium 235 on the most economical and efficient scale yet reached. More recently, another addition (K–31) has been projected and preliminary research design work is under way.

Barrier Improvement

The fundamental development which makes the gaseous diffusion plant possible is the porous barrier through which the uranium isotopes diffuse and separate. Since the efficiency of the process depends upon the separating characteristics of thousands of these barriers in series, even a small improvement in the performance of the barrier material will yield a very significant over-all improvement in plant performance.

The development and evaluation of better barriers at K–25 will save millions of dollars in the construction of K–29, since it would have been necessary to install much more equipment to achieve the desired production rate using the old-type barriers.

Equipment Decontamination

Since uranium hexafluoride is extremely reactive, metallic equipment exposed to it gradually becomes coated with deposits of ura-

nium reaction products. To protect the health of those repairing the equipment and to recover the valuable uranium 235, it has been necessary to develop processes for the efficient removal and recovery of these residues.

Several processes have been evaluated in an installation which was established both to handle the current turnover of equipment, and to serve as a pilot plant. Engineering design is in progress on a proposed permanent facility for this operation.

Fluorocarbon Research

Because of the high chemical reactivity of uranium hexafluoride, it was necessary to develop an entire series of fluorine-carbon compounds, similar to the hydrocarbons, to be used as lubricants, cooling liquids, and plastic materials in the gaseous diffusion system. These materials, while very satisfactory for the intended use, have the drawback of being quite expensive to manufacture.

Further studies on the potential applications for the fluorocarbon plastic, fluorothene (described in the Fifth Semiannual Report), have resulted in the development of "fritted fluorothene," a chemically inert filtering medium. This plastic filter is easily fabricated and has the remarkable property of being inert to strong acids, alkalis, anhydrous hydrofluoric acid, and most other strong chemicals.

Instruments

Typical of the instrument development work at K–25 is a recently completed modification of the recording mass spectrometers which continually analyze the gas streams of the cascade. A systematic program was carried out as follows:

a) Instrument connections to the process system were revised so that the number of operating units could be reduced 75 percent.

b) Over-all reliability of the instruments was improved by replacing all glass parts with metal.

c) Mechanical refrigeration was substituted for liquid nitrogen cold traps.

d) The sensitivity of the spectrometer was increased 20 times.

In terms of over-all performance, improved reliability and sensitivity were obtained along with a demonstrated cost saving of more than $750,000 per year.

The fact that uranium emits alpha rays has led to an interest in radiation detection devices which can be used to show the presence of

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uranium contamination. A recently developed instrument, called the "Sampson," is seven times as sensitive toward uranium as the "Zeuto," the standard, project-wide, alpha-survey meter. The sensitivity is constant for the life of the instrument, and the calibration is linear over its entire range. The Commission has found this device of sufficient interest to enter into a production contract for its manufacture by a commercial instrument company.

Isotopic Concentration

Significant advances have been made in the techniques of determining the ratio of uranium 235 to uranium 238 in various samples of uranium. Installations in other parts of the atomic energy project frequently use samples measured at K–25 as comparative standards for their own determinations.

An extended study was recently completed on the re-evaluation of the uranium 235 content of naturally occurring uranium with a much higher precision and accuracy than any value previously reported. Knowledge of this value is important since it is a fundamental datum point in atomic energy.

Chemical Analysis

In addition to isotopic analyses, a large number of chemical analyses are required at K–25 for process control, and this has inspired research on new analytical methods for the determination of uranium, fluorine, and other process materials.

In developing analytical methods of higher speed, precision, and accuracy, full use is made of modern statistical interpretation of data. Some examples of analytical research recently completed include:

a) A very precise method for the determination of uranium in uranium hexafluoride.

b) Procedures for the determination of traces of fluorocarbons in air.

c) Methods for the determination of several trace elements in uranium.

d) A procedure for the determination of small amounts of oxygen in tank nitrogen.

e) Precision studies of the spectrochemical determination of trace elements in uranium.

f) An X-ray absorption method for the determination of uranium in water solutions.

g) A procedure for rapid identification of a number of uranium compounds on the basis of their crystallographic properties.

Critical Mass

Since large quantities of enriched uranium 235 must be handled under many different conditions in the operation of the K–25 plant, it is extremely important to know how much uranium can be placed in a container under various conditions before a chain reaction will take place. A series of critical mass experiments carried out at K–25 during the last 2 years has resulted in data which makes it possible to define safe operating limits, without sacrificing economy by the arbitrary use of extreme safety factors in the design of equipment.

General

In a plant such as K–25, where there are thousands of duplicate units operating in series, it has been possible to derive significant results from what would normally appear to be infinitesimal changes in operating conditions. For example, a $30,000 annual saving was derived from a 20-degree Fahrenheit increase in the temperature of the lubricating oil supplied to several thousand bearings—the decreased viscosity of the oil resulting in an over-all decrease in power loss in the bearings equivalent to that amount of money. The entire system has been subjected to a painstaking survey for factors of this sort.

Processing of Feed Materials

The chains of plants that convert raw uranium into the atomic energy feed materials—uranium hexafluoride gas for Oak Ridge, fabricated uranium metal for Hanford—use processes that are more closely related to known industrial methods than those at other points in the production of fissionable materials. Yet the processes used were adopted under pressure of time during the war. All of them have been improved in one way or another during the past 3 years.

A recent example is the new plant now under design for producing uranium hexafluoride, the feed material for the K–25 plant, which is one of the significant costs in the production of enriched uranium 235. During the past 2 years an exhaustive study has been made of possible processes which could replace the batch methods now used for its production. Recently this work was completed with a successful pilot-plant demonstration of an economical continuous process which will substantially reduce feed material costs in a full-scale plant.

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PROCESS CONTROL

Although most of the feed materials processes are not new, the chemical specifications that must be met at the plants are extreme. Substances of laboratory purity must be produced on an industrial scale. As any deviation from specifications might result in serious difficulties when the materials enter subsequent processing, it is essential that purity be closely controlled by chemical analysis from raw materials to final products. Such purity control requires analytical determinations of greater precision and of a more specialized nature than are common in commercial laboratories.

New Brunswick Laboratory

To handle this work and to assist with analytical problems throughout the industry, the Commission put into operation in June 1949 an analytical laboratory at New Brunswick, New Jersey, administered by the AEC New York Operations Office, which is responsible for the processing of feed materials. It is the only major AEC-owned laboratory directly operated by the Government.

The New Brunswick Laboratory must analyze a host of materials, many of them purchased from independent suppliers. The results of analyses determine payment by the AEC for materials supplied and materials produced in AEC plants. It is desirable, therefore, that analyses be performed by an agency acceptable to contractors and suppliers.

The Laboratory has four branches:

a) *General Analytical Branch.* Analyzes uranium and thorium raw materials as well as various special products for use in production program.

b) *Special Problems Branch.* Develops methods for use in analysis of materials. Analyzes materials beyond the scope of the General Analytical Branch.

c) *Radiochemical Branch.* Analyzes ores, soils, water and other materials for minute amounts of radium, uranium, or thorium by radiochemical means.

d) *Spectrochemical Branch.* Performs spectrochemical analyses of various types of materials of interest to production and reactor programs. Develops spectrochemical methods for analysis of these materials.

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New Analytical Techniques

An essential service of the Laboratory, useful throughout the ato energy program, is the development of methods of measurement quantities of material smaller than have ever been measured bef The determination of amounts of uranium in soil has been acc plished by measuring the amount of fluorescent light emitted by uranium in a sample of the soil which had been fused with sodi carbonate and sodium fluoride. In this manner some ordinary s have been shown to contain about 7 millionths of an ounce of urani in an ounce of the soil.

Uranium and thorium form a series of radioactive elements by disintegration of one radioisotope into another. In its radioch istry branch, the Laboratory isolates these naturally radioactive ments and determines their concentration in various types of sam by means of radioactivity. New types of ultra-sensitive instrume capable of determining one-billionth of one-billionth of an ounce radioactive material have been developed to meet the needs of Commission in its health and safety programs and in research ores.

Certain elements may absorb neutrons or may seriously affect corrosion-resistance properties of metals projected for use in the actor development program. The New Brunswick Laboratory has b investigating methods of analysis for materials to be used in this p gram and has developed and correlated chemical and spectrochem methods for practically all the elements in question. Specially sta ardized samples have been prepared and distributed to the diffe Commission contractors and laboratories interested in these materi

In connection with the raw materials program, the Laboratory prepared for sale analyzed samples of low grade pitchblende and notite for use by interested laboratories for aid in assaying urani ores. A manual entitled "Methods for the Determination of Urani and Thorium in Their Ores" has been written for public sale to aid sayers in their work.

A rapid method of analysis for thorium has been developed, tak but four hours, based on the use of solvent extraction. Heretof the determination of thorium was a long drawn out procedure tak as much as 4 or 5 days for completion.

Raw Materials Process Delevopment

The world's uranium supply today comes from a few relati highgrade deposits of rather limited extent. New discoveries of s ilar richness may result from the present intensive search; but best prospects for uranium sources that will meet expanding requ

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ments lie in large low-grade deposits—deposits that contain less than a pound of uranium per ton. In the past, these deposits were of little interest, but attention is now turning to the large low-grade sources such as shales, phosphates, and lignites. A similar transition has marked the history of most metal mining. As demands increase, deposits once considered worthless become important sources of supply.

Research and ingenuity are required to develop economical methods for mining and processing most low-grade ores. In the case of very low-grade uranium deposits, the mining itself does not present a problem because most of the deposits will be mined for other constituents of the ores, and uranium recovery will be a byproduct operation. The concentration, or extraction, of uranium from low-grade materials is a new problem, however, one of major importance to the Nation's atomic energy program. It holds the key to increased domestic production as well as increased supplies from foreign sources.

U. S. RESEARCH WITH ORES

The Commission has aggressively pursued this problem with the aid of several industrial contractors, universities, and governmental agencies—notably the Carbide and Carbon Chemicals Corporation, the Dow Chemical Company, the Battelle Memorial Institute, the Massachusetts Institute of Technology, and the U. S. Bureau of Mines.



Grinding uranium ores in preparation for experimental research at Oak Ridge National Laboratory (Y–12 site). The extremely low concentration of uranium in domestic oil shales and low-grade carnotites necessitates the use of large quantities of raw materials in laboratory experimental work.

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The AEC and certain of the contractors mentioned above ha sisted for example, along with the United Kingdom, and the African Government, in certain research problems relating to t traction of uranium from South African gold ores. There are way technical discussions on this problem which may lead t stantial uranium production from gold ores.

Intensive research and process development is continuing o grade deposits in the United States. Results from various re projects indicate that uranium extraction from low-grade do deposits may be technically possible and that the problem is to a satisfactory product at reasonable cost.

Production of uranium from Colorado Plateau ores, the only p domestic source of uranium, is being increased by expanded oper and also by better metallurgical recovery. Efforts to improve lurgical practice are still in progress.

Projects Under Way

One group of research workers at the Y–12 site of Oak Ridge ratory is concentrating its attention on the improvement of the tite acid-leaching process to determine optimum conditions for ium recovery and attempting to develop new methods for ren uranium from leach solutions.

The Battelle Memorial Institute is working on roasting tech and alkaline-leaching methods of these carnotite ores.

The Bureau of Mines assists in the operation of the Monticello, ore processing mill by testing various types of ores available fo essing and by studying plant performance. The Bureau and th igher Company, metallurgical engineers, cooperated in developi flow sheet for this mill.

RESEARCH AND WEAPONS

Nowhere else in the atomic energy program is effectiveness search and development more vital than in the field of atomic we In order to maintain progress in this field, it is necessary to cov whole range of activities from fundamental investigations in science to applied research, practical development, and prod engineering. This includes work in mathematics, physics, chem metallurgy, electronics, and ordnance, and involves specialized ment and facilities.

For reasons of national security, only a small part of the re story on weapons can be revealed. The following examples wil an indication of some of the types of research carried on.

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Bomb Computations

It might be assumed that the physical processes which take place in an exploding atomic bomb must be necessarily more difficult to understand than those in such well known phenomena as the burning of coal or the explosion of a TNT charge. Actually, nuclear reactions can be treated with assurance and mathematical precision.

The explosion of an atomic bomb produces tremendously high temperatures of many million degrees, and under these conditions the atoms forming all material bodies are completely broken up into bare atomic nuclei and free electrons. These nuclei and electrons are comparatively simple physical entities, in contrast to the complicated molecules involved in various reactions of ordinary chemistry, and their behavior can be treated by exact methods of mathematical physics.

The situation is very similar to that existing in astronomical sciences where, paradoxically, we know more about the properties of matter in the central regions of the sun and distant stars then we do about the properties of material forming the core of the earth only a few thousand miles under our feet. Here again the difference lies in the fact that, where the central regions of our globe are comparatively cool (around a thousand degrees) and are thus formed from matter in a molecular state, the matter inside the stars is completely broken up into nuclei and free electrons by the extremely high temperatures of many million degrees. Also, where geophysicists cannot be quite certain about the basic question of whether the earth's core is solid or liquid, astrophysicists can calculate the physical characteristics of matter inside the stars.

Since the temperatures inside the stars are of the same order as those developed in exploding fissionable material (both being due to progressing nuclear reactions), physicists use the same mathematical methods to interpret the events occurring in atomic explosions that astrophysicists employ in analyzing stellar formations millions of light years away.

Critical Assemblies at Los Alamos

An important research problem is the experimental determination of the amount of fissionable material, called the "critical mass," needed for a chain reaction to occur. This amount depends upon such a variety of conditions—including the type of fissionable material, the geometrical shape, and the surrounding media—that experimental determination is essential. This is accomplished by the gradual assembly of material under the conditions of interest until the emission of neutrons indicates that the chain reaction has started and therefore that the critical mass has been reached.

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The Los Alamos Scientific Laboratory has engaged in these stu and measurements since 1943. During the war, critical assem were restricted primarily to tests of the specific types of materials geometries immediately useful in weapons. Other critical assem were made, however, that were not of specific weapon design but of more fundamental or general interest.

The Water Boiler

For example, a controlled chain-reacting system of uranium enri in the U 235 isotope as an aqueous uranium salt solution was assem to verify predicted effects of using enriched uranium in ch reacting systems. The success of this assembly was such that a sr shielded thermal reactor of essentially the same design was built l This reactor is called the "Los Alamos Water Boiler" because it U 235 in liquid solution. It operates at several kilowatts of power has numerous experimental facilities for irradiations and emissio neutron beams, which are used extensively for laboratory neu investigations.

Prompt and Delayed Neutrons

A controlled nuclear reactor maintains a self-sustaining chain tion with the aid of both "prompt" and "delayed" neutrons. of the neutrons are emitted promptly, the instant when fi occurs, while about one percent are emitted with an average dela several seconds. These delayed neutrons allow the chain rea of a nuclear reactor to be controlled. In a bomb, the reaction not depend upon the delayed neutrons, but proceeds using only prompt neutrons.

The Dragon

In 1944, a very important critical assembly called the "Dragon" made to simulate an atomic bomb. In this assembly a piece of riched uranium was allowed to fall through a hole in a larger qua of enriched uranium. During the short time the two pieces f together, the amount of fissionable materials was so great that prompt neutrons alone from fission caused a chain reaction to ceed momentarily. This experiment, known as "tickling the Drag tail" was hazardous because of the possibility of a small nuc explosion; however, it contributed greatly both to the knowledg atomic explosions and to our fundamental information regar delayed neutrons.

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The Fast Reactor

In 1946, the Laboratory undertook the construction of a reactor using plutonium metal rods as the fuel elements. This is known as the fast reactor because it uses fast neutrons to maintain the fission chain, instead of the thermal or slow neutrons used in all other existing reactors. It is a small shielded unit, cooled by circulating mercury and operating at powers somewhat higher than 10 kilowatts. Numerous irradiation facilities are provided, and fast neutron beams of energies averaging not far below those produced by fission are available. During construction, many critical assemblies of value to the reactor development program were made using plutonium in various lattice arrangements and in different media. The fast reactor is the only one known using plutonium, fast neutrons, and liquid metal coolant.

Elimination of Hazards

In keeping with the war urgency, the critical assemblies were originally done by hand but with full awareness of the hazards involved. Comprehensive safety rules were established, the rules assuming careful procedures and cross-checking of decisions by senior personnel but based almost entirely on personal judgment and responsibility. The end of the war permitted a complete change of philosophy regarding the critical assembly procedures. Reliance is now placed on mechanisms rather than entirely on human judgment, and all assemblies are operated by remotely controlled machines. If these machines or any associated equipment fail, personnel are not endangered. The mechanisms are equipped with automatic tripping devices which cause the fissionable material to be rapidly disassembled to a safe arrangement if any part of the mechanisms fail, or if the reaction proceeds too rapidly toward the critical stage. The experimenter can make the disassembly at will.

Experimenting at a Distance

All personnel are at considerable distances (a minimum of one-fifth mile) from the assembly laboratory, but the assembly is observed at all times by the use of television transmitters and receivers. An experiment to be performed is first described in detail in writing, then submitted for approval to senior staff members. The experiment is performed under the exact conditions described and with a technical safety man in authority who presides at each approach to critical conditions. The complexity of such experimental arrangements,

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using servo-mechanisms, television, and hydraulic actuators, requ
a highly coordinated scientific and engineering program.

The changeover in operating procedures during 1946 and
resulted in an almost complete stoppage of routine critical assem
for about one year while the new remotely controlled laboratory
built. Now, however, any accident which inadvertently allo
prompt criticality to be reached would not endanger the perso
Manual operations would still be much faster and less complic
but would carry with them a hazard to human life which cann
tolerated in this country in peacetime.

Objectives of Tests

The critical assembly group at Los Alamos is now concerned
three main programs:

a) Testing of specific configurations for planned assemblies of fis
able material.

b) Determining the safety of fabricating and storing fissio
materials.

c) Studying the behavior of critical systems which will lead to l
understanding of the basic principles of such systems.

The first function is an obvious part of a weapons laboratory
gram. However, all the functions, in addition to their importa
this laboratory, have application in all phases of reactor researc
are essential to any long-range program of using atomic energ
nonmilitary purposes. The specialized assemblies which have
made at Los Alamos have contributed and continue to contribu
these peacetime programs.

Eniwetok Proving Ground

One of the novel AEC research facilities is the Proving Gr
on Eniwetok Atoll. Its most unusual feature is its location—
miles from any other AEC installation, on a few coral islands i
middle of the Pacific Ocean. This location was selected so th
Commission could insure that personnel and informational se
would not be jeopardized during weapons tests.

The first atomic weapons test made at the Eniwetok Proving Gr
Operation Sandstone, was planned and executed in a short
Existing facilities and military stocks and supplies were adapte
use wherever possible. There was no permanent construction.

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Building for the Future

It now appears that periodic tests of atomic weapons will be made at Eniwetok, and that construction of semipermanent facilities is justified, for both economy and efficiency. Accordingly a contract has been let with the engineering firm of Holmes and Narver, of Los Angeles, to assist in planning and to design and construct semipermanent housing, utilities, and communications in the Atoll.

As a part of the program for periodic tests at the proving ground, a permanent test division has been organized at the Los Alamos Laboratory. This division is responsible for coordinating the scientific and technical activities at the proving ground, for formulating the Laboratory's experimental program for full-scale tests, and for directing relevant research at both Eniwetok and Los Alamos.

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AEC MANAGEMENT FOR RESEARCH

Research in the national atomic energy program reaches into nea every State in the Union and is controlled centrally but decentrali in administration. The Atomic Energy Commission finances a manages this diverse and wide-spread enterprise; assists contract in handling personnel matters; plans or authorizes constructi assists in the distribution of scientific and technical information, a maintains the necessary security control over it.

In this section, and in those that follow, this report recounts development of administrative elements of the program.

The growth and development of physical science research in atomic energy program during the last 3 years can best be underst in the light of the requirements of the Atomic Energy Act of 1 and of the organization as of January 1, 1947, when the Commiss assumed responsibility.

The Act of 1946

Section 3 of the Act provides the following guide to the Ato Energy Commission in regard to research:

Research assistance. The Commission is directed to exercise powers in such manner as to insure the continued conduct of resea and development activities in specified fields by private or pul instructions or persons, and to assist in the acquisition of an e expanding fund of theoretical and practical knowledge in such fie To this end, the Commission is authorized and directed to make rangements (including contracts, agreements, and loans) for conduct of research and development activities relating to—

a) Nuclear processes.

b) Theory and production of atomic energy, including proces materials, and devices related to such production.

c) Utilization of fissionable and radioactive materials for medi biological, health or military purposes.

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d) Utilization of fissionable and radioactive materials and processes entailed in the production of such materials for all other purposes, including industrial uses.

e) Protection of health during research and production activities.

Research by the Commission. The Commission is authorized and directed to conduct, through its own facilities, activities and studies of the types specified above.

The Heritage from MED

The principal Government-owned research facilities under the Manhattan Engineer District at the end of 1946 were these:

Clinton Laboratories at Oak Ridge, Tennessee; operated by the Monsanto Chemical Company.

Los Alamos Scientific Laboratory, Los Alamos, New Mexico; operated by the University of California.

Argonne National Laboratory, Chicago, Illinois; operated by the University of Chicago, with a board of governors representing 25 midwestern universities and research institutions.

Radiation Laboratory at the University of California, Berkeley, California (only certain buildings and equipment were Government owned).

Brookhaven National Laboratory, Patchogue, Long Island (this was under construction at Camp Upton and destined to be operated by Associated Universities, Inc., representing nine major eastern universities).

Knolls Atomic Power Laboratory, Schenectady, New York; (under construction and to be operated by General Electric Company).

Dayton Engineer Works near Miamisburg, Ohio; (under construction and to be operated by Monsanto Chemical Company).

Besides the Government-owned facilities, a large number of other institutions and universities held contracts from the MED for research and development work that contributed directly to the program. Prominent among these were: Battelle Memorial Institute, Columbus, Ohio; Columbia University, New York; Iowa State College, Ames, Iowa; Massachusetts Institute of Technology, Cambridge, Massachusetts; National Bureau of Standards, Washington, D. C.; United States Geological Survey, Washington, D. C.; University of Rochester, Rochester, New York; University of Washington, Seattle, Washington; Victoreen Instrument Company, Chicago, Illinois; and Washington University, St. Louis, Missouri.

The major research programs as the MED turned over operations included those for weapons, physics of reactors, development of materials for reactor construction, radioactive isotopes, metallurgy,

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fundamental nuclear physics and chemistry, ceramics, and radio biology.

The framework in which a peacetime research program could b built was established. However, many of the scientific facilities wer temporary, housing was often poor and inadequate as in many wa communities, and the scientific and technical staff had fallen fro around 8,000 during the war to between 3,500 and 4,000. Since tha time the AEC has replaced and expanded scientific facilities an erected permanent housing; it has filled out and enlarged the scientifi and technical staff.

The AEC Pattern of Research Management

Research is so much a part of all undertakings of the national atom energy enterprise that its management is an integral part of th entire administrative fabric. The Commissioners make major dete minations of policy and, through the General Manager, control th entire scientific effort. Advisory committees assist in many phas of research.

The directors of program divisions—Production, Military Applic tion, Reactor Development, Engineering, Biology and Medicine, R search—recommend on policy and direct assignment of research task The managers of field offices let and supervise authorized contract

The management divisions of AEC—the Office of the Gener Counsel, Finance, Organization and Personnel, Security, and Publ and Technical Information Service—all support or service resear programs.

Control of laboratory programs is centered in program divisio for which each laboratory performs a major portion of its wor Assignments of research undertakings are made through field offi managers (management of laboratories is discussed in Chapter VI Argonne and Schenectady answer to the Reactor Development Di sion; Los Alamos and Sandia to the Military Application Divisio K–25 to the Production Division; and Oak Ridge and Brookhaven the Divisions of Research and Biology and Medicine in their particul fields.

For all program divisions, except Research, the research work largely in support of other responsibilities. The Division of Resear is responsible for the development and supervision of the research pr gram involving the physical sciences in AEC installations and outsi organizations, including the isotope program, transfer of special n terials and equipment among research installations, and the patte for dissemination of technical information in the atomic ener program.

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Division of Research

The Division of Research includes six branches and two extension offices. The Physics and Mathematics Branch develops and supervises programs of fundamental research in AEC installations, and in outside organizations, involving investigation into the fields of physics and mathematics, including general supervision of the AEC fellowship program in physical sciences and the nuclear physics program jointly financed by the AEC and the Office of Naval Research and administered by the ONR.

The Chemistry Branch develops and supervises programs for fundamental research in the field of chemistry, as well as investigations of chemical process development and chemical analysis in AEC installations. In addition, it develops and supervises the program of fundamental research in chemistry financed by AEC and carried on by outside organizations, and is responsible for broad supervision of the Commission's isotope research and production program.

The Metallurgy Branch develops and supervises programs of fundamental research in AEC installations and outside organizations involving investigation in the fields of metallurgy, ceramics, and related materials.

The Technical Cooperation Branch coordinates and manages interchange of information, visitors, and special research materials and equipment between the AEC and British and Canadian atomic energy projects under policies approved by the Commission, maintaining active liaison with the program divisions on all pertinent matters.

The Materials and Information Branch supervises the transfer of unique materials and equipment among research installations and the public and develops the program for dissemination and use of technical information in the atomic energy program. In connection with the work of this branch, an extension office is maintained at Oak Ridge, Tennessee.

The Budget and Administrative Branch is responsible for budget formulation and control of research programs and internal administration of the Division.

THE RESEARCH TRAINING PROGRAM

Since the war, it has been recognized that success in carrying forward the Nation's scientific development depends to a great extent on providing adequate numbers of well-trained scientists. To meet this need, as one means of fulfilling its obligations for advancing atomic energy sciences under the Act of 1946, and upon the recommendation of the General Advisory Committee, the Commission established a fellowship program in January 1948. The National Research

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Council of the National Academy of Sciences undertook its administration—selecting fellows, approving research projects, evaluating the fellows' progress and their findings.

The Fellowship Program

During its operation, there have been nearly 500 participants in the fellowship program at a total cost to the Government of about $1,200,000. This fall, the program of fellowships for the 1950–51 academic year was substantially modified as a consequence of a fellowship rider in the Independent Offices Appropriation Act for 1950.* The rider provided that any person receiving an AEC fellowship award must undergo a loyalty clearance, whether or not his particular research project requires him to have access to secret information. Under previous provisions, security clearance was required for fellows only when their project involved restricted data.

The Commission—through the National Research Council—had granted fellowships for the 1948–49 and 1949–50 academic years in five categories: predoctoral research fellowships in physical and in biological sciences; and postdoctoral fellowships in physical, medical, biological and agricultural sciences. In the 1950–51 academic year, postdoctoral fellowships will be offered, through the NRC, only for advanced training in fields of research closely related to the national atomic energy program, in which access to secret atomic energy data is needed. Predoctoral fellowships will not be offered at all through the National Research Council for reasons arising out of the fellowship rider.

The AEC is seeking to have university groups, associated with the atomic energy enterprise in various sections of the country, undertake administration of fellowships under the present law so as to restore the program to its former scope. This effort has made some progress, but even if the universities undertake the program, the setting up of administrative machinery will take time, and it is not clear how quickly examination of proposed projects and selection of fellows could begin.

*The applicable portion of the Act: "SEC. 102–A. No part of any appropriation contained in this title for the Atomic Energy Commission shall be used to confer a fellowship on any person who advocates or who is a member of an organization or party that advocates the overthrow of the Government of the United States by force or violence or with respect to whom the Commission finds, upon investigation and report by the Federal Bureau of Investigation on the character, associations, and loyalty of whom, that reasonable ground exists for belief that such person is disloyal to the Government of the United States: *Provided,* That any person who advocates or who is a member of an organization or party that advocates the overthrow of the Government of the United States by force or violence and accepts employment or a fellowship the salary, wages, stipend, grant, or expenses for which are paid from any appropriation contained in this title shall be guilty of a felony and, upon conviction, shall be fined not more than $1,000 or imprisoned for not more than one year, or both: *Provided further,* That the above penal clause shall be in addition to, and not in substitution for, any other provisions of existing law."

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To fulfill previous commitments, applications for renewal of existing nonsecret predoctoral fellowships, and postdoctoral fellowships in medicine, will be accepted by the National Research Council, subject to the loyalty investigation as required by the Appropriation Act, mentioned above.

New Requirements for Fellows

Complying with the Appropriation Act, signed by the President on August 24, 1949, the Commission established procedures for FBI investigations of all AEC fellows and for the screening, analyzing, and reviewing of the investigative reports.

Nonsecret research. In cases where the fellow would not have access to restricted data, and no derogatory information is found, a fellowship-type approval is granted. Where the investigation has reflected some derogatory information about an applicant for a nonsecret piece of research, the reports are reviewed by a panel. The panel applies the same criteria used by the President's Loyalty Review Board established under Executive Order 9835. After reviewing the panel's recommendations, the General Manager decides whether fellowship approval should be granted.

Secret research. If the fellow is to have access to restricted data, the investigative reports are evaluated in accordance with the Commission's criteria for determining eligibility for clearance for AEC and contractor employees.

30 Now in Secret Work

Of the 421 who now hold AEC fellowships, 30 are engaged in research work which requires them to have access to secret atomic energy data (they already have received full AEC security clearance) and 391 are in nonsecret work. All save 77 of these fellows in nonsecret work were appointed before August 24 when the Appropriations Act went into effect, and hence they have been required only to sign a loyalty oath and noncommunist affidavit, as has been required of all fellows since May 22. The other fellows, appointed or reappointed after August 24, are of course subject to loyalty investigations as described above.

Under the NRC program set up for the 1950–51 year, about 75 new fellowships and 175 renewals will be offered. The cost of this program will run between $600,000 and $900,000, depending on the number of new awards made. The AEC will continue fellowships in health physics—it will offer about 20—which formerly were a part of the

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Research Council's predoctoral program, and will work out an alternate system of administration. These fellowships always have required full security clearance and will continue to do so.

Other Research Training Programs

The modification of the fellowship program will not affect the research work which graduate students are carrying on at AEC laboratories. At present there are 32 such students at Brookhaven, Argonne and Oak Ridge.

Oak Ridge Institute of Nuclear Studies

At Oak Ridge, the Commission has an operating contract with the Oak Ridge Institute of Nuclear Studies (ORINS) to assist in meeting its obligation for the training of scientists.

The Institute, a non-profit educational corporation of 24 Southern universities, utilizes the facilities of the Atomic Energy Commission at Oak Ridge in a program of research and training in the nuclear sciences. In October 1946 the State of Tennessee granted ORINS a charter of incorporation, and in April 1947 a contract was entered into between the Institute and the Atomic Energy Commission. Since that time the Institute has expanded its facilities and its service to the Atomic Energy Commission research training program.

Organizationally, the main governing body of the ORINS in a council composed of one member from each of the sponsoring institutions. The council elects a board of directors, composed of 9 members, which is charged with administering the property and affairs of the Institute. ORINS has four divisions.

University Relations Division. A graduate training program through which graduate students may complete thesis research is operated in the Oak Ridge laboratories of the Commission. In another major program university faculty members are encouraged to carry out in Oak Ridge laboratories research of interest to the laboratories and to the scientist.

This division also administers a program which enables Oak Ridge Scientific and technical workers to continue graduate education while they are employed. The University of Tennessee provides the teaching personnel. Three annual awards of $500 each, contributed exclusively by participating universities and known as Science Research Awards, are given for papers published by students or faculty members of the sponsoring institutions.

Special Training Division. This division was created to help meet the requirements of mature research workers who needed special train-

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ing in new techniques in the nuclear sciences. A prime responsibility of this division is to assist universities in taking over this type of training.

The most pressing demand for special training was in the use of radioisotopes for research. The Atomic Energy Commission was meeting legitimate requests for radioisotopes, radiation instrument manufacturers were producing counters and other essential scientific equipment with great speed, but too few research scientists knew how to apply radioisotopes to their work with safety and efficiency.

Through a series of 11 courses, 368 scientists from over 170 laboratories in this country and abroad have been trained. Some colleges and universities now offer courses in radioisotope techniques and in a few years such courses are expected to become standard in college curricula.

Medical Division. A study of the treatment of cancer and other malignant diseases, with special emphasis on the use of radiation and radioactive materials, is being undertaken by the Medical Division. Twenty Southern medical schools are cooperating. This program will include training additional medical personnel in new techniques developed at Oak Ridge.

Educational Services Division. The American Museum of Atomic Energy is operated in Oak Ridge by the Educational Services Division as a public service. It is open to the public at a nominal charge. Within certain limitations, this Division provides atomic energy displays and other educational material to universities, academies of science, and other public or educational organizations.

Further Programs

Another program operates under the auspices of the Associated Universities, Incorporated, which makes facilities of the Brookhaven National Laboratory available to certain scientists doing private research on projects of interest to the atomic energy program.

Basic research contracts, reported in the next section of this report, not only contribute research information but as an incidental result help in further training of some of their participants.

AEC CONTRACT RESEARCH

The Atomic Energy Commission contracts for basic unclassified research in university and college laboratories currently at an annual rate, for research in the physical sciences, of about 6.5 million dollars. These contracts are for two sorts of research:

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a) Basic research to solve a particular problem such as one dealin with reactor design or isotope separation. The Commission seek the services of specific scientists under these contracts and usuall pays the full costs.

b) Basic research of the typical university sort, undertaken to ad to the general fund of knowledge applicable to atomic energ development. The Commission shares research costs of the projects to an extent arrived at by negotiation.

Many of the university and college scientists now engaged on the contracts helped staff the wartime atomic energy project. They in clude some of the Nation's leading workers in fields related to atom energy. When AEC determined to support unclassified basic re search, it sought the assistance of these men. The problem was ho to enable them to undertake additional research, of interest to th progress of the atomic energy enterprise, without depriving the students of essential training.

Inquiry revealed that many of the scientists could take on AE projects if the handicap of lack of financing were removed. AE funds in limited amounts would correct these deficiencies, and increa the volume of basic atomic energy research. From the university viewpoint, and that of the national interest also, a method of contr had to be established to assure that contract research work would n encroach seriously on the major university task of training more scie tists. The procedure adopted stipulates that the AEC will recei proposals for basic research through the management of universiti and colleges where capable scientists are willing to expand or continue a research program, provided their projects are such th they might be of interest to the development or use of atomic energ

importance of the proposed project to atomic energy development; (*c*) general need of the AEC for more individuals trained in the field of study involved; (*d*) financial condition of the university involved and the relationship that additional funds might have to program expansion; (*e*) likelihood that information affecting the security of the Nation will be developed and feasibility of providing the safeguards that might become necessary.

ONR Contracts

In 1947 when the Commission became responsible for advancing atomic energy research, virtually the only Government assistance being given universities in the vital field of nuclear research came from the Office of Naval Research. The funds available, even for this limited support, were diminishing. More than two years ago, therefore, AEC commenced contributing to the support of this work. Today there are 63 ONR-AEC research projects in physical sciences in American universities.

ONR and the AEC are currently agreeing on which specific projects in nuclear physics should be supported in whole by ONR, in whole by AEC, and jointly by ONR and AEC. By the last quarter of calendar year 1949, AEC had contracted for research, or transferred to the Office of Naval Research for contracts, the following sums: in physics research, a total of 6.3 million dollars of which 5 million dollars was administered by ONR; in chemistry research, a total of $400,000; in metallurgy, all handled by AEC, some $1,100,000; in mathematics, about $200,000 of which AEC administered all except about $14,000. The total is about $7,900,000 of which AEC directly administered about $2,900,000 and ONR about $5,000,000.

FINANCING RESEARCH

The Atomic Energy Commission's total operating and capital outlay in its three basic research and development programs during the year that ended June 30, 1949, was approximately 128 million dollars. This amount covers research in physical science, biology and medicine, and reactor development but does not cover research of the process-improvement type which is included under the weapons and source and fissionable materials programs. Of this amount approximately 33 million dollars was spent on research in the physical sciences. In comparison, according to a report of the President's Scientific Research Board, all other civilian agencies of the Government were expending in 1947 a total of 20 million dollars for basic research and 45 million dollars for applied research and development projects.

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The patterns followed by the Government for financing small-sca civilian research and large military research programs have be modified somewhat to fit the needs of long-term atomic research. review of the background of the research contracts taken over by t Commission may indicate the reasons for modification.

The contracts for nuclear research had their beginnings in 19 when the newly organized Office of Scientific Research and Develo ment was given an appropriation to carry on such work. OSRD ha few precedents for the kind of operation in which it was to engag The urgent need for certain research and development work was t central idea of the project. OSRD did pioneer work in the attem to devise methods of financial control that would protect the publ interest in the proper expenditure of funds without unduly infringi upon the primary objective.

When the Manhattan Engineer District of the War Departme took over the atomic bomb project on May 1, 1943, the outstandi OSRD contracts were continued although they differed greatly fro the standard Army contract. Some of these contracts were la taken over by AEC. The experience of its predecessors has be invaluable to the Commission. The changes in financial provisio and accounting that have been made in putting the present proj on a peace time basis are chiefly owing to the changes in the natu of the project itself. Some of the financial and accounting pr lems that plagued the administrators of the project in the beginni as outlined in the official histories, can now be considered settl Others, such as determination of indirect costs, provisions for adequ accounting and financial reporting, vouchering procedures, and fi settlement of contracts have called for continuing attention. attempting to handle such problems and any apparently new on the Commission has followed the policy of first considering what h been done before.

Financial Aspects of Contracting for Research

Previous studies of methods of financing research have genera recognized the need for flexibility in the scope of the work and si plicity in the financial and administrative controls. In financing search by contract, the first problem to be met is to develop contra that are appropriate for the particular varieties of research servi required. Certain financial aspects call for consideration:

The contract must provide for judgment on the contractor's op ations in terms of financial as well as research results. The size the contract may condition its financial terms. For the type of w under way in research laboratories, cost estimates often cannot be m

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easily or accurately and this must be recognized in writing the contract.

The type of contractor as well as the type of research work to be performed affects the contract used. The Commission's research contractors include individuals, universities, groups of universities, industrial firms, independent research institutions, and other Government agencies. Of these, the group of universities is probably the only type of contractor that is peculiar to research in nuclear science. For many years, some groups of industrial firms have operated cooperative laboratories, but the incorporation of a group of universities to operate a national laboratory is a postwar addition to the economic and social scene.

Two Types of Contracts

According to their payment provisions, the Commission's contracts for research fall into two broad types. One type provides for payment of a predetermined sum, which may be paid in installments. The second type of contract provides for reimbursement of current cost, or cost-plus-a-fixed-fee, and is generally financed by monthly advances of funds.

The Lump-Sum Contract

In letting a so-called lump-sum contract, the chief financial problem is to predetermine as closely as possible what the actual cost of work performed under the contract will be. Representatives of the Commission make a comprehensive examination of the individual situation, particularly when the prospective contractor is engaged in similar work outside of the contract. By their nature, lump-sum contracts are most effective where the course of research activities is reasonably predictable and the cost of the work to be performed can be estimated with a fair degree of accuracy.

The use of this type of contract for research operations requires that the contract negotiators include both scientists and accountants qualified to judge and to determine the reasonableness and accuracy of the cost estimates. Such contracts are generally limited to basic research projects of relatively small cost, where the contractor and the Commission have agreed to joint financial support of the work.

The Cost-Type Contract

The intention under a research contract may be to pay a contractor his actual cost, to pay a share of the cost or, less frequently, to pay a fee in addition to cost. Educational institutions and research founda-

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tions generally have a policy of operating without profit and some have entered into cost-sharing contracts with the Commission for basic research in which they and the Commission have a particular interest.

In addition to having a substantial independent interest in certain research activities undertaken under Commission contracts, universities and research foundations stand to gain experience and know-how in the field of nuclear science. They stand to gain particularly in undertaking work, located on their own grounds, that is closely allied to their own programs and that may result in their being furnished research facilities not otherwise available because of the large cost. Unlike these institutions, the business concern in undertaking an atomic energy contract may be giving up an opportunity to make a profit through the use of its staff and equipment in some other activity. The payment or nonpayment of a fee is, therefore, one of the questions to be considered on its merits and settled when a contract is negotiated.

Contract Management

In general, research contracts are negotiated by AEC operations offices within the framework of the broad policies established in Washington. A research proposal accompanied by a budget of estimated costs may be sent to the appropriate Washington division of AEC either directly or through an operations office. If the proposal is approved, the responsible operations office will make a contract within the scope of the research work agreed upon with the Washington office. Although recommendations are made by the Washington divisions concerning the principal items of the proposed budget, such as the dollar levels for salaries, equipment, and alterations of facilities, the detailed budget is the responsibility of the Operations Office. The form and content of each individual contract is determined during the negotiation. An attempt is made to obtain consistency between similar research projects conducted by similar organizations. Since the Operations Offices, strategically located in 8 cities throughout the country, are generally in closer proximity to the contractors, they administer the business aspects of the research contracts.

The administration of a cost-sharing contract for fundamental research is frequently simplified by having certain costs identified as those to be borne by the AEC and others as those to be borne by the research institution. This identification of certain costs with the research institution is not a fixed and invariable AEC policy, for the Commission considers that determining its total contribution under such contracts is more important than the allocation of that contribution to particular cost items.

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Financial Provisions of Contracts

From a financial point of view, one of the most important parts of a contract is the cost-reimbursement provision. The Commission staff early undertook a study of contract cost provisions. The existing contracts were tested against the Commission's cost-reimbursement policy which was first stated in July 1947, namely, that all contractors with cost-reimbursement-type contracts shall be reimbursed for the necessary costs, direct and indirect, incurred in carrying forward the provisions of their contracts and that such costs shall be determined by generally accepted accounting principles consistently applied.

In developing financial operations within this broad framework, the Commission has recognized that the contractors and the agency have a mutual interest in arriving at an accurate determination of allowable contract costs. The Commission is interested in getting its assignment carried forward with dispatch and in paying each contractor what is justifiably due him, at the same time making sure that it is carrying out its responsibility as a trustee of public funds. The educational institutions and other organizations taking part in research are interested for their part in having the record show that they have given value for payments to them.

Overhead Costs

Certain overhead cost provisions of limited applicability developed by the Office of Scientific Research and Development and continued by the Manhattan Engineer District for nonprofit contracts, were designed to eliminate a possible profit to the contractor by providing for a refund of any excess above the contract's total costs and expenses upon final settlement. As pointed out by the President's Scientific Research Board,* the fact that OSRD recaptured approximately 18 million dollars in overhead costs through voluntary contract renegotiation indicates the magnitude of the overhead problem, particularly for universities.

Improvement Sought

Since the amounts of excess overhead accumulated by some contractors were substantial, and since the early contracts had not provided for audit of such items by the Government, the need for revision of the contracts in this regard for peacetime operations was apparent. Steps were therefore taken to improve on the early overhead arrangements. Such improvements required keeping the amount of over-

*"The Report of the Chairman of The President's Scientific Research Board," August–September 1945, Vols. 1–5, Government Printing Office, Washington 25, D. C.

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head reimbursements more in line with the indirect costs actually being incurred under the contract while continuing the protection of the contractor against Government disallowances of costs where expenditures had been made in good faith. This was particularly important for nonprofit educational institutions so as to protect them against incurring any loss that would require them to draw upon their normal educational funds.

In drawing up new cost-type contracts, or in extensions of existing contracts, a cost-reimbursement provision that would possibly solve the difficulty was worked out. The proposed contract provided that the Commission would reimburse the contractor for all costs incurred by it in carrying out the terms of the contract, and that costs were to be determined in accordance with generally accepted accounting principles applicable to operations of the type performed under the contract and consistently applied. It also provided that at such intervals as might be mutually agreed upon, but no less often than once each year, the Commission would review with the contractor the amount of the costs and expenses including (*a*) overhead computed in accordance with generally accepted accounting principles consistently applied and (*b*) all costs and expenses, not otherwise reimbursed, which are actually incurred by the contractor in good faith arising out of or connected with the work under the contract.

Any excess in payments to the contractor for the period under review would be applied by the contractor to the cost of subsequent work under the contract or refunded to the Government, and any deficit in such payments would be paid to the contractor immediately by the Government.

The reimbursement policy of covering the total cost of this type of contract was predicated upon the fact that there are generally accepted accounting principles for arriving at total cost. By substituting this policy of paying total cost determined by generally accepted principles for provisions which included predetermined costs without provision for periodic review, the Commission instituted a practical method of protecting both the Commission and the contractor.

The means for determining reimbursable indirect costs under research and development contracts for on-campus work has been a more difficult problem. It has been the central topic of discussion in the conferences held with committees of business officers of educational institutions and study on this problem is continuing.

Research Accounting

The early decision of the Atomic Energy Commission to apply industrial finance and accounting methods to the atomic energy project as a whole, as described in the Fifth Semiannual Report to

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the Congress, met with immediate approval from industrial contractors generally. For research, however, the matter was more complicated. The educational and research institutions with which the Commission had contracts generally did not have the same type of accounting system as the industrial concerns. Many of these institutions received most of their funds from grants and appropriations and had not been accustomed to account for the use of the funds in a way that would fit into the financial reporting of the atomic energy program as a whole.

In December 1947, the public accounting firm that had been engaged to review the Government and contractor accounting under a typical cost-type research contract taken over by AEC confirmed the opinion that the type of contract negotiated under the urgency of war conditions did not provide for the use of accounting records and procedures that would be classified as adequate under normal conditions.

Difficulties Under Contract

In reviewing operations under this form of contract, the public accountants had attempted to determine whether the financial and accounting provisions of the contract had been carried out, and whether the practices in use were satisfactory or unsatisfactory for continued use. They found that, with minor exceptions, the accounting operations of both the contractor and the Government met the provisions of the contract, but that the contract itself needed to be revised if general and cost-accounting information were to be required. For instance, the contract provided that the system of accounting to be employed by the contractor should be that customarily utilized by the contractor in the regular conduct of its business. The accountants found that inclusion of this provision kept additional accounting work at a minimum, but that the contractor's accounting system was designed to furnish only the information required for its own accounting objectives. The Commission's requests for information in addition to that normally furnished under the contractor's system, therefore could not be met and were objected to on the justifiable basis that they were not authorized under the contract.

There were several deficiencies in the typical research contractor's accounting system and in the Government's method of auditing. The outstanding faults were the incomplete cost records, the lack of monetary controls over materials and property, the practice of transferring the materials and facilities without monetary control, and the duplication of audit effort.

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The Basic Policy

In putting the atomic energy program on a long-term, peacetime basis, one of the chief problems was to devise a system for providing to the internal management, the Congress, and the public, the financial data each of these groups needs, and to provide such data in understandable language.

The most common financial question asked about a research project has generally been "What is the cost?" Getting the answer to that question has been no simple matter. As an examination of the early operations showed, it was impossible under the system that had been used to determine the cost of a particular research project.

Educational institutions customarily set up accounts for their various organizational divisions such as physics, chemistry, and services and maintenance. To obtain meaningful data concerning atomic energy research, however, financial information must be reported in terms of each research activity or program of the Commission. Since one university may have its science organized into three departments and another into ten, depending upon such factors as educational emphasis or the particular interests or capacities of individual faculty members, financial data grouped by such divisional classifications could not be consolidated and compared and would be of little use in managing the atomic energy work.

To provide a solid basis for budget estimating and control, the account classifications used by the various organizations, for the research conducted for the Commission, needed to be in accord with the research activity classifications used by the Commission. For instance, the Commission needs to collect costs for the work on a particular particle accelerator under one account classification, and the work in the general area of pure physical research in other accounts, even though a single university division may be conducting both types of work. For the Commission's purpose, its own functions rather than the organizational divisions of its contractors are meaningful units for classifying costs.

The Commission has recognized, in its finance policies, the close interrelation of providing funds for research, controlling research objectives within budgeted amounts, and controlling costs generally. As has previously been recognized in industrial research organizations, an adequate cost accounting system interrelated with budgetary control requires (*a*) measuring costs for comparison with the budget, both by specific objective and in total; (*b*) identifying costs with organizational units with sufficient accuracy to fix responsibility for control by those responsible for the various research activities; and (*c*) providing information for controlling pay roll, materials, and

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verhead and their subclassifications before the identity of such costs is lost by consolidation.

The introduction of the comprehensive accounting system and the cost-based budget has put greater emphasis on participation by research directors in cost planning as related to program planning. The Commission has attempted to follow good business practices without hampering the contractors and without imposing any unnecessary controls or objectionable requirements. The Commission feels it has advanced toward the goal of combining scientific freedom and financial safeguards.

Cost Trends in Physical Science Research

AEC physical research operating costs, exclusive of depreciation, are expected to increase from approximately 26 million dollars in fiscal year 1949 to over 31 million dollars in fiscal year 1950.

One of the more significant developments is the large increase of work performed outside the Commission's own laboratories and installations. In fiscal year 1949, such work made up 14.5 percent of the total physical research program, and in fiscal year 1951 contracts for work outside Commission-owned laboratories are expected to reach nearly 32 percent of the program. While the work in Commission-owned laboratories by major research contractors will remain fairly constant, work in the laboratories of educational and research institutions under the much more numerous smaller contracts will increase substantially. This indicates a real growth of scientific effort in this very important field.

Large-scale enterprises generally require a large investment in physical facilities and the atomic energy program is no exception to this. In fact during this initial period, the Commission's capital requirements as related to operating expenses may exceed those of many so-called heavy industries. In 1949 the three research programs—physical research, reactor development, and biology and medicine—called for an outlay of 70 million dollars for plant and equipment. Of this amount, 27 million dollars was for physical-research facilities. In 1950 the total capital cost for the three programs will be 76 million dollars of which 25 million dollars will go into facilities for physical research. About half of the total cost of research facilities is for construction of research tools such as reactors and accelerators as distinguished from more conventional laboratory buildings and research equipment.

SCIENTIFIC AND TECHNICAL INFORMATION SERVICE

The Atomic Energy Commission and its contractors operating the atomic energy enterprise are both producers and consumers of scien-

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tific and technical information. The technical information service required for the program includes all of the familiar elements: libraries, journals, reports, indexing, and abstract services, cataloging, and publication. As a consumer, the atomic energy program collects and selects from the world's scientific and technical literature the portions which are relevant to its purposes. As a producer, it feeds back into the body of scientific knowledge its own research findings that are unclassified or can be declassified.

Confronted with the necessity of making rapid selections of particular information from the tremendous mass of scientific publications, the Commission has found many of the standard bibliographical practices slow, cumbersome, and ineffective. Hence, research into the ways in which information can be more quickly selected, organized, and put to use is a major aspect of the AEC technical information program.

As a producer of information, the Commission is required by the Atomic Energy Act of 1946 to maintain "a program for the control of scientific and technical information which will permit the dissemination of such information to encourage scientific progress." The key terms in this requirement are *control* and *dissemination*. The system of control must provide for the restricted dissemination of classified information to scientists and engineers working in the enterprise and for an effective method of disseminating unclassified and declassified material to the scientific and technical community at large.

The job of accomplishing this dual purpose is complicated by decentralized research and reporting activities. In 1949, 350 contractors produced about 4,000 reports, of which 2,900 were classified and subject to security control and limited distribution.

Before these reports, both classified and unclassified, can be fully put to use, they must be reproduced, listed, disseminated, indexed, abstracted, cataloged, etc.

Classified Information

Scientists everywhere are accustomed to certain established forms of scientific communication. The first is the research report, which in turn becomes an article in a scientific journal, an item in an abstracting service, an index entry in a catalog, a chapter in a treatise, and ultimately part of the contents of a technical library. Since much of AEC's research work falls in the area of "restricted data" and cannot become a part of this regular pattern, the Commission has had to set up a special system of communication within the atomic energy program.

Classified research reports must be limited in circulation, yet they

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must also be available readily to all scientists within the project who are working on the same or related problems. At present, most of these reports are circulated as individual documents. The Commission, however, has established a classified scientific journal in the field of metallurgy and ceramics, and may extend the scope of this method of circulating information within the enterprise.

Standard Lists Set Up

Most classified reports are prepared in multiple copies by the individual AEC laboratories and are distributed directly to other Commission installations. This avoids the delay of processing all reports through a central office, but it requires a system of safeguards to insure that only authorized persons receive copies. This direct though limited distribution is controlled by standard distribution lists. The AEC Division of Research, in agreement with other divisions concerned, prepares these lists, which contain categories of distribution and define the scope of each. Each category appearing in the Standard Distribution Lists—isotope separation, reactors, metallury, ceramics, etc.—is accompanied by a scope note which specifies what activities shall be included, what excluded. The listing of a name of a site laboratory, office, or agency under any category constitutes authorization for the distribution of reports in a given category and the reports are automatically sent to the addresses listed.

Abstracts Circulated

As the second element in the Commission's pattern of scientific communication within the enterprise, "Abstracts of Classified Research and Development Reports" are issued semimonthly. Authorized recipients of this publication are kept informed currently of all classified research in progress throughout the project except for certain highly classified reports and reports of limited interest which are omitted.

Last year, 1,630 classified documents were abstracted. Each copy of ACRDR is numbered and assigned to a definite recipient. With full regard to security requirements, these abstracts are an indispensable tool for digesting and bringing together the diverse results of the classified research program in atomic energy. Copies of classified reports are stored in the more than 30 classified document rooms maintained by the Commission. AEC libraries and document rooms contain more than 500,000 research and development reports in organized collections. The Washington headquarters maintains a complete collection of all reports produced, and the document room

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maintained at Oak Ridge serves as a distribution center for supplying collections elsewhere. These collections are not files, but highly organized repositories in which research reports take the place of ordinary technical books and journals.

Cataloging Reports

AEC catalogs all reports received and distributes cards to other document collections. For each individual report there is an author card, a report number card, and sufficient subject cards for a complete subject index to the report. During 1949, AEC cataloged 8,085 reports and sent 2,485,886 cards to 68 document rooms. The reports cataloged included 4,678 that were new and 3,407 which required recataloging or had accumulated in the backlog from the war years. This wartime backlog has now been eliminated and cataloging of research and development reports is on a fully current basis. A complete catalog of AEC reports now contains approximately 200,000 cards covering about 38,000 reports.

Scientists use journals to maintain their awareness of current progress in their specialties, but such journals must be supplemented with handbooks, compendia, and treatises. The Commission is preparing a series of such books as a classified part of the National Nuclear Energy Series. There are at present about 60 classified volumes scheduled for inclusion in this series. At the close of 1949, manuscripts for 26 of these volumes were on hand of which 12 were in the final stages of editing and preparation for printing in Oak Ridge.

Exchange of Information With Department of Defense

The Military Liaison Committee assisted in setting the policies and procedures for interchanging technical reports and information between the AEC and various agencies of the Department of Defense. Current classified and unclassified AEC research reports are now moving by standard distribution to designated agencies of the Armed Services that need certain categories of technical information. Approximately 800 reports are furnished monthly to military officers and their research facilities.

Procedures have also been established for the handling of specific Department of Defense requests for technical reports and information, including restricted data. Conversely, the AEC currently receives and distributes to appropriate research laboratories technical information developed by military agencies. This exchange of technical information is expanding to the mutual benefit of AEC and Department

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of Defense research programs, and has helped avoid duplication in research.

Unclassified Information

The Commission's unclassified information services for the men working in the program supplement the regular patterns of scientific publication and dissemination. The basic element is the collection of all journals and books which are likely to contain information relevant to the projects being carried on by the Commission and its contractors. Throughout the enterprise there are active technical libraries serving laboratories and research installations. Many of the Commission's major laboratories are far from university and industrial centers, and research libraries have had to be built and staffed along with laboratories and production plants.

To the extent that research projects are located on university campuses or at established industrial centers, project personnel are able to use existing libraries. A new technical library is established by the Commission only in conjunction with a new major installation, in keeping with the policy set forth in the section on library facilities in the report of the President's Scientific Research Board—

> For those materials of frequent reference to be physically accessible to the research worker, the technical library has to be located in or near the laboratory. However, provision of adequate library facilities is an expensive task calling for trained personnel. These two facts, in combination, add weight to the conclusion * * * that large laboratories are better than small isolated units. Only in the large laboratory can the expense of adequate library resources be spread over research operations extensive enough to make library cost a relatively negligible item of overhead.

Thus, major technical libraries supported by Commission funds are located at Oak Ridge, Knolls, Westinghouse, Brookhaven, Argonne, Los Alamos, Sandia, and Hanford where they service major laboratories, and at Washington for the use of the headquarters staff.

Publication Encouraged

The Commission sponsors a considerable volume of unclassified research and also maintains a program for declassifying research results which no longer require security control. The unclassified and declassified reports have been released to the scientific and technical public in various ways. As a major method of dissemination, the Commission encourages project scientists to make their own arrangements for publication in established, privately-supported scientific periodicals.

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The Commission's policy in this regard is supported by an overwhelming number of project scientists who do not wish to see the Commission or any other part of the Federal establishment assume the responsibility for publishing their contributions to research. Unfortunately, private scientific societies are unable, at the present time, to publish all results of the greatly expanded volume of federally supported research.

The National Research Council will shortly organize a conference of editors of the leading scientific journals to formulate their views on the extent of Federal responsibility for the support of scientific publication. The Atomic Energy Commission will weigh the result of this conference before attempting to estimate the extent of its obligation to extend financial support to such journals.

Distributing Reports

In the meantime, the Commission is reproducing and distributing the unclassified and declassified AEC reports which have not been published in the regular scientific journals. These reports are available on an exchange basis to universities, learned societies, research institutions, etc., and are sold to individuals or institutions unable to enter into exchange arrangements.

As a final method of disseminating unclassified scientific and technical information, the Commission has established the "National Nuclear Energy Series," described in the next section.

The following table summarizes the unclassified and declassified reports so far released by the Commission (figures approximate):

Reports published in scientific journals	1,20
Reports distributed by the Technical Information Branch (Oak Ridge)	1,12
Reports to be included in the National Nuclear Energy Series	1,15

National Nuclear Energy Series

The National Nuclear Energy Series developed by condensation of separate writing programs originating at Chicago, Berkeley, Los Alamos, and other project laboratories. Each site planned to write scientific accounts of its research programs. By November 194 arrangements were completed to combine all the separate programs into one over-all series covering all phases of the project. The classified volumes (approximately 60) will, of course, be available only within the atomic energy project. The remaining 50 volumes will be declassified and made available to the general scientific and technical community.

As part of its general policy to encourage private publication of unclassified research results, the Commission invited bids from private

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firms for publishing the Series. The McGraw-Hill Publishing Company was selected and has already issued eleven volumes, the first of which appeared in 1948. (See Appendix 7 for description of published and projected NNES volumes.)

Nuclear Science Abstracts

Although the Commission is not a major publisher of unclassified scientific papers, it has established a major abstracting publication in the field of nuclear science. "Nuclear Science Abstracts" in less than 2 years has become a valuable tool for research workers. The Commission publishes the abstracts to meet such problems as the fact that (*a*) existing abstract services like "Chemical Abstracts" and "Physics Abstracts" do not cover unpublished research reports; (*b*) program research requires faster abstracting services than existing abstracts provide; and (*c*) nuclear science cuts across many diverse fields such as medicine, agriculture, geology, ceramics, industrial sanitation, instrumentation, metallurgy, chemistry, and physics.

"Nuclear Science Abstracts" is issued twice monthly at Oak Ridge. Each issue is indexed, and cumulative indexes are prepared semiannually. The use of mechanical sorting, collating, and printing machines allows preparation of cumulative indexes without setting new type for separate cumulations. The abstracts are available without charge to all scientists officially connected with the atomic energy program, and on an exchange basis to universities, hospitals, medical schools, research institutions, scientific societies.

Technical Information Committee and Panel

The General Manager has established two advisory bodies in the field of technical information. The Technical Information Committee consists of representatives of the Research Division, Division of Biology and Medicine, Division of Military Application, Division of Reactor Development, Raw Materials Office, Office of Classification, and the Division of Public and Technical Information Service. The Technical Information Panel includes representatives of the major contractors. These two groups meet regularly to evaluate the effectiveness of existing technical information services and to consider plans for the extension of such services.

In addition to these formal organizations, technical and reference librarians in AEC installations have organized an informal librarians' conference which meets twice a year. One valuable product of these meetings has been the preparation of a "Manual for Servicing and Control of Classified Research and Development Reports."

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Research in Techniques

The proper utilization of research results requires effective bibliographical controls consisting of catalogs, indexes, bibliographies, abstract reviews, and services. The volume of technical information from the national research effort is now so great that the present systems are rapidly becoming outmoded. This situation has become particularly serious where specialists in several research fields frequently need to join forces to solve common problems.

Rapid Selector

The Commission has attempted to develop new techniques and procedures for the storage, recording, selection, and dissemination of information. The Commission has joined with the Department of Agriculture in developing a machine known as the Rapid Selector. The selector operates like a research worker looking through the cards in a library catalogue, but at much greater speed. With properly coded entries, the machine will scan up to 120,000 subject entries per minute, compared to 15 or 20 entries which a fast worker may examine in the same time. Moreover, it will reproduce an abstract of a document on the spot, or, if properly set up, the original document, saving time now spent in searching the shelves of local libraries or in waiting for information to come from distant places.

A 2,000-foot reel of film used in the present selector provides space for text and code for 60,000 abstracts or an equal number of text pages. As many as six different coded entries may be made for each abstract or page, or a total of 420,000 entries on the entire reel.

First use of the selector by the Atomic Energy Commission will be for the maintenance of records of new research with radioisotopes.

In addition to the Rapid Selector, the Commission has developed typewriter composition for texts to be printed by photo-offset means, and it has utilized business machines for the reproduction and rapid accumulation of indexes.

Indexing Machines

The business machines used for cumulating and printing indexes are also used to control the receipt and distribution of classified documents. Under the old system the initial logging record was made by hand and troubles caused by human error were always present. It took one typist a whole day to type out all receipts for a large standard distribution. The tabulating machine requires only about a half hour. The largest number of documents transmitted in any one month

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1948 was a little over 5,000 and this required the use of extra personnel. In March 1949 using machines, the library section was able to ship almost 9,000 documents with fewer personnel.

Reproduction of Material

The Joint Congressional Committee on Printing has authorized the Atomic Energy Commission to maintain a field printing plant at Oak Ridge for departmental printing. This plant reproduces "Nuclear Science Abstracts," index cards, bibliographies, and reports. As noted above, the program of decentralized research and reporting provides for preparation of reports for project dissemination by the various contractors. However, when a contractor lacks facilities for the reproduction and dissemination of his reports, the Oak Ridge plant will reproduce such reports for project distribution from a master copy prepared by the contractor. During 1949, the plant at Oak Ridge printed 25,000,000 pages.

CONTROL OF INFORMATION

The Commission has continued to give careful consideration to the basic policies underlying the control of information. The Commission, guided by the pertinent provisions of the Atomic Energy Act, has determined that information should be controlled so as to promote the common defense and security by—

a) Withholding from those whose objectives may be inimical to the interests of the United States, information which could be used by them to the detriment of this Nation's security.

b) Providing adequate information for a vigorous and efficient pursuit of the goals of this Nation's atomic energy and related programs, in a manner consistent with democratic traditions.

The secrecy classification to be applied to any item of information thus depends upon a balance between the value of that information to inimical interests and the value expected to accrue to the United States through its dissemination.

In its consideration of policies in such matters, the Commission has recognized that the essential assets of the United States in atomic energy, as in other fields, are the ability and experience of industry, the knowledge and enthusiasm of scientists, and the maintenance of momentum in all technical fields. Many of these assets lie outside the Commission's organization and depend to an essential degree upon scientists, technicians, and industrialists having free access to adequate information.

The importance of accountability to the public must be considered, likewise, in determining information-control policy. In a democracy, the people must be able to judge the action of their representatives and officials, and to pass intelligently on policy. The Commission believes that information about a public enterprise of such magnitude as the atomic-energy program should be withheld only for reasons soundly based upon the common defense and security.

The essential factors in appraising whether particular items of information must be kept secret depend in part on a technical judgment as to the pertinence of the information to the objectives of this Nation's over-all program. In forming this judgment, the Commission looks to key technical personnel associated with its activities. It also depends on many factors of nontechnical nature such as, for example, matters related to military operations, civil defense, plant protection, or international relations. In this judgment the Commission must obtain the views of competent authorities in its own organization and in other agencies. The Commission recognizes that control of information requires constant exercise of judgment, in the last analysis, by every individual concerned with classified information.

Unclassified Areas

The Commission has had under continual scrutiny the boundaries between, on one hand, restricted data or classified information and, on the other, that information which can be "published without adversely affecting the common defense and security" (Sec. 10 (b) of the Atomic Energy Act). In 1948 the Commission established certain "unclassified areas" in which work could be performed generally free from security restrictions. This had the effect of considerably reducing the extent of Commission research activities covered by secrecy regulations. (See Fifth Semiannual Report.)

The experience of the last year has shown that this procedure has been successful. Many laboratories now submit technical articles in these unclassified areas directly to various publications. By monitoring these papers, AEC has verified that this process has not released information which could be considered "restricted data." By thus enabling scientists and engineers to publish certain kinds of research work, AEC has assisted dissemination of material that does not require secrecy. At the same time, by reducing unnecessary classification review, AEC has been able to concentrate maximum effort on keeping secret information whose release would be contrary to the public interest.

The use of unclassified areas has helped to remove unnecessary restrictions on some research and development work in AEC labora-

tories. A large volume of work has been done under procedures not substantially different from those existing in any university or industrial laboratory. Of more than 1,250 technical papers released for publication during 1949 (not including the National Nuclear Energy Series), only about 40 percent were formally reviewed through the declassification system. The other 60 percent were in unclassified areas and were sent directly to professional journals and periodicals by the laboratory or individual author.

International Coordination on Secrecy Policies

The specific "Declassification Guide," drawn up to assist operation under the Commission's policy on control of technical information, and held in common by the United States, United Kingdom, and Canada, is a document agreed to by the three countries. On September 26 to 28, 1949, the Third International Declassification Conference was held in Chalk River, Ontario, Canada, to assure continued coordination of secrecy policies and practices. Consideration is now being given to possible revisions in secrecy policies which may be desirable in the light of the Russian atomic explosion. A preliminary discussion of these matters will take place at a meeting of declassification representatives of the three nations scheduled to be held at Harwell, England, in February 1950.

Agreement of the three nations on the categories of technical information to be released, or declassified, has minimized misunderstandings. It has resulted also in reasonably uniform standards of secrecy for the fund of information shared by the three nations, through their joint wartime effort and through the Technical Cooperation Program.

Internal Organization

During the summer of 1949 the Commission created the post of Director of Classification whose office absorbed the Declassification Branch of the Public and Technical Information Services. The Office of the Director of Classification is responsible for interpreting the Commission-approved rules and guides, not only for declassification, but also for the original classification of new information.

This change reflects an increasing interest in the problem of secrecy as well as a recognition that classification (assignment of an appropriate secrecy category) is as important as declassification (release from the restricted data category). As in the previous organization, technical guidance is provided by expert consultants, principally the Committee of Senior Responsible Reviewers and a large group of Responsible Reviewers. The conscientious assistance given by these

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experts in their continual review of the technical aspects of declassification has been valuable to the Commission in maintaining control of information in accordance with the general policies adopted by the Commission pursuant to the Atomic Energy Act.

PROTECTION OF CLASSIFIED DOCUMENTS

The protection of restricted data is the responsibility of the Atomic Energy Commission under the Act of 1946. The Commission adopted the regular Government classifications of *top secret*, *secret*, and *confidential*, to indicate the degree of importance of information. A vast number of classified documents have come into existence under the Commission; together with those originated by the Manhattan Engineer District, the number is well into the millions.

To develop and effectuate appropriate security measures to safeguard these documents adequately, and to provide for suitable accountability, has been a major task of the Division of Security.

Top Secret Control

Soon after the Commission assumed responsibility for the atomic energy project, it was apparent that improved procedures for the control of, and accountability for, classified documents were desirable. Special emphasis was placed on improving the control of top secret documents since the most sensitive information with respect to the national defense and security is given that classification. As the first step, a project-wide inventory of top secret documents was ordered and a Top Secret Control Office was established as a branch of the Division of Security.

Following this initial inventory, instructions were issued which set forth the procedures to be followed in preparing, handling, safeguarding, and accounting for top secret documents. Semiannual inventories are also required.

The present procedures provide the central control office with immediate information as to documents newly originated, and those which have been reclassified or destroyed. They also provide a record of the transfer of custody of every top secret document from one person to another, including the transfer of safeguarding responsibility from courier to courier during transmittal. This system, implemented by inventories, affords a continual check on each top secret document in existence, the total number of which runs into tens of thousands.

Only a limited number of AEC officials and certain contractors have been designated as authenticating officials with authority to classify a document as top secret. The number of persons authorized to

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receive or keep such documents is held to the minimum consistent with good administration, and these persons are so authorized only if their duties require them to have the information contained in a specific document.

Secret and Confidential Control

Research and development reports comprise a substantial portion of the documents in the secret and confidential classifications. At the time the Commission assumed responsibility, it was not known how many such documents existed nor where they were located. Hence, an inventory of these reports was ordered at all Commission installations.

This inventory revealed over 700,000 of these research and development reports throughout the project, varying from some 2,000 at the smaller installations to over 200,000 at one of the larger plants.

To this inventory figure, compiled as of December 31, 1948, there are added each month approximately 15,000 new reports. Because of the volume of these documents and the importance of the data they contain there is a tremendous problem of internal control and accountability. This problem is magnified when these documents are transmitted from one installation to another.

In addition to appropriate records which reflect the preparation, receipt, custody and transmittal of these reports, there has been developed a system of transfer and accountability stations, through which reports are transmitted, so that each individual report may be properly controlled, and information may go only to those persons who require the information.

In addition to the documents classified as top secret and the research and development reports classified as described above, there are hundreds of thousands of other classified documents such as drawings, blueprints, photographic film and prints, administrative and operating reports, letters, memoranda, teletypes, etc., which also require safeguards.

Records are maintained locally by offices of operations, or by individual offices or installations, which give the number, disposition, and location of these documents.

PHYSICAL SECURITY OF RESEARCH OPERATIONS

As of the close of 1949, some 900 research laboratories, institutions, and consultants were under contract with the AEC to conduct scientific research, some aspects of which must be safeguarded in accordance with the Atomic Energy Act of 1946. These range from the extreme security importance of the Los Alamos Scientific Laboratory, employ-

ing hundreds of persons on research and development of atomic weapons, to the individual scientist in a university laboratory. Obviously, Los Alamos requires elaborate safeguards, whereas the individual scientists may work with none or with relatively few restrictions.

To monitor the safeguarding requirements of a research program of such magnitude and diversification requires some 3,000 security contacts and inspections a year in practically every state of the Union.

Safeguarding Secret Research

In order to devise a practical security system for a laboratory at which research of a classified nature is to take place, it is first necessary to determine just which aspects of the research are secret and, therefore, must be safeguarded. This determination requires expert scientific judgments. When it is made, the laboratory buildings or areas in which the secret research is to be carried on are physically segregated by fencing, walls, or other barriers; and access is controlled by guards or special receptionists.

An estimated 1,500 guards are employed to safeguard AEC and contractor research laboratories. Overall, 20 percent of AEC employees and 9 percent of contractor employees constitute the security guard force.

A further protection is set up by making a determination as to the persons who will be permitted access to these areas. Persons admitted will include not only scientists and technicians in charge of scientific research but also the staff of secretaries, clerks, guards, doctors, plumbers, janitors, carpenters, painters, consultants, machinists, and glass blowers essential to operation and maintenance of a complex modern laboratory.

All such persons must be investigated and cleared. It is then necessary to issue to each individual identifying credentials for the areas within the laboratory where he is to work. These are of tamper-proof type and coded to indicate the areas to which the holder is entitled to go. Many persons require full access to all areas; others, with lesser responsibility, have reasonable limitations placed on the extent of their access.

The devising of practical safeguards for atomic materials is a complex business because many of the materials are almost continuously in use in experimentation. These elements are frequently changed chemically, alloyed or mixed with other materials, and in some cases transmuted to new elements. Elaborate testing and bookkeeping arrangements are necessary, in addition to physical safeguards.

These are in addition to safes, vaults, and special alarm and detection equipment for the storage of these materials, and a security system

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which must include a number of other practical safeguards for the laboratory areas where they are in active use.

Protection of Shipments

The protection of shipments of vital materials and transfer of secret papers between laboratories and other installations is a continuing problem. Safeguards must not only be provided against espionage, theft, and damage, but also against the possibility of certain toxic and radioactive substances injuring the public.

Thousand-mile shipments of special elements which are not only highly toxic and dangerous but which have a short "half life" and decay rapidly, must be made with speed, safety, and security. In addition to firearms of various types required for the protection of secret materials and documents, therefore, many AEC couriers must also be equipped with portable Geiger counters and other radiation monitoring and special equipment, and trained in their use.

Although thousands of ton-miles of special security shipments are conducted monthly between AEC installations, it is significant that to date there has been no known theft, loss, or compromise with respect to such shipments, and no instance in which the materials shipped caused injury to any person.

PERSONNEL SECURITY IN RESEARCH

Before persons may have access to restricted data or to exclusion areas where the most secret work is carried on, they must be investigated as to character, loyalty, and associations. Under the Atomic Energy Act, individuals who are to be employed by the Atomic Energy Commission or who are to have access to restricted data while employed by an AEC contractor or licensee must be investigated by the FBI and, thereafter, on the basis of this report, the Commission must determine that permitting such an individual to have access to "restricted data" will not endanger the common defense and security.

Even on unclassified research projects the Commission, as a precautionary measure, may often require the principal investigator (or other suitable monitor) to be cleared, to become familiar with the Commission's program, and to have a working knowledge of the classification and declassification requirements. Such projects, while unclassified in their conception, may lead into areas involving restricted data. Adequate security clearance enables such research activities to meet the needs of the AEC and still safeguard restricted data. However, in research projects where the chance of restricted data being

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discovered is essentially zero, no security requirements are imposed.

The AEC's program for controlling visits to exclusion areas, designed to prevent unauthorized persons from access to restricted data or to areas where classified work is being performed, permits visits with minimum delay between the AEC's various sites where the research employees are engaged in related fields of endeavor. The correlation of such data through visits, symposiums, and through the distribution of reports is controlled so as to retain compartmentalization with respect to production and weapon information and activities.

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VI

THE ATOMIC ENERGY LABORATORIES

The atomic energy laboratories—the National Laboratories and the other great establishments which carry out the research projects of the atomic energy program—are the heart of the industry's scientific effort. Founded by the Manhattan District, expanded and reorganized by the Atomic Energy Commission, they constitute one of the greatest efforts toward organized basic and applied research in the Nation's history.

They are remarkable in that the facilities are owned and financed by the Federal Government, but operated by private contractors—famous universities and leading industrial concerns which have established and conducted excellent research programs on their own.

LABORATORY HISTORY

The Manhattan Engineer District brought together more than 7,000 scientists and engineers who successfully attacked one facet of the atomic energy problem after another, culminating in the bomb attacks on Hiroshima and Nagasaki. When the wartime assignment was completed, many scientists turned to other work more to their liking. Within a year, the research program, which had commanded the attention of roughly 5 to 6 percent of the Nation's research scientists and engineers, lost more than half its staff, and among those who left were many of the Nation's ablest scientific workers.

With the establishment of the Atomic Energy Commission a year later, it was clear that the pace of atomic weapons research had to be renewed, and that applied research must be supported step-by-step by fundamental advances in science. Without such support, a weapons research program would be futile even though the pressure for progress remained high.

The Commission could not, of course, reassemble for peacetime work such an array of scientific talent as had carried the war program to success. The wartime urgency was lacking; many of those formerly in the program preferred other kinds of work; and many were training the scientists of the future, a task also of major importance to the Nation's welfare.

In the face of severe handicaps, especially the shortage of scientists which developed during and after the war, it was necessary to recruit

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substantially a new atomic energy research team. Between Jul
and July 1948, the program recruited enough research and de
ment personnel to increase its total from a little over 4,000 to
than 7,000, approximately the number assembled for war work b
MED. As of July 1949, nearly 9,000 scientists and research engi
were at work on AEC research projects. (See table.) The
emphasis now goes toward improving the quality of the total

Scientific and Engineering Staffing in AEC Projects

Fiscal year	Start	Loss	New	
1946	7, 000–8, 000	3, 500–4, 500	0–500	3, 500
1947	3, 500–4. 000	500–1, 500	1, 000–1, 500	4, 000
1948	4, 000–4, 500	500–1, 500	3, 500–4, 500	7, 000
1949	7, 000–7, 500	500–1, 000	2, 000–2, 500	8, 500
1950	8, 500–9, 000			

The new team contained fewer "big-names" of science and wa
posed largely of younger scientists and engineers. They repre
approximately the same fields of science as under MED, excep
the number of scientists in the biological and medical fields h
creased from 2 to 8 percent, and the proportion of engineers ros
30 percent to 45 percent.

LABORATORY MANAGEMENT

There is little attempt at uniformity in the organization or ope
of AEC laboratories; this is a matter of policy on the part
atomic energy program. The administration of laboratories pr
very different problems which are related closely to the type
search carried on in each. An effort directed toward the de
ment of a new military weapon can be highly organized an
trolled to prevent diversion of effort into unimportant byways.
this type of work is carried on, as during the wartime program
patterns are followed.

Discoveries in pure science, however, do not come through
technique. The essential feature of a strong basic science labo
is the freedom of individual scientists to pursue the problem
seem most promising and interesting. Often the sidelines will b
fruitful than the main line of investigation. Many of sc
greatest basic discoveries have come in this way.

For this kind of progress, programs cannot be mapped o
ahead and rigidly adhered to. Administration, and budgetary
trol, must take these things into consideration, and operations

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LABORATORIES

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be adjusted to match. The type of direction suitable for a planned program of applied research not only will not work for basic research, but may actually impede progress.

At the same time, to challenge the trained minds of scientists—the ultimate resource on which progress depends—programs of applied research must be appropriately leavened with the opportunity for pure research, and an optimum apportionment must be encouraged. Atomic energy laboratories not only combine basic and applied research to varying degrees, but also include work in many different scientific disciplines. Some laboratories, such as those of Knolls and Westinghouse, concentrate exclusively on applied research and development. Some, such as Ames and the Radiation Laboratory, Berkeley, both university laboratories partly financed by the Government, devote an overwhelming majority of their projects to basic work. The Radiation Laboratory includes important biological research teams as well as those that work in nuclear physics, and this is true also of the national laboratories.

Under these conditions, trying to establish uniformity of management would hamper accomplishment. The Atomic Energy Commission, acting on the advice of its associated scientific and industrial counselors, has insofar as it is possible left detailed administration in the hands of the individual laboratory management. The Commission aims to simplify accounting procedures and such operating routine as keeping stated hours, making reports, and such other administrative matters as scientists find tend to interfere with their concentration on scientific problems.

Policies of Administration

Beyond this, the Atomic Energy Commission has been able to establish certain broad policies on such matters as salaries, provision for ample basic research and provision of travel funds, so that the essential interchange of information among scientists may be facilitated. It has, moreover, arranged periodic conventions of atomic scientists for the same purpose, and assisted distribution of papers on scientific findings.

Assistance to laboratories is provided in recruiting scientific personnel. This system operates in two ways. Laboratories are assisted, on request, to reassign scientists, who have outgrown current assignments, to other openings within the program where their expanding abilities can be put to greater use. Also applicants to laboratories, which do not need their services, may be referred elsewhere within the program.

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An Aid to Recruitment

Of special interest as a recruitment policy is a program inaugurated at Los Alamos during the summer of 1947. College students, mostly at the graduate level, are employed during the summer months. The students become regular employees of the Laboratory and require clearance in the usual manner. In addition to performing important service, they learn a great deal about the nature of the Laboratory. Upon returning to their classes in the fall, they are able to report a great deal which is not classified about their experience, and in many cases these students hope to obtain full-time positions after completing their schooling. This plan also has the advantage of providing the Laboratory with an excellent opportunity to judge the quality of these individuals as prospective permanent employees. Also, in cases where permanent employment is contemplated, university work may be oriented to provide the best possible preparation.

This program has been of such value to the Laboratory that it has been gradually expanded. Sixty-nine students, representing 33 colleges and universities, spent the summer of 1949 at the Laboratory. Chosen from among 403 applicants, all but 9 were at the graduate level. They were a highly competent group.

Similarly, Brookhaven had 14 science students employed during the summer months of 1949.

THE CONTRACT AND AEC POLICY

Commission policies on salaries, travel allowances, and such matters are put into effect through the contracts which are written with the operators of particular laboratories. This is possible since contracts are written on the basis of reimbursable costs, sometimes with, sometimes without, an operator's fee. Thus, the Commission authorizes salaries for scientists at the "going-rate", so that scientists are in general paid on the basis of the salary they could command for their services elsewhere. This results, largely, in a scale of pay that is commensurate with that paid in industrial laboratories throughout the country. Contract provision is made similarly for adequate travel allowances.

Provision for Basic Research

The same contract device is used to assure that a proportion of basic research shall be carried on in those laboratories where it is appropriate, and where it will assist in the work of the Commission. The proportion has varied, and will continue to vary, from laboratory to

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laboratory, with the type of project handled there and with its management and background. It is not, of course, always possible to draw a clear line between what is basic and what applied research, but out of some 60 million dollars devoted to research and development in eight major laboratories, about two-thirds was for work which probably can be called applied research, and the balance for what may be classed as basic. At Ames and Berkeley, for example, at least three quarters of the research could be called basic, whereas at Argonne and Oak Ridge more than half is on the applied side.

Initially, the prime concern of the Atomic Energy Commission was to concentrate the immediately available facilities and staff on the most urgent problems—particularly in production of fissionable materials and improvement of weapons. Of equal concern to the Commission and its principal advisers was the necessity of supporting and stimulating fundamental, or basic, research—first of all, to help restore the levels of fundamental research activity so seriously reduced throughout the country during the war years, second to increase its support and volume.

Consistently, in its reports of the last 3 years, the Commission has been able to show progress in its developmental and applied research programs. Processes have been improved at Oak Ridge and Hanford, and in preparing ores and feed materials; marked economies have been accomplished as a result; a more effective weapon has been designed and tested; assembly line methods have been worked out for bomb manufacture. These are the end-results of both basic and applied research, and of engineering development.

LABORATORY PERSONNEL

Laboratory management has many aspects—the provision of adequate equipment and supplies, the apportionment of types of research, its direction and administration—but there can be no question that the productiveness of any laboratory depends most heavily upon the quality of the scientists it can attract, and upon providing them with the climate most conducive to their best work. Scientific research is creative work; it cannot be measured by the yard, or by the man-year. The Commission has attempted, through getting the best contractors and laboratory directors, through adequate provision of scientific equipment and of housing accommodations where necessary, and by encouragement of a favorable climate for research, to make its laboratories attractive to men of high calibre.

It has certain obstacles to overcome. The Government is not always highly regarded as an employer among the larger scientific community, and the security restrictions which are a necessary part of the

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atomic energy program impose certain handicaps. For example, they prevent general publication of research results on which scientists depend for fitting together the various segments of knowledge which they separately uncover.

The contractor method of operation helps to overcome these obstacles. And, as pointed out, the Commission takes many positive steps to assure working conditions which will attract the best scientists.

Some Key Questions

A definition of the complex of conditions which compose freedom of research and which the Commission fosters in its laboratories is found in questions such as the following:

a) To what extent may individual staff members determine on the basis of their own interests and enthusiasm the research programs to be followed?

b) What opportunities exist for staff members to advance continuously in their fields of specialty?

c) To what extent are scientists provided with opportunities to report on their research to other scientists, within the same laboratory as well as in others, to compare results and in general to have the benefit of the new ideas which may result from such exchanges?

d) What administrative arrangements are made to permit and encourage individual scientists to work at the times of day and for the numbers of hours per day which will produce the best research?

e) To what extent are scientists freed from duties and responsibilities considered to be nonscientific, such as administrative duties, preparation of budgets, and various other matters generally referred to as "red tape"?

f) How much leave is granted to scientists for vacations, sickness, further education, attendance at meetings of professional societies, consulting to other laboratories, temporary employment elsewhere, etc.?

g) How are research expenses accounted for and justified, and to what extent does research budgeting divert scientists from research?

As an approach to the industry-wide problem of attracting and successfully utilizing scientific talent, the staff of the Commission, early in 1947, undertook a study of personnel administration in large research installations. A Scientific Personnel Committee was established under the chairmanship of Dr. F. Wheeler Loomis, chairman

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of the department of physics, University of Illinois, to conduct this study.

After studying the Commission laboratories, and reviewing other laboratories' policies, the committee made recommendations on such matters of personnel policy as tenure of staff members, methods of salary administration, transfer of scientists from one project to another, exchange of information among scientists, vacations and sick leave, insurance and retirement plans, travel expenses, and the provision of educational opportunities.

The recommendations of the Scientific Personnel Committee have assisted the Commission staff members in discussing personnel policies with research contractors and in some instances in determining what expenses should be reimbursable. Many of the Loomis Committee's recommendations as to the interchange of employees, travel expenses, opportunities to attend professional society meetings, and provision of educational opportunities for younger scientists are in effect in the laboratories.

Salary and benefit studies. Toward the end of 1948 the University of California, at Los Alamos, conducted a salary survey for scientists and engineers in industrial and Government laboratories throughout the country. Data from a representative sample of laboratories showed average salaries paid on the basis of education and years of experience. The data were used as a guide in establishing salary levels at Los Alamos and were also made available to other Commission contractors. A more up-to-date survey is currently nearing completion at Los Alamos.

To provide the Commission and its contractors with similar guidance in deciding upon employee benefits in research laboratories, a survey among approximately 30 large representative industrial laboratories is nearing completion under the joint sponsorship of the Atomic Energy Commission and the Bureau of Labor Statistics. Up-to-date facts are being gathered about the practices for research personnel regarding retirement and insurance annuities, vacation and leave policies, payment for overtime work, hazard pay, payment of travel expenses, attendance at professional society meetings and other related matters.

Planning research. Scientists in university research enjoy great latitude in selecting areas for study, and in purchase and use of equipment within the scope of alloted funds. The university laboratories in which most pure science has been developed have generally recognized this principle.

Industrial laboratories, on the other hand, have generally had rather specific assignments. The director and his staff plan programs to

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carry out assignments, delegate parts of the program to laboratory groups. This method has been characteristic of research directed toward better electric lamps, television, finding oil underground, and countless other applications of science. It appeals strongly to scientists who gain much satisfaction from seeing the practical benefits of their work.

In Commission laboratories, different practices are followed in the freedom of individuals to plan and carry out their own research. Brookhaven and the Radiation Laboratory allow maximum freedom. The success of these institutions in recruiting and retaining outstanding research scientists is undoubtedly due in part to this.

Primarily concerned with basic research, these two laboratories also have important and specific research problems of a practical nature assigned to them.

The two National Laboratories at Argonne and Oak Ridge have a larger proportion of their personnel and facilities assigned to specific projects, and there are fewer opportunities for basic research. In each case, however, there is a substantial amount of basic research growing out of the interests and abilities of members of the staff.

As a general rule, in the different laboratories, there are few individuals who have no responsibility for applied research, just as there are few with no opportunity to participate in basic research.

Maximum progress depends upon a blend of basic and applied research in such a way as both to attract high-grade people and to use their abilities on the solution of practical problems as well as on basic research.

Promoting professional growth of scientists. The greatest experts in science are those who are able not only to stay abreast of progress in their field and in related fields but are able to be in the lead. They are the ones who demand the opportunity to keep on learning. Opportunities for professional growth at a research institution help attract such men.

Such laboratories as Berkeley and Ames, located on or near a university campus, have a real advantage in this respect. At Oak Ridge, the Oak Ridge Institute of Nuclear Studies has arranged with the University of Tennessee to make courses in science and engineering available to employees in Oak Ridge. More than 80 of the 600 scientific and technical personnel of ORNL are taking such courses. Similar arrangements have been made by the General Electric Co. in Hanford in cooperation with 5 universities in Oregon, Washington, and Idaho. Programs are under way at both Los Alamos and Sandia, in cooperation respectively with the extension division of the University of California and the University of New Mexico in Albuquerque.

Scientists benefit through opportunities to meet with other scientists

about research problems of common interest. Most Commission research contractors provide such opportunities. Meetings of the American Physical Society, American Chemical Society, and other scientific and engineering societies are usually sprinkled with representatives from Commission installations. In some cases, individuals attend at their own expense on leave of absence. More often, at least a part of the expense is borne by the laboratory; in many cases total expenses are borne by the laboratory.

Special information meetings are organized by the Commission about twice a year. The last meeting in Oak Ridge was attended by about 300 scientists from other laboratories. These meetings parallel public professional society meetings and permit discussion of classified research.

Seminars to provide scientists with an opportunity to discuss their research, held at Brookhaven, have attracted much favorable attention among scientists. Similar meetings organized at Argonne, Oak Ridge, Los Alamos, the Radiation Laboratory, and other AEC laboratories, have attracted many of the Nation's outstanding scientists into these institutions.

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APPENDIX 1

U. S. Atomic Energy Commission, Principal Staff, and Managers of Operations Offices

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Executive Officer, Program Council.	David B. Langmuir.
Director of Classification	James G. Beckerley.
General Counsel	Joseph Volpe, Jr.
Controller	Lindsley H. Noble (Acting).
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Director, Division of Production	Walter J. Williams.
Director, Division of Engineering.	George G. Brown.
Director, Division of Military Application.	Brig. Gen. James McCormack, Jr.
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Director, Division of Organization and Personnel.	Fletcher C. Waller.
Director, Public and Technical Information Service.	Morse Salisbury.
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Hanford (Washington)	F. C. SCHLEMMER.
Idaho	L. E. JOHNSTON.
New York (New York)	WILBUR E. KELLEY.
Oak Ridge (Tennessee)	RICHARD W. COOK.
Raw Materials (Washington, D. C.).	JESSE C. JOHNSON.
Santa Fe (New Mexico)	CARROLL L. TYLER.
Schenectady (New York)	JAMES C. STEWART.

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APPENDIX 2

MEMBERSHIP OF COMMITTEES

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Senator TOM CONNALLY (Texas).
Senator MILLARD E. TYDINGS (Maryland).
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Brig. Gen. HERBERT B. LOPER, United States Army.
Rear Adm. RALPH A. OFSTIE, United States Navy.
Rear Adm. TOM B. HILL, United States Navy.
Maj. Gen. DAVID M. SCHLATTER, United States Air Force.
Brig Gen. ROSCOE C. WILSON, United States Air Force.
Brig. Gen. ALVIN R. LUEDECKE, United States Air Force, executive secretary.

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AARON HORVITZ, lawyer and arbitrator, New York and New Jersey; Commissioner of Conciliation, U. S. Department of Labor; former chief hearing officer and special mediator, National War Labor Board.
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consultant to and formerly of the staff, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

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Dr. RALPH CARLISLE SMITH, chief, Documentary Division, Los Alamos Scientific Laboratory, Los Alamos, N. Mex., and ARNOLD KRAMISH, AEC, Washington, D. C., serve as joint secretariat to the Board.

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EDWARD W. MOREHOUSE, vice president, General Public Utilities Corp., New York, N. Y.

WALTON SEYMOUR, director, Division of Power, and director, Program Staff, Office of the Secretary, U. S. Department of the Interior, Washington, D. C.

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Dr. A. O. BECKMAN, president, National Technical Laboratories, South Pasadena, Calif.
GEORGE H. BUCHER, vice chairman of board, Westinghouse Electric Corp., Pittsburgh, Pa.
Dr. RICHARD S. MORSE, president, National Research Corp., Cambridge, Mass.
H. B. NEAL, president, Kinney Manufacturing Co., Boston, Mass.
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JOHN A. VICTOREEN, chairman of board, The Victoreen Instrument Co., Cleveland, Ohio.

Advisory Committee for Idaho Processing Plants

F. W. SCHUMACHER, chairman; associate director, Standard Oil Development Co., Westfield, N. J.
F. L. CULLER, chemical engineer, Oak Ridge National Laboratory, Oak Ridge, Tenn.
Dr. STEPHEN LAWROSKI, chief, Chemical Engineering Division, Argonne National Laboratory, Chicago, Ill.
Dr. JAMES MARSDEN, chief, Chemistry Division, Knolls Atomic Power Laboratory, Schenectady, N. Y.
DICK DUFFEY, chemical engineer, Reactor Development Division, AEC, Washington, D. C.

Advisory Committee on Isotope Distribution

Dr. G. FAILLA, chairman; professor of radiology, Columbia University Medical School, New York, N. Y.
Dr. PAUL C. AEBERSOLD, chief, Isotopes Division, AEC, Oak Ridge, Tenn.
Dr. H. A. BARKER, department of plant nutrition, University of California, Berkeley, Calif.
Dr. HENRY BORSOOK, head of department of biochemistry, California Institute of Technology, Pasadena, Calif.
Dr. AUSTIN M. BRUES, director of biology division, Argonne National Laboratory, Chicago, Ill.
Dr. HAROLD COPP, assistant professor of physiology, University of California Medical School, Berkeley, Calif.
Dr. ROBLEY D. EVANS, professor of physics, Massachusetts Institute of Technology, Cambridge, Mass.
Dr. HYMER L. FRIEDELL, director of department of radiology, Lakeside Hospital, Western Reserve University, Cleveland, Ohio.
Dr. A. H. HOLLAND, JR., director of office of research and medicine, AEC, Oak Ridge, Tenn.

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DR. JOSEPH W. KENNEDY, chairman of department of chemistry, Washington University, St. Louis, Mo.

DR. ROBERT F. MEHL, director, Metals Research Laboratory, Carnegie Institute of Technology, Pittsburgh, Pa.

DR. L. F. NIMS, chairman of biology department, Brookhaven National Laboratory, Upton, Long Island, N. Y.

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JOHN A. DIENNER; of Brown, Jackson, Boettcher & Dienner, Chicago, Ill.; former president, American Patent Law Association.

HECTOR M. HOLMES; of Fish, Richardson & Neave, Boston, Mass.

CASPER W. OOMS; of Dawson, Ooms, Booth & Spangenberg, Chicago, Ill.; former U. S. Commissioner of Patents.

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(*Charles Fahy, former chairman, resigned effective December 15, 1949.*)

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THOROLD F. FIELD, consulting mining engineer, Duluth, Minn.
WILBER JUDSON, vice president and director, Texas Gulf Sulphur Co., New York, N. Y.
ROBERT E. MCCONNELL, mining engineer, McConnell Foundation, New York, N. Y.
WALTER L. MAXSON, metallurgist, Oliver Iron Mining Co., Duluth, Minn.
ERNEST H. ROSE, chemical engineer, Tennessee Coal, Iron & Railroad Co., Birmingham, Ala.
WALTER O. SNELLING, consulting chemist and director of research, Trojan Powder Co., Allentown, Pa.
ORVIL R. WHITAKER, consulting mining engineer, Denver, Colo.
CLYDE E. WILLIAMS, chemical engineer, director, Battelle Memorial Institute, Columbus, Ohio.

Reactor Safeguard Committee

Dr. EDWARD TELLER, chairman; professor of physics, Institute of Nuclear Studies, University of Chicago, Chicago, Ill.
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Col. BENJAMIN HOLZMAN, meteorologist, Office of Director of Research and Development, U. S. Air Force, Washington, D. C.
Dr. JOSEPH W. KENNEDY, chairman of department of chemistry, Washington University, St. Louis, Mo.
Dr. JOHN A. WHEELER, Palmer Physical Laboratory, Princeton University, Princeton, N. J.
Dr. ABEL WOLMAN, head of department of sanitary engineering, Johns Hopkins University, Baltimore, Md.

Safety and Industrial Health Advisory Board

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HORATIO BOND, chief engineer, National Fire Protection Association, Boston, Mass.
WILLIAM F. BROWN, safety director, Consolidated Edison Co. of New York, New York, N. Y.
BERNARD R. CALDWELL, deputy chief of police, Los Angeles, Calif.
Dr. PHILIP DRINKER, professor of industrial hygiene, Harvard School of Public Health, Boston, Mass.
RICHARD FONDILLER, president, Woodward & Fondiller, New York, N. Y.
Dr. HYMER L. FRIEDELL, director of department of radiology, Lakeside Hospital, Western Reserve University, Cleveland, Ohio.
ARTHUR E. GORMAN, sanitary engineer, AEC, Washington, D. C.
HERBERT M. PARKER, superintendent, health instrument divisions, General Electric Co., Hanford, Wash.
JACK J. SMICK, associate actuary, Woodward & Fondiller, New York, N. Y.
Dr. ABEL WOLMAN, head of department of sanitary engineering, Johns Hopkins University, Baltimore, Md.

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Security Survey Panel

JOHN S. BUGAS, chairman; vice president for industrial relations, Ford Motor Co., Detroit, Mich.

DAVID LUKE HOPKINS, executive vice president and director, The Safe Deposit and Trust Co., Baltimore, Md.; vice president of board of trustees, Johns Hopkins University, Baltimore, Md.

Dr. PAUL E. KLOPSTEG, director of research, Technological Institute, Northwestern University, Evanston, Ill.; member, Board of Governors, Argonne National Laboratory, Chicago, Ill.; and member of executive committee, American Institute of Physics.

J. ARTHUR MULLIN, president, Glenvale Products, Detroit, Mich.; vice president, Standard Life and Accident Insurance Co., Detroit, Mich.

Stack Gas Problem Working Group

Dr. ABEL WOLMAN, chairman; head of department of sanitary engineering, Johns Hopkins University, Baltimore, Md.

Dr. PHILIP DRINKER, professor of industrial hygiene, Harvard University School of Public Health, Boston, Mass.

Dr. LYLE GILBERTSON, research division, Air Reduction Sales Co. Laboratory, Murray Hill, N. J.

Dr. GEORGE R. HILL, director of department of agricultural research, American Smelting & Refining Co., Salt Lake City, Utah.

Dr. H. F. JOHNSTONE, professor of chemical engineering, University of Illinois, Urbana, Ill.

EARL P. STEVENSON, president, A. D. Little, Inc., Cambridge, Mass.

Dr. W. P. YANT, director of research, Mine Safety Appliances Co., Pittsburgh, Pa.

Ad Hoc Committee on Technological Information for Industry

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HENRY A. BARTON, director, American Institute of Physics, New York, N. Y.

H. E. BLANK, editor, Modern Industry, New York, N. Y.

GENE HARDY, Washington editor, Chilton Publications, Inc., Washington, D. C.

KEITH HENNEY, consulting editor, Electronics and Nucleonics, McGraw-Hill Publishing Co., Inc., New York, N. Y.

EDWARD KREUTZBERG, editor, Penton Publishing Co., Washington, D. C.

WALTER J. MURPHY, editor, Chemical and Engineering News, American Chemical Society, Washington, D. C.

W. A. PHAIR, managing editor, The Iron Age, Chilton Publications, Inc., New York, N. Y.

J. J. SMITH, American Institute of Electrical Engineers, New York, N. Y.

GEORGE STETSON, editor, Mechanical Engineering, American Society of Mechanical Engineers, New York, N. Y.

R. E. THUM, editor, Metal Progress, American Society for Metals, Cleveland, Ohio.

P. J. VAN ANTWERPEN, editor, Chemical Engineering Progress, American Institute of Chemical Engineers, New York, N. Y.

Dr. ALBERTO F. THOMPSON, secretary; chief, Technical Information Branch, AEC, Washington, D. C.

Technical Information Panel

Dr. ALBERTO F. THOMPSON, chairman; chief, Technical Information Branch, AEC, Washington, D. C.

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Dr. RUSSELL BALDOCK, research physicist, Stable Isotopes Department, Carbi
Carbon Chemicals Corp. (Y–12), Oak Ridge, Tenn.

Dr. L. G. BASSETT, professor of chemistry, Rensselaer Polytechnic Institute, T
N. Y.

Dr. HENRY A. BLAIR, director, Atomic Energy Project, University of Roche
Rochester, N. Y.

Dr. BREWER F. BOARDMAN, chief, Technical Information Division, ORE, A
Oak Ridge, Tenn.

Dr. JOHN Z. BOWERS, deputy director, Division of Biology and Medicine, A
Washington, D. C.

Dr. A. J. DEMPSTER, director, Mass Spectroscopy and Crystallography Divis
Argonne National Laboratory, Chicago, Ill.

W. E. DREEZEN, administrative aide to director, Ames Laboratory, Ames, Iow

Dr. M. M. HARING, director, Mound Laboratory, Miamisburg, Ohio.

SYLVAN HARRIS, manager, Documents Department, Sandia Corp., Albuquer
N. Mex.

JOHN F. HOGERTON, technical reports director, The Kellex Corp., New York, N.

Dr. JOHN P. HOWE, chief, Metallurgy Division, Research Laboratory, Kn
Atomic Power Laboratory, Schenectady, N. Y.

R. B. KORSMEYER, production engineering supervisor, and head, Design and
velopment Department, Carbide & Carbon Chemicals Corp. (K–25), Oak Rid
Tenn.

Dr. E. J. MURPHY, assistant to research director, Oak Ridge National Laborat
Oak Ridge, Tenn.

Dr. G. M. MURPHY, professor of chemistry, New York University, New York, N.

Dr. DANIEL J. PFLAUM, chief, Materials and Information Branch, Division
Research, AEC, Washington, D. C.

Dr. CHARLES SLESSER, director, Technical Information and Declassification Se
ice, AEC, New York, N. Y.

Dr. RALPH CARLILE SMITH, chief, Documentary Division, Los Alamos Scient
Laboratory, Los Alamos, N. Mex.

C. G. STEVENSON, chief librarian, General Electric Co., Richland, Wash.

L. R. THIESMEYER, executive assistant to director, Brookhaven National Labo
tory, Upton, N. Y. (Resignation effective Dec. 31, 1949.)

Dr. R. K. WAKERLING, chief, Information Division, Radiation Laboratory, Ber
ley, Calif.

Dr. H. D. YOUNG, director, Information Division, Argonne National Laborat
Chicago, Ill.

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APPENDIX 3

Major Research Centers of the U. S. Atomic Energy Commission

Ames Laboratory (Iowa State College, contractor)

Ames, Iowa

Director ---------- Dr. F. H. Spedding
Associate Director ---------- Dr. H. A. Wilhelm
Assistant to Director ---------- Dr. E. I. Fulmer

Argonne National Laboratory (University of Chicago, contractor)

Chicago, Ill.

The participating institutions are:

Battelle Memorial Institute
Carnegie Institute of Technology
Case Institute of Technology
Illinois Institute of Technology
Indiana University
Iowa State College
Kansas State College
Loyola University (Chicago, Ill.)
Marquette University
Mayo Foundation
Michigan College of Mining and Technology
Michigan State College
Northwestern University
University of Missouri
University of Nebraska
University of Pittsburgh
Notre Dame University
Ohio State University
Oklahoma Agricultural and Mechanical College
Purdue University
St. Louis University
University of Chicago
University of Cincinnati
University of Illinois
University of Iowa
University of Kansas
University of Michigan
University of Minnesota
University of Wisconsin
Washington University (St. Louis, Mo.)
Western Reserve University

Director ---------- Dr. Walter H. Zinn
Deputy Director ---------- Dr. Norman Hilberry

Brookhaven National Laboratory (Associated Universities, Inc., contractor)

Upton, Long Island, N. Y.

The participating institutions are:

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

Director ---------- Dr. L. J. Haworth

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Knolls Atomic Power Laboratory (General Electric Co., contractor)

Schenectady, N. Y.

Director—Dr. K. H. KINGDON
Associate Head—Dr. HARVEY BROOKS

Los Alamos Scientific Laboratory (University of California, contractor)

Santa Fe, N. Mex.

Director—Dr. NORRIS E. BRADBURY
Technical Associate Director—Dr. JOHN H. MANLEY
Administrative Associate Director—ROBERT M. KIMBALL

Mound Laboratory (Monsanto Chemical Co., contractor)

Miamisburg, Ohio

Director—Dr. M. M. HARING
Assistant Director—Dr. JOSEPH J. BURBAGE
Assistant Director—Dr. ROBERT A. STANIFORTH
Executive Director—PRESCOTT SANDIDGE

Oak Ridge Institute of Nuclear Studies (contractor)

Oak Ridge, Tenn.

The sponsoring universities of the Institute are:

Alabama Polytechnic Institute	University of Arkansas
Catholic University of America	University of Florida
Duke University	University of Georgia
Emory University	University of Kentucky
Georgia Institute of Technology	University of Louisville
Louisiana State University	University of Mississippi
Mississippi State College	University of North Carolina
North Carolina State College	University of Oklahoma
Rice Institute	University of Tennessee
Tulane University of Louisiana	University of Texas
Virginia Polytechnic Institute	University of Virginia
University of Alabama	Vanderbilt University

Chairman of Council—(Vacant)
Vice Chairman of Council—Dr. LOUIS A. PARDUE (Act. chairman)
President of Institute—Dr. PAUL M. GROSS
Vice President of Institute—Dr. C. W. BEAMS
Executive Director of Institute—Dr. WILLIAM G. POLLARD

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Oak Ridge National Laboratory (Carbide & Carbon Chemicals Corp., contractor)

Oak Ridge, Tenn.

Director ..... Dr. C. E. Larson
Executive Director ..... S. C. Barnett
Research Director ..... Dr. A. M. Weinberg

Radiation Laboratory (University of California, contractor)

Berkeley, Calif.

Director ..... Dr. E. O. Lawrence
Associate Director ..... Dr. Donald Cooksey

Donner Laboratory of Medical Physics (Radiation Laboratory)

Berkeley, Calif.

Director ..... Dr. J. H. Lawrence
Assistant Director ..... Dr. Hardin Jones

Crocker Laboratory—Medical Physics (Radiation Laboratory)

Berkeley, Calif.

Director ..... Dr. Joseph G. Hamilton

Reactor Testing Station

Idaho Falls, Idaho

Manager, Idaho Operations Office ..... L. E. Johnston
Assistant Manager ..... W. C. Funk

Rochester Atomic Energy Project (Rochester University, contractor)

Rochester, N. Y.

Director ..... Dr. H. A. Blair
Business Manager ..... C. M. Jarvis

Sandia Laboratory (Sandia Corp., subsidiary of Western Electric Co., contractor)

Sandia Base, Albuquerque, N. Mex.

President ..... George A. Landry
Vice President ..... F. Schmidt

Westinghouse Electric Corp., Atomic Power Division (contractor)

Pittsburgh, Pa.

Manager, Westinghouse Atomic Power Division ..... C. H. Weaver
Technical Director ..... Dr. Charles M. Slack

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APPENDIX 4

Distribution of Isotopes From Isotopes Division

OAK RIDGE, TENN.

DOMESTIC	NUMBER OF SHIPMENTS				
	Aug. 2, 1946, to June 30, 1947	July 1, 1947, to June 30, 1948	July 1, 1948, to June 30, 1949	July 1, 1949, to Dec. 31, 1949	Total to Dec. 31, 1949
Shipments classified by broad field of utilization:					
Radioactive Isotopes:					
Medical Therapy	407	884	1,564	1,128	
Animal Physiology	280	712	890	509	
Physics	82	175	271	140	
Chemistry	74	188	254	102	
Plant Physiology	49	107	195	84	
Industrial Research	42	68	135	81	
Bacteriology	11	53	79	30	
Other	----------	4	187	127	
Total	945	2,191	3,575	2,201	
Stable Isotopes:					
Physics	27	175	245	167	
Chemistry	12	69	68	37	
Animal Physiology	16	35	33	19	
Industrial Research	----------	21	4	2	
Plant Physiology	----------	5	9	2	
Bacteriology	----------	2	4	----------	
Other	----------	----------	6	----------	
Total	55	307	369	227	
Shipments classified by kind of Isotope:					
Radioactive Isotopes:					
Iodine 131	276	741	1,213	848	
Phosphorus 32	260	747	1,221	678	
Carbon 14	88	134	148	101	
Sodium 24	32	113	152	132	
Sulfur 35	31	35	89	45	
Gold 198, 199	63	23	39	9	
Calcium 45	22	40	55	31	
Iron 55, 59	26	34	48	25	
Cobalt 60	24	22	55	29	
Potassium 42	23	24	53	36	
Strontium 89, 90	7	15	17	10	
Other (61)	93	263	485	257	
Total	945	2,191	3,575	2,201	8,912
Stable Isotopes:					
Deuterium oxide (heavy water)	31	115	116	38	
Deuterium (hydrogen 2)	22	97	79	59	
Boron 10 and 11	2	35	32	27	
Oxygen 18	----------	23	17	8	
Electromagnetic concentrated	----------	37	125	95	
Total	55	307	369	227	

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DISTRIBUTION OF ISOTOPES FROM ISOTOPES DIVISION—Continued

DOMESTIC	TOTAL NUMBER OF SHIPMENTS TO DEC. 31, 1949	
	Radioactive	Stable
Shipments classified by State and Territory:		
Alabama	20	1
Arkansas	29	----
California	824	57
Colorado	30	1
Connecticut	170	34
Delaware	26	7
Florida	62	----
Georgia	129	3
Illinois	662	151
Indiana	123	30
Iowa	43	3
Kansas	4	2
Kentucky	32	----
Louisiana	157	5
Maine	2	----
Maryland	543	31
Massachusetts	1,047	102
Michigan	318	23
Minnesota	358	22
Mississippi	4	----
Missouri	306	12
Montana	----	4
Nebraska	73	----
New Jersey	88	28
New Mexico	10	----
New York	1,190	106
North Carolina	100	10
Ohio	639	111
Oklahoma	3	8
Oregon	85	4
Pennsylvania	535	71
Rhode Island	1	1
South Carolina	29	----
Tennessee	247	11
Texas	390	27
Utah	37	2
Virginia	67	2
Washington	74	4
West Virginia	1	1
Wisconsin	258	46
District of Columbia	189	38
Hawaii	7	----
Total	8,912	958

FOREIGN	TOTAL NUMBER OF SHIPMENTS TO DEC. 31, 1949	
	Radioactive	Stable
Shipments classified by country:		
Argentina	44	----
Australia	90	----
Belgium	81	----
Brazil	6	----
Canada	26	----
Colombia	1	----
Cuba	1	----
Denmark	70	----
Egypt	1	----
Finland	3	----
France	23	----
Iceland	2	----
Italy	5	----
Mexico	1	----
Netherlands	35	----
New Zealand	5	----
Norway	32	----
Peru	7	----
Spain	3	----
Sweden	110	----
Switzerland	23	----
Turkey	1	----
Union of South Africa	27	----
United Kingdom:		
Bermuda	14	----
British West Africa	1	----
England	88	----
Total	700	----
Shipments classified by kind of isotope:		
Phosphorus 32	339	----
Iodine 131	169	----
Carbon 14	64	----
Sulfur 35	40	----
Iron 55, 59	30	----
Cobalt 60	18	----
Calcium 45	14	----
Strontium 89, 90	8	----
Other	18	----
Total	700	----

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APPENDIX 5

FELLOWSHIP BOARDS AND AEC FELLOWSHIPS FOR 1949–1950

FELLOWSHIP BOARDS OF THE NATIONAL RESEARCH COUNCIL

Postdoctoral Research in Physical Sciences

Dr. ROGER ADAMS, chairman; professor and head, Department of Chemistry, University of Illinois, Urbana, Ill.

Dr. CARL D. ANDERSON, professor of physics, California Institute of Technology, Pasadena, Calif.

Dr. KENNETH T. BAINBRIDGE, professor of physics, Harvard University, Cambridge, Mass.

Dr. GEORGE GLOCKLER, professor of physical chemistry and head, Department of Chemistry and Chemical Engineering, The State University of Iowa, Iowa City, Iowa.

Dr. WILLIAM W. RUBEY, principal geologist, United States Geological Survey, Washington, D. C.

Postdoctoral Research in Biological and Agricultural Sciences

Dr. R. G. GUSTAVSON, chairman; chancellor, University of Nebraska, Lincoln, Nebr.

Dr. H. K. HARTLINE, professor of biophysics, Johns Hopkins University, Baltimore, Md.

Dr. G. EVELYN HUTCHINSON, professor of zoology, Yale University, New Haven, Conn.

Dr. W. J. ROBBINS, director of the New York Botanical Garden; professor of botany, Columbia University, New York, N. Y.

Dr. L. J. STADLER, professor of field crops, University of Missouri, Columbia, Mo.

Postdoctoral Research in Medical Sciences

Dr. HOMER W. SMITH, chairman; professor of physiology, New York University, Bellevue Medical Center, New York, N. Y.

Dr. PAUL B. BEESON, professor of medicine and chairman, Department of Medicine, Emory University School of Medicine, Atlanta, Ga.

Dr. AUSTIN M. BRUES, director, biology division, Argonne National Laboratory, Chicago, Ill., associate professor of medicine, University of Chicago, Chicago, Ill.

Dr. SAM L. CLARK, professor of anatomy and associate dean, Vanderbilt University School of Medicine, Nashville, Tenn.

Dr. HYMER LOUIS FRIEDELL, professor of radiology, Western Reserve University, Cleveland, Ohio.

Dr. JOSEPH G. HAMILTON, associate professor of experimental medicine and radiology and associate professor of medical physics, Crocker Laboratory, University of California, Berkeley, Calif.

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Predoctoral Research in Physical Sciences

Dr. HENRY A. BARTON, chairman; director, American Institute of Physics, New York, N. Y.
Dr. JOHN C. BAILAR, JR., professor of chemistry, University of Illinois, Urbana, Ill.
Dr. TOM W. BONNER, professor of physics, Rice Institute, Houston, Tex.
Dr. J. WILLIAM BUCHTA, professor of physics and chairman, Department of Physics, University of Minnesota, Minneapolis, Minn.
Dr. G. A. HEDLUND, professor of mathematics, Yale University, New Haven, Conn.
Dr. CHARLES C. PRICE, professor of chemistry and head, Department of Chemistry, University of Notre Dame, Notre Dame, Ind.

Predoctoral Research in Biological Sciences

Dr. DOUGLAS WHITAKER, chairman; professor of biology and dean of graduate study, Stanford University, Palo Alto, Calif.
Dr. ERIC G. BALL, professor of biological chemistry, Harvard University Medical School, Boston, Mass.
Dr. H. BODINE, professor of zoology, The State University of Iowa, Iowa City,

AEC Fellowships in Biological, Physical, and Medical Sciences—Continued

	BIOLOGICAL		PHYSICAL	
	Name	Field	Name	Field
MARYLAND				
Johns Hopkins University, Baltimore.	----------	----------	Shuler, K. E	Theoretical physics.
MASSACHUSETTS				
Harvard University, Cambridge.	----------	----------	Gomer, R	Physical chemistry.
			Koshland, D	Organic chemistry.
			Weisenborn, F. L	Physical chemistry.
Harvard University Medical School, Boston.	Wilcox, P. E	Physical Chemistry.		
Massachusetts General Hospital, Boston.	Stadtman, E. R	Biochemistry.		
Massachusetts Institute of Technology, Boston.	----------	----------	Clapp, R. E	Theoretical physics.
			Goldstein, H	Do.
			Spruch, L	Physics.
New England Deaconess Hospital, Boston.	Holt, M. W	Physiology.		
MISSOURI				
University of Missouri, Columbia.	Barton, D. W	Genetics.		
	Hirshfield, H. I	Zoology.		
NEW JERSEY				
Institute for Advanced Study, Princeton.	----------	----------	Glauber, R. J	Physics.
			Lepore, J. V	Do.
			Slotnick, M	Theoretical physics.
Princeton University, Princeton.	Levedahl, B. H	Biochemistry	Cooke, W. D	Physical chemistry.
			Griffith, W. C	Experimental physics.
NEW YORK				
Columbia University, New York City.	----------	----------	Bersohn, R	Theoretical physics.
Cornell University, Ithaca.	----------	----------	Gluckstern, R. L	Nuclear physics.
			Jungerman, J. A	Theoretical physics.
American Museum of Natural History, New York City.	Clark, E	Genetics and Ecology.		
PENNSYLVANIA				
University of Pittsburgh, Pittsburgh.	Wolken, J	Biophysics.		
WISCONSIN				
University of Wisconsin, Madison.	Potter, R. L	Biochemistry.		
ENGLAND				
University of Cambridge, Cambridge.	Finkle, B. J	do		
SWITZERLAND				
Federal Technical Highschool, Zurich.	----------	----------	Peaslee, D. C	Nuclear physics.

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AEC Fellowships in Biological, Physical, and Medical Sciences—Continued

Postdoctoral (Medical)

	Name	Field
CALIFORNIA		
University of California, Berkeley	Biggs, M. W	Medical physics and biochemistry.
	Elmlinger, P. J	Medical physics.
	Foreman, H	Oncology.
	Huff, R. L	Radiology.
	Masouredis, S. P	Metabolism.
	Palmer, R. F	Pathology.
	Prentice, T. C	Internal Medicine.
	Smith, A. H	Metabolism.
COLORADO		
University of Colorado, Denver	Goodwin, L. D	Biochemistry, physiology.
CONNECTICUT		
Yale University, New Haven	Tait, C. D., Jr	Neurophysiology.
ILLINOIS		
Argonne National Laboratory, Chicago	Arnold, J. S	Internal Medicine.
University of Chicago, Chicago	Finkelstein, P	Proteins and enzyme systems.
	Jennings, F. L	Metabolism.
	Johnson, F. B	Do.
	Redfield, R. R	Protein synthesis.
	Sheline, G. E	Internal Medicine.
	Stevens, K. M	Protein systhesis.
University of Illinois, Urbana	Faraghan, W. G	Cell tissue growth and development.
MARYLAND		
Johns Hopkins Hospital, Baltimore	Athens, J. W	Physiological chemistry.
MASSACHUSETTS		
Harvard University Medical School, Boston	Hoeprich, P. D	Pharmaco-therapeutics.
Massachusetts General Hospital, Boston	Hoffman, M. C	Surgery.
	Keller, E. B	Biochemistry.
	Wight, A	Surgery.
Joseph H. Pratt Diagnostic Hospital, Boston	Raben, M. S	Physiology.
MICHIGAN		
Harper Hospital, Detroit	Birkhill, F. R	Internal Medicine.
MISSOURI		
Washington University, St. Louis	Winkelmann, R. K	Do.
NEW YORK		
Columbia University, New York City	Geary, J. R	Biophysics.
Cornell University, New York City	Kinney, J. M	Surgery.
Sloan-Kettering Institute, New York City	Goldthwait, D. A	Biochemistry.
	Hellman, L. D	Metabolism.
University of Rochester, Rochester	Bly, C. G	Pathology.
	*Colgan, J. W	Radiology.
NORTH CAROLINA		
Bowman-Gray School of Medicine, Winston-Salem.	Aikawa, J. K	Infectious Diseases.
Duke University, Durham	Sinskey, R. M	Ophthalmology and Otolaryngology.
	Wrenn, F. R., Jr	Surgery.
OHIO		
Western Reserve University, Cleveland	Levine, S	Metabolism of fungi and bacterial physiology.
	Powell, C. P., Jr	Metabolism.
OREGON		
University of Oregon Medical School, Portland.	Cathey, W. J	Medicine.
	Hutchens, T. T	Physiology.

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AEC Fellowships in Biological, Physical, and Medical Sciences—Continued

	Name	Field
PENNSYLVANIA		
University of Pennsylvania, Philadelphia	Weed, L. L.	Medicine.
TENNESSEE		
Vanderbilt University, Nashville	Coniglio, J. G.	Medical biochemistry.
UTAH		
University of Utah, Salt Lake City	Chase, M. S.	Hematology.

Predoctoral (Biological and Physical)

	BIOLOGICAL		PHYSICAL	
	Name	Field	Name	Field
CALIFORNIA				
University of California, Berkeley.	Baer, B. S.	Bacteriology.	Hayward, R. W.	Physics.
	Falkenheim, M.	Biophysics.	Vaught, R. L.	Mathematics.
	Forker, L. L.	Physiology.		
	Goldberg, R. C.	do.		
	Hendrickson, J. R.	Zoology.		
	Ingraham, J.	Microbiology.		
	Petersen, B. S.	Physiology.		
	Sleeper, B. P.	Bacteriology.		
	Stepka, W.	Plant Nutrition.		
University of California, Los Angeles.	Levine, R. P.	Botany.	Sachs, D. C.	Physics.
California Institute of Technology, Pasadena.	Bowen, G. H. Jr.	Biophysics.	Duncan, D. B.	Do.
			Jones, L. H.	Chemistry.
	Clayton, R. K.	Biophysics.	Thomas, R. G.	Physics.
	Haskins, F. A.	Biochemical Genetics.		
	Kurtz, E. B.	Botany.		
	Lindsley, D. L., Jr.	Genetics.		
	McKee, J. W.	Radiological Physics.		
Stanford University, Palo Alto.	Bachmann, B. J.	Biology.	Heffner, H.	Electrical Engineering.
	Bergheim, J. M.	Biochemistry.	Wangsness, R. K.	Physics.
	Christensen, E.	Physiology.		
	Funkhouser, J. W.	Biology.		
	Yocum, C. S.	Biology.		
COLORADO				
University of Colorado, Boulder.	Heaney, R. J.	Biochemistry.		
CONNECTICUT				
Yale University, New Haven.	Astrachan, L.	Physiological Chemistry.	Green, L. W.	Mathematics.
			Schenkman, E. V.	Do.
	Dowmont, Y. P.	Biochemistry.		
	Morowitz, H. J.	Biophysics.		
	Rubin, B.	Pharmacology.		
	Share, L.	Physiology.		
DELAWARE				
University of Delaware, Newark.	----------	----------	Keyes, J. J.	Chemical Engineering.
FLORIDA				
University of Florida	Kulwich, R.	Animal Industry.		

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AEC Fellowships in Biological, Physical, and Medical Sciences—Continued

	BIOLOGICAL		PHYSICAL	
	Name	Field	Name	Field
ILLINOIS				
University of Chicago, Chicago.	Bryant, S. H.	Biophysics	Bengelsdorf, I. S.	Chemistry.
	Conn, E. E.	Biochemistry	Bloom, S. D.	Physics.
	Ferguson, M. L.	Botany	Chupka, W. A.	Chemistry.
	Ganz, A.	Pharmacology	Davis, S. G.	Do.
	Kantner, H. H.	Biophysics	Dye, H. A.	Mathematics.
	Sacher, G. A.	Physiology	Greenman, N. N.	Geology.
	Victoreen, H. T.	do	Griffin, E. L.	Mathematics.
			Halperin, J.	Chemistry.
			Hartzler, A. J.	Physics.
			Kadison, R. V.	Mathematics.
			Kalkstein, M.	Chemistry.
			Leighton, M. W.	Geology.
			Martin, R. L.	Physics.
			McNeer, R. M.	Chemistry.
			Miller, C. E.	Mathematics.
			Montet, G. L.	Chemistry.
			Newlander, A.	Mathematics.
			Osterbrock, D.	Astronomy.
			Price, C. M.	Mathematics.
			Ratner, H.	Chemistry.
			Reed, G. W.	Do.
			Shapiro, A. S.	Mathematics.
			Steinberger, R.	Chemistry.
			Uhlir, A.	Physics.
			Weiner, L. M.	Mathematics.
			Weiser, D. W.	Physical Chemistry.
			Williams, E. S.	Mathemtics.
University of Illinois, Urbana.	Koeppe, R. E.	Biochemistry	Bannister, R. G.	Chemistry.
	McCormick, M. H.	do	Crawford, J. V.	Do.
	Sallach, H. J.	do	Dalton, R.	Do.
	Spencer, W. F.	Agronomy	Diven, B. C.	Physics.
			Dressel, R. W.	Do.
			Englund, B. E.	Chemistry.
			Klema, E. D.	Physics.
			Livesay, G. R.	Mathematics.
			Lloyd, S. P.	Physics.
			McClelland, A.	Chemistry.
			Newell, G. F.	Physics.
			Poos, G. I.	Chemistry.
			Saur, A. J.	Physics.
			Schaap, W. B.	Chemistry.
			Segall, B.	Physics.
			Steuber, W.	Do.
			Stump, R.	Do.
			Zimmerman, E. J.	Do.
Northwestern University, Evanston.			Rosenberg, R. M.	Chemistry.
INDIANA				
University of Indiana, Bloomington.	Feldman, L. I.	Bacteriology	Bruner, J. A.	Physics.
	Watson, J. D.	do	Fatora, F. C.	Chemistry.
Notre Dame University, Notre Dame.			Kirk, P. F.	Do.
			Merts, E. C.	Do.
			Michel, R. H.	Do.
			Noyes, J. C.	Physics.
			Schillinger, E. J.	Do.
			Schwarz, H. A.	Chemistry.
			Struble, R. A.	Mathematics.
			Volland, E. E.	Chemistry.
			Wolicki, E. J.	Physics.
Purdue University, Lafayette.	Garner, H. R.	Bacteriology and Biochemistry.	Harris, R. H.	Chemistry.
			Johannesen, R. B.	Do.
			Teitelbaum, C. L.	Do.
IOWA				
State University of Iowa, Iowa City.			Holland, R. E.	Physics.
			Malmberg, P. R.	Do.
			Nelson, B. K.	Do.

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AEC Fellowships in Biological, Physical, and Medical Sciences—Continued

	BIOLOGICAL		PHYSICAL	
	Name	Field	Name	Field
LOUISIANA				
Tulane University, New Orleans.			Ellis, J. W	Mathema
Louisiana State University, New Orleans.	Krebs, J. S	Pharmacology.		
MARYLAND				
University of Maryland, College Park.			Matsuda, K	Chemistry.
Johns Hopkins University, Baltimore.	Fitzhugh, R	Biophysics	Shapiro, G	Mathemati
	Goodgal, S. H	RadiationBiology		
	Greengard, P	Biophysics.		
	Nisonoff, A	Biochemistry.		
MASSACHUSETTS				
Harvard University, Cambridge.	Dietlein, L. F	Zoology	Aronson, R. F	Physics.
	Rennels, E. G	Biology	Bodansky, D	Do.
	Richards, F. M	Physical Chemistry.	Conroy, H	Chemistry.
	Ryther, J. H	Biology	Corley, R. S	Do.
	Savat, R. S	Physical Chemistry.	Ford, G. C	Physics.
	Schneiderman H. A.	Biology	Keilson, J	Do.
	Smith, T. C	do	Klein, A	Do.
	Travis, D	do	Kolsky, H. G	Do.
	Woodland, J. T	do	Landauer, R	Do.
			Lazarus, R. B	Do.
			Mottelson, B. R	Do.
			Okrent, D	Do.
			Ordway, G. L	Chemistry.
			Richardson, J. M	Physics.
			Sirvetz, M. H	Chemistry.
			Storer, J. E	English & Physics.
			Van Tamelen, E	Chemistry.
			Wolfsohn, N. Z	Mathemati
			Brettler, B. J	Mechanical
Massachusetts Institute of Technology, Cambridge.	McCulloch, D	Biology	Devaney, J. J	Physics.
	O'Meara, J. P	Food Technology.		
			Geller, L	Mathemati
			Gell-Mann, M	Physics.
			Goldring, L. S	Chemistry.
			Malm, R. E	Physics.
			Marshall, J. H	Do.
			O'Neill, B	Mathemati
			Pease, R. L	Physics.
			Plank, H. F	Chemistry.
			Rorschach, R. L	Chem. Eng
			Sagalyn, P	Physics.
			Sanford, J. K	Chemistry.
			Sangster, R. C	Do.
			Schweinler, H. C	Physics.
			Secrest, E. L	Do.
			Shapiro, M	Do.
			Stelson, P. H	Do.
Boston University, Boston.	Wilson, M. E	Biochemistry.		
MICHIGAN				
University of Michigan, Ann Arbor.	Pieczur, E. A	Botany	Brafman, F	Mathemati
			Briggs, C. F	Do.
			Frye, G. M	Physics.
			Moy, S. T. C	Mathemati
			Nemerever, W. J	Do.
			Schamp, H. W	Physics.
			Shreffler, R. G	Do.
			Tyner, D. A	Chemistry.
			Wahr, J. C	Physics.
Michigan State College, Lansing.	Silva, H	do		
Wayne University, Detroit.			Golden, H. R	Chemistry.

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AEC Fellowships in Biological, Physical, and Medical Sciences—Continued

	BIOLOGICAL		PHYSICAL	
	Name	Field	Name	Field
MINNESOTA				
University of Minnesota, Minneapolis.	Sandhaus, S.	Radiological Physics.	Kelber, C.	Physics.
	Schuster, D. H.	do	Leland, W. T.	Do.
	Thompson, A. M.	Physiology	Robbins, H.	Do.
	Van Norman, R. W.	Botany.		
University of Missouri, Columbia.	Barnhart, M. I.	Zoology.		
	Barton, J.	do		
	Farnsworth, M. W.	do		
	MacEwan, A. M.	Botany.		
	Zarudnaya, K. I.	Genetics.		
St. Louis University, St. Louis.	Buehler, H. J.	Biochemistry.		
Washington University, St. Louis.			Cleland, M. R.	Do.
			Heller, W. R.	Do.
			Townsend, J.	Do.
NEBRASKA				
University of Nebraska, Omaha.	Pittenger, T. H.	Agronomy.		
	Schmidt, J. W.	do		
NEW JERSEY				
Princeton University, Princeton.			Ehrman, J. B.	Do.
			Fennell, J. P.	Mathematics.
			Ferrell, R. A.	Physics.
			Nash, J. F.	Mathematics.
			Peisakoff, M. P.	Do.
			Pond, T. A.	Physics.
			Smith, A. W.	Chemistry.
			Wilets, L.	Physics.
Rutgers University, New Brunswick.			Gray, S.	Do.
NEW YORK				
Columbia University, New York City.	Hill, R. F.	Biophysics	Aurora, S.	Mathematics.
	Korman, S.	Biochemistry	Brown, R. H.	Do.
	McClement, P.	Biophysics	Heller, A.	Do.
	McMaster, R. D.	Zoology	Lepson, B.	Do.
	Miller, H. K.	Biochemistry	Rosen, J. B.	Chemical Engineering.
	Prescott, B. A.	do	Steinhardt, F.	Mathematics.
	Waronson, S.	Biology	Weneser, J.	Physics.
Cornell University, Ithaca.			Camac, M.	Do.
			Goldberg, S.	Mathematics.
			Keck, J. C.	Physics.
			McCoy, R. E.	Chemistry.
			Peshkin, M.	Nuclear Physics.
			Shapiro, A. M.	Physics.
Fordham University, New York City.			Cerwonka, E.	Chemistry.
New York University, New York City.	Aaronson, S.	Biology	Berezin, E.	Physics.
	Schiffman, G.	Biochemistry	Jaffe, B. M.	Do.
	Slobodiansky, E.	do		
Polytechnic Institute of Brooklyn.	Ekstein, D. M.	Biophysics	Held, K. M.	Chemistry.
Radcliffe College, New York City.	Twarog, B.	Biology.		
Rensselaer Polytechnic Institute, Troy.			Gier, T. F.	Chemical Engineering.
University of Rochester, Rochester.	Angleton, G. M.	Radiological Physics.	Auerbach, T.	Physics.
	Bair, W. J.	do	Perry, A. M.	Do.
			Reynolds, H. L.	Do.
	Barker, R. F.	do	Rouvina, J.	Do.
	Barr, I. A.	do	Tamor, S.	Do.
	Black, S. C.	do		
	Breckenridge, B. M.	Physiology.		
	Cool, W. S.	Radiological Physics.		

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AEC Fellowship in Biological, Physical, and Medical Sciences—Continued

	BIOLOGICAL		PHYSICAL	
	Name	Field	Name	Field
University of Rochester, Rochester—Con.	Gallimore, J. C.	Radiological Physics.		
	Grace, J. L.	Physiology.		
	Kanwisher, J. W.	Biophysics.		
	Levinskas, F. G. J.	Pharmacology.		
	Millar, F. K.	Biophysics.		
	Morken, D. A.	Radiological Physics.		
	Richmond, J. E.	Health Physics.		
	Rouser, G. L.	Biochemistry.		
	Shandley, P. D.	Radiological Physics.		
	Simon, G.	do.		
	Thomas, L. R.	do.		
	Watanabe, T.	do.		
NORTH CAROLINA				
Duke University, Durham.	Anderson, N. G.	Zoology	Goad, W. B.	Physics.
	Cohn, D. V.	Biochemistry.		
University of North Carolina, Chapel Hill.	----	----	Albenesius, E. L.	Chemistry.
			Hayes, R. L.	Do.
OHIO				
Ohio State University, Columbus.	Garvey, J. S.	Bacteriology	Grove, G. R.	Physics.
	Madison, M. C. R.	Zoology	Hochwalt, C. A.	Chemistry.
			Sheriff, R. E.	Physics.
	Wood, D. L.	Biophysics.		
Case Institute of Technology, Cleveland.	----	----	Fawcett, S. L.	Do.
PENNSYLVANIA				
Carnegie Institute of Technology, Pittsburgh.	----	----	Achter, M. R.	Metallurgical engineering.
			Blewitt, T. H.	Physics.
			Hinman, G. W.	Do.
			Opinsky, A. J.	Metallurgical engineering.
			Pearlstein, E. A.	Physics.
University of Pennsylvania, Philadelphia.	Kerschner, J.	Zoology	Ferguson, G. A.	Do.
	Vincent, W. S.	do	Sherard, G. W.	Do.
University of Pittsburgh, Pittsburgh.	Cartwright, T. E., Jr.	Biophysics.		
Pennsylvania State College, State College.	----	----	Lowrie, R. E.	Metallurgy.
RHODE ISLAND				
Brown University, Providence.	----	----	Brown, N. L.	Chemistry.
			Crowell, A. D.	Physics.
			Moore, E. F.	Mathematics.
			Schwartz, B. L.	Do.
TENNESSEE				
Oak Ridge National Laboratory, Oak Ridge.	Bernard, S. R.	Radiological Physics.		
	Bradley, F. J.	do.		
	Brodsky, A.	do.		
	Buck, F. W.	do.		
	Byrom, J. P.	do.		
	Cember, H.	do.		
	Emerson, L. C.	do.		
	Rogers, L. R.	do.		
	Sanders, S. M.	do.		
	Sodaro, R. M.	do.		
	Warren, W. V.	do.		
University of Tennessee, Memphis.	----	----	Harrison, W. B.	Chemical Eng.

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AEC Fellowship in Biological, Physical, and Medical Sciences—Continued

	BIOLOGICAL		PHYSICAL	
	Name	Field	Name	Field
TEXAS				
Rice Institute, Houston	----------	----------	Terrell, N. J.	Physics.
WASHINGTON				
State College of Washington, Pullman.	Rediske, J. H.	Botany.		
University of Washington, Seattle.	----------	----------	Potter, D. S.	Do.
WISCONSIN				
University of Wisconsin, Madison.	Copenhaver, J. H., Jr.	Zoology	Adair, R. K.	Do.
			Adams, E. N.	Do.
	Yates, R. C.	Biology	Austern, N.	Do.
			Rice, W. E.	Chemistry.
			Willeford, B. R.	Do.
CANADA				
McGill University, Montreal.	Greulich, R.	Anatomy.		

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APPENDIX 6

Research Contracts and Guide for Contract Application

Current AEC Unclassified Contracts for Physical Research [1]

Chemistry

Columbia University: V. LaMer, Filtration of Aerosols; T. I. Taylor, Separation of Isotopes by Chemical Exchange.

Illinois Institute of Technology: H. Gunning, Studies of the Decomposition of Organic Molecules by Metal-Photosensitization; M. Kilpatrick, Basic Chemistry of Ruthenium.

Oregon State College: T. H. Norris and J. Huston, A Study of Generalized and Base Phenomena with Radioactive Tracers; J. Schulein, Separation of Deuterium from Hydrogen by Means of Zirconium Metal.

Rensselaer Polytechnic Institute: L. G. Bassett, Fundamental Investigation of the Mechanism of Solvent Extraction of Inorganic Ions.

Washington State College: H. Dodgen, The Formulae and Stability of Complex Ions in Solution; M. Lindner, Stationary States of Light Nuclei through a Search for Several Unknown Isotopes.

University of Arkansas: R. Edwards, Chemical Effects of Nuclear Transformation.

University of California: J. Hildebrand, Studies in Intermolecular Forces and Solubility.

University of Kansas: J. Maloney, The Application of Radioactive Tracers to the Design of Distillation Columns Separating Multicomponent Mixtures.

University of Notre Dame: M. Burton, Research in Radiation Chemistry; M. Burton, Purchase and Installation of 2 Mev Van de Graaff Generator.

University of Pittsburgh: R. Levine, Synthesis of Beta-diketones and Beta-Ketoesters with Heterocyclic Nuclei.

University of Rochester: E. Wiig, Radiochemistry.

University of Wisconsin: F. Daniels, Thermoluminescence in Crystals; J. Willard, Application of Radioactive Tracers.

Mathematics

Harvard University: H. Aiken, Operation of the Aiken Mark I Computer.

Institute for Advanced Study: J. R. Oppenheimer, Applied Mathematics and Theoretical Physics; J. von Neumann, Development of High Speed Electronic Digital Computer.[2]

[1] December 1, 1949.

[2] Joint project with Department of Defense administered under contract with the Army Ordnance Department.

Kenyon College: O. M. Nikodym, Hilbert Space.

University of Tennessee: W. Givens, Algebraic Applications of Canonical Matrices.[3]

Metallurgy

Alfred University: C. R. Amberg and V. D. Frechette, Phase Relations of Metal-Ceramic Combinations.[3]

Carnegie Institute of Technology: R. S. Smoluchowski, Grain Boundaries and Lattice Imperfections; J. C. Warner and D. W. McKinney, Fundamental Research on Corrosion of Metals and Alloys; J. C. Warner and P. Fugassi, Thermodynamic Properties of Binary Alloy Systems.

Columbia University: C. Bonilla, Heat Transfer to Molten Metals.

General Electric Company: J. D. Nisbet, Development of Special Alloys; J. H. Hollomon, Fundamental Metallurgical Research.

Massachusetts Institute of Technology: J. Chipman and G. Scatchard, Thermodynamics of Metal Solutions; M. Cohen, Solid Solutions and Grain Boundaries; A. M. Gaudin, Tracer Techniques in Mineral Engineering; F. H. Norton, Development of a Method for Measuring the Thermal Conductivity of Refractory Materials at High Temperatures and on Relatively Small Specimens.

Sylvania Electric Products, Inc.: W. E. Kingston, Self-Diffusion and High Temperature Phenomena.

University of Pittsburgh: W. Wallace, Thermochemistry of Alloys.

University of California: E. R. Parker, Creep of Alloys.

Physics

American Institute of Physics: H. A. Barton, Heavy Nuclear Particles.[3]

California Institute of Technology: C. D. Anderson, Cloud Chamber Cosmic Ray Studies;[3] J. DuMond, Gamma Ray Spectroscopy;[3] W. A. Fowler, Proton and Deuteron Reactions in Light Nuclei;[3] W. R. Smythe, Measurement of Energy-Mass Ratio.[3]

Carnegie Institute of Technology: E. C. Creutz, Construction of 145-inch Cyclotron.[3]

Case Institute of Technology: R. S. Shankland and E. F. Shrader, Research with Betatron.

Catholic University: F. L. Talbott, Reactions in Light Nuclei.[3]

Columbia University: J. R. Dunning, Research Using 170-inch Cyclotron;[3] J. R. Dunning, Neutron Cross-Section Measurements.

Cornell University: R. R. Wilson, Research Using 300 Mev Synchrotron.[3]

Duke University: W. M. Nielsen, Cosmic Ray Studies.[3]

Franklin Institute: W. F. G. Swann, Research on Energy Levels, Counters, and Cosmic Ray Studies.[3]

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[3] Contracts administered through Office of Naval Research, Washington, D. C.

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General Electric Co.: H. C. Pollock, 80–Mev Synchrotron;[3] J. W. Lawson, [illegible] ferrous Synchrotron.[3]

Harvard University: N. Ramsey, Cosmic Ray Studies, Nuclear Moments, [illegible] Research Using 95-inch Cyclotron.[3]

Indiana University: A. C. G. Mitchell, Beta and Gamma-Ray Spectros[illegible] Studies.[3]

Johns Hopkins University: G. Dieke, Spectroscopy of Hydrogen Isotopes; D. [illegible] Inglis, Research in the Field of Nuclear Reactions.

Massachusetts Institute of Technology: J. R. Zacharias, Accelerators, Co[illegible] Rays, Radioactivity, and Theoretical Studies.[3]

National Academy of Sciences: R. C. Gibbs, Studies of Radioactivity Standard[illegible]

New York University: S. A. Korff, Cosmic Ray Studies;[3] M. Shamos, Cosmic R[illegible] Studies.[3]

Ohio State University: J. N. Cooper, Nuclear Research with Statitron.[3]

Princeton University: J. A. Wheeler, Cosmic Ray Research;[3] M. G. White, Pro[illegible] Nuclear Reactions.[3]

Purdue University: R. O. Haxby, Research Using 300 Mev Synchrotron;[3] F. [illegible] Rieke, Research Using Linear-Electron Accelerator;[3] E. Bleuler, Nuclear R[illegible] tions in Medium and Heavy Nuclei.[3]

Rice Institute: T. W. Bonner, Studies on Proton, Deuteron, and Neutron R[illegible] tions in Light Nuclei.[3]

Rutgers University: F. G. Dunnington, Studies on Nuclear-Magnetic Mom[illegible]

St. Louis University: A. H. Weber, Investigation of Beta-Decay at Low Energ[illegible]

Stanford University: F. Bloch, Nuclear Moments Studies;[3] E. L. Ginzton, [illegible] velopment of High Power Klystrons for 1 Bev Linear Accelerator.[3]

State College of Washington: G. W. Johnson, Diffusion of Solids.[3]

Syracuse University: Kirt Sitte, Research on Cosmic Rays.

University of California (Berkeley): R. B. Brode, Cosmic Ray Research;[3] (L[illegible] Angeles) J. R. Richardson, High Energy Proton and Range-Energy Experimen[illegible] W. F. Giauque, Low-Temperature Research.[3]

University of Chicago: S. K. Allison, Scattering, Decay Schemes, Nuclear Spec[illegible] Studies;[3] H. L. Anderson, Research Using 170-inch F. M. Cyclotron;[3] M. Sch[illegible] High Altitude Cosmic Ray Studies.[3]

University of Illinois: F. W. Loomis, Betatron, Cyclotron, Neutron, and Ra[illegible] activity Research.[3]

University of Kansas: J. D. Stranathan, Construction of 2.5 Mev Electrost[illegible] Generator.[3]

University of Michigan: J. M. Cork, Beta- and Gamma-Ray Spectra Studi[illegible] W. E. Hazen, Cloud Chamber Cosmic Ray Studies.[3]

[3] Contracts administered through Office of Naval Research, Washington, D. C.

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University of Minnesota: J. T. Tate, Scattering by Light Nuclei;[3] J. T. Tate, Cosmic Ray Research;[3] John Williams, Development of 50 Mev Linear Ion Accelerator.

University of Nebraska: Theodore Jorgensen, Jr., Research on Range-Energy Relation of Slow Ions.

University of Notre Dame: B. Waldman, Research on Nuclear-Energy Levels.[3]

University of Pennsylvania: Foster Nix, Superconductivity of Alloys; W. E. Stephens, Gamma-Ray Studies Using Betatron.[3]

University of Pittsburgh: A. J. Allen, Studies on Beta-Ray Spectra, Magnetic Moments and Slow Neutron Studies.[3]

University of Rochester: G. B. Collins, Research Using 130-inch F. M. Cyclotron.[3]

University of Southern California: C. M. Van Atta, Beta-Ray Spectra Studies.[3]

University of Washington: J. E. Henderson, Cloud Chamber Cosmic Ray Studies;[3] J. E. Henderson and C. L. Utterback, Construction of 60-inch Cyclotron.[3]

University of Wisconsin: W. W. Beeman, Small-Angle Scattering of X-rays;[3] R. G. Herb and H. H. Barschall, Cross Section Measurements; J. O. Hirschfelder, Ultrasonic Research;[4] Robert G. Sachs, Theory of Very Light Nuclei.

Vanderbilt University: Sherwood K. Haynes, Mass Spectrograph Studies.

Washington University: A. L. Hughes, Studies on Radioactivity, Nuclear Spectra Theory;[3] R. D. Sard, Cosmic Ray Research.[3]

Wesleyan University: H. E. Duckworth, Research Using Mass Spectrograph.

Westinghouse Electric Corp.: W. Shoupp, Nuclear Excitation Functions.[3]

Yale University: G. Breit, Nuclear Theory Studies;[3] C. G. Montgomery, Neutron Production Studies;[3] E. C. Pollard, Protron, Neutron, and Coincidence Studies;[3] R. L. Schultz, Design Studies for a Linear Electron Accelerator;[3] W. W. Watson, Studies on Isotope Separation and Related Topics.

GUIDE FOR SUBMITTING PROPOSALS TO U. S. AEC FOR SUPPORT OF RESEARCH PROJECTS

The Atomic Energy Act of 1946 enables the Commission to assist the research programs of universities and other independent research institutions in the United States in certain fields of science related to atomic energy. While projects receiving such assistance must be in areas of scientific research where advancement may be expected to stimulate development of the applications of atomic energy, or to increase the fundamental knowledge in this field, they need not necessarily be directly related to the specific problems which are under study in the various Commission installations.

One type of arrangement which the Commission has adopted for providing such assistance is by direct contract between the Commission and the institution in which the work is to be carried out. Such contracts usually assist in the sup-

[3] Contracts administered through Office of Naval Research, Washington, D. C.
[4] Administered under Navy Department contract with Bureau of Ordnance.

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port of the work of individual scientists whose research projects have been approved by the Commission. In the majority of cases it has been the Atomic Energy Commission's experience that these projects can be conducted without security restrictions.

Proposals for assistance in the support of research projects are usually initiated by the scientist interested in carrying out the work. In most cases the interested scientist discusses such projects informally, either by letter or personal visit if feasible, with some member of the Division of Research (when the project is in the physical sciences) or the Division of Biology and Medicine (when the project is in the biological or medical sciences). If, on the basis of preliminary discussions, the project appears eligible for consideration by the Commission, then a formal proposal is submitted. Formal proposals should cover the following points insofar as they are applicable:

1. *Scope and present status.* This should include a statement of the work to be undertaken, its relation to the present state of knowledge in the field and to related work in progress elsewhere. References to the literature should be given, if appropriate.

2. *Scientific motivation.* This should include the reasons for undertaking the project and the potential scientific significance of the results.

3. *Materials, equipment, and facilities.* This should cover all items required to carry out the project with a clear statement of which are already available and which will have to be procured.

4. *Scientific personnel.* This should cover the scientific investigators who will work on the project with brief statements of their research experience and publications. If the proposal calls for employing additional scientific personnel this should be clearly stated. Reprints of articles relating to the project and published by individuals proposing to participate in it, will be welcomed.

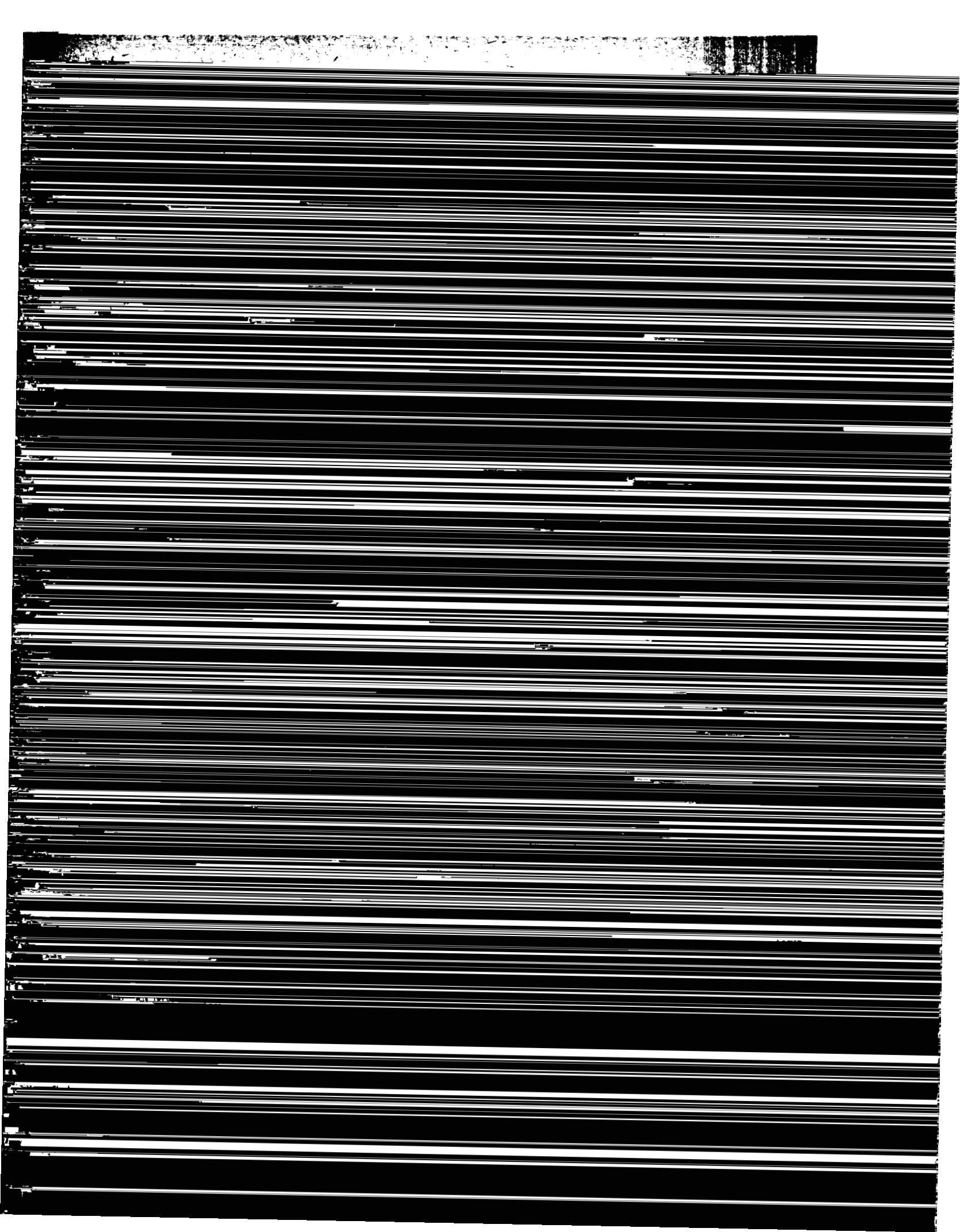
5. *Proposed budget.* This should give a realistic estimate of the total cost of the project and should not be limited to the items which it is proposed that the Commission will pay for. (Items to which it is difficult to assign a cash value or cost should be listed without giving a dollar estimate.) The budget should itemize salaries and major items of capital equipment and should include such items as expendable equipment, communication, travel, etc. The proposed duration of the project should be stated but the budget should be prepared on an annual or monthly basis.

6. *Proposed division of support.* The items which it is proposed that the institution will furnish, those that the Commission would pay for, and those to be obtained from other sources, should be designated.

7. *Other responsibilities of investigators.* A specific statement should be included of all other financial support for the investigations of the scientists involved in this proposal. This should include all other projects which involve these persons, whether supported by the institution or outside sources and should clearly indicate where Federal Government funds are involved. More general information as to the approximate financial picture for the research of the entire department should also be given.

8. *Administrative information.* Published and other generally available information concerning the institution in which the research is to be carried out is helpful. This may include such items as the latest university catalog, recent financial statements, annual reports of the president and other administrative officers.

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APPENDIX 7

The National Nuclear Energy Series

The National Nuclear Energy Series has been planned as a comprehensive account of the scientific and technical developments resulting from the research work done under the auspices of the AEC and its predecessor, the Manhattan Engineer District. The national laboratories and the major contractor-operated research institutions are preparing integrated accounts of their research results. The printed material currently scheduled for the series will total approximately 110 volumes. The 50 declassified volumes are to be published by the McGraw-Hill Book Co., under contract with Columbia University as the representative for the Atomic Energy Commission and its major research contractors. The 60 classified volumes will be reproduced for limited distribution within the Commission.

The National Nuclear Energy Series developed from plans for technical records of research programs originating more or less simultaneously at the Metallurgical Laboratory in Chicago, the Columbia University-operated laboratories in New York City, University of California Radiation Laboratory, and Los Alamos. These plans date back to 1944, when much basic research had been completed, and some project scientists could give their attention to preparing comprehensive accounts of their results. In November 1945, plans were made to coordinate the writing programs at all the installations to produce a single series covering all aspects of the project.

The declassifiable volumes of the National Nuclear Energy Series will be grouped into eight divisions, as follows:

Division I—Electromagnetic Separation Project
Division II—Gaseous Diffusion Project
Division III—Special Separations Project
Division IV—Plutonium Project
Division V—Los Alamos Project
Division VI—University of Rochester Project
Division VII—Materials Procurement Project
Division VIII—Manhattan Project

To date eleven volumes of the Series have been published. These are:

Histopathology of Irradiation From External and Internal Sources. Edited by William Bloom, M. D.; Division IV, Volume 22I, 808 pages. This is an advanced treatment of the histopathological and cytological effects of total-body irradiation by radioactive agents.

Pharmacology and Toxicology of Uranium Compounds. Edited by Carl Voegtlin and Harold C. Hodge; Division VI, Volume 1, 1,084 pages. A summary of approximately 3 years' work on the toxicity of uranium compounds and the mechanism of uranium poisoning. The book also includes a section on the toxicity of fluorine and hydrogen fluoride.

Engineering Developments in the Gaseous Diffusion Process. Edited by Manson Benedict and Clarke Williams; Division II, Volume 16, 129 pages. This volume sets forth the research and engineering developments pertaining to novel auxiliary devices developed in connection with the gaseous diffusion plant. The work applies principally to special plant instruments, vacuum engineering, development of heat-transfer equipment, and absorption of uranium hexafluoride and fluorine.

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Spectroscopic Properties of Uranium Compounds, by G. H. Dieke and A. B. F. Duncan; Division III, Volume 2, 290 pages. This volume presents a comprehensive correlation of absorption measurements with fluorescence spectra data. New experimental techniques described represent advances in organic chemistry.

Bibliography of Research on Heavy Hydrogen Compounds. Compiled by Alice H. Kimball, edited by Harold C. Urey and Isidore Kirschenbaum; Division III, Volume 4C, 350 pages. A compilation of about 2,000 references to published documents dealing with research on the heavy hydrogen isotopes is given in this book. As a bibliography of such research, the volume constitutes a useful tool for the scientist interested in isotope research.

Ionization Chambers and Counters: Experimental Techniques, by Bruno Rossi and Hans Staub; Division V, Volume 2, 243 pages. The volume discusses the modern principles of ionization chambers and counters, and presents details of a number of detectors developed and used at the Los Alamos Scientific Laboratory for the study of different kinds of radiation.

Electronics: Experimental Techniques, by W. C. Elmore and Matthew L. Sands; Division V, Volume 1, 417 pages. As a description of the most useful circuits for making nuclear and other physical measurements, this volume constitutes a manual of the circuit elements and complete circuits for electronic instruments.

The Transuranium Elements—Research Papers. Edited by Glenn T. Seaborg, Joseph J. Katz, and W. M. Manning; Division IV, Volume 14B, 1,733 pages. This work consists of over 150 original research papers on the transuranium elements—neptunium, plutonium, americium, and curium—and similar topics. For reference and orientation purposes, a historical discussion of the research work is included.

The Characteristics of Electrical Discharges in Magnetic Fields. Edited by A. Guthrie and R. K. Wakerling; Division I, Volume 5, 376 pages. This volume covers most of the significant studies on the characteristics of electrical discharges in magnetic fields carried on by the University of California Radiation Laboratory in connection with the development and operation of the electromagnetic process for the separation of U 235. Primary emphasis is placed on studies of electrical discharges in the vapors of uranium compounds. The information included is considered to be an important contribution to the understanding of the theory of gaseous discharges.

Vacuum Equipment and Techniques. Edited by A. Guthrie and R. K. Wakerling; Division I, Volume 1, 264 pages. This volume is a compilation of observations made by University of California Radiation Laboratory personnel in the course of developing high vacuum equipment for use in the electromagnetic separation plant. The requirements for routine production and maintenance of high vacuum on a scale never previously undertaken necessitated considerable pioneering work on both equipment and testing.

The Chemistry and Metallurgy of Miscellaneous Materials: Thermodynamics. Edited by Laurence L. Quill; Division IV, Volume 19B, 329 pages. Ten original papers on thermodynamic properties of the elements and several of their compounds are presented in this volume.

The Atomic Energy Commission has received manuscripts for 10 additional volumes of the Series which will be published during 1950 under the following titles:

Pharmacology and Toxicology of Uranium Compounds: Monograph II. Edited by Carl Voegtlin and Harold C. Hodge; Division VI, Volume 2.

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Biological Studies With Polonium, Radium, and Plutonium. Edited by R. M. Fink; Division VI, Volume 3.

Analytical Chemistry of the Manhattan Project. Edited by C. J. Rodden; Division VIII, Volume 1.

Preparation, Properties, and Technology of Fluorine and Organic Fluoro Compounds. Edited by Charles Slesser and Stewart R. Schram; Division VII, Volume 1.

Radio-chemical Studies: The Fission Products. Edited by Charles C. Coryell and Nathan Sugarman; Division IV, Volume 9.

Industrial Medicine. Edited by Robert S. Stone, M. D.; Division IV, Volume 20.

Toxicology of Uranium: Survey and Collected Papers. Edited by Albert Tannenbaum, M. D.; Division IV, Volume 23.

The Chemistry of Uranium. Edited by E. Rabinowitz and J. J. Katz; Division VIII, Volume 5.

Collected Papers on the Chemistry of Uranium. Edited by E. Rabinowitz and J. J. Katz; Division VIII, Volume 6.

Physical Properties of Heavy Water. Edited by Isidore Kirshenbaum; Division III, Volume 4A.

About 30 additional manuscripts for declassified NNES volumes are in an advanced stage of preparation and should be submitted during 1950.

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APPENDIX 8

Report to the President by the Atomic Energy Labor Relations Panel

June 1, 1949 to October 31, 1949

Origin of Panel. The Atomic Energy Labor Relations Panel had its origin in the "Report of the President's Commission on Labor Relations in the Atomic Energy Installations." This report, which was submitted to the President on April 18, 1949, recommended (sec. 5):

That the Atomic Energy Commission establish a Labor Relations Panel of three impartial members appointed by the President from nominations submitted to him by the Commission.

That the Panel be empowered to take jurisdiction of any management-labor dispute which collective bargaining and the normal processes of conciliation have failed to resolve and which threatens to interfere with an essential part of the Atomic Energy program.

The report was signed by William H. Davis, chairman; Aaron Horvitz, and Edwin E. Witte, members; John T. Dunlop, consultant, and Donald B. Straus, executive secretary.

On April 26, 1949, President Truman announced the appointment of William H. Davis as Chairman of the Atomic Energy Labor Relations Panel. In making this appointment, he said:

The establishment of the Panel was recommended by the special commission after a 7 months' study of labor relations in atomic energy installations. I have studied the excellent report of the special commission, and agree with the Atomic Energy Commission that the recommendations in the report should be adopted as a sound means toward preventing and adjusting labor disputes in this important field.

I am confident that labor and management will seek settlement of disputes in atomic installations by voluntary procedures and mutual agreement, and that they will call upon the Panel only as a last resort. Conscientious bargaining and the use of existing conciliation services must minimize the calls upon the Panel, for it can be effective only if its help is seldom sought, and then only in the most difficult cases. It is not and must not be a substitute for collective bargaining.

The Panel will settle only disputes affecting vital operations in atomic plants, impossible to adjust by collective bargaining and through existing conciliation services. The Panel will operate on a part-time basis.

The Panel plan is being adopted for a trial period of 2 to 3 years. It is subject to termination at the discretion of the Atomic Energy Commission.

On June 4, 1949, the President announced the appointment of Aaron Horvitz and Edwin E. Witte, to the other two positions on the Panel, thus repeating on the newly created Panel the original membership of the Commission that prepared the report.

Function of the Panel. The Panel operates according to the policies set forth in the Report to the President on April 18, 1949. It is "empowered to take jurisdiction of any management-labor dispute which collective bargaining and

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the normal processes of conciliation have failed to resolve and which threaten to interfere with an essential part of the atomic energy program." The Panel derives additional authority from the voluntary agreements of contractors and unions in atomic energy installations not to interrupt production or services, or to make without mutual consent changes in the terms and conditions of employment, until after the Panel has had an opportunity either to settle the dispute by mediation or else to make recommendations to the parties and to the Atomic Energy Commission for its settlement. In short, the Panel procedures constitute an additional step in collective bargaining which the parties agree to exhaust. Meanwhile, they put the right to strike or to lock-out in escrow with the Panel.

After a labor dispute has been brought to its attention, the Panel has 15 days in which to determine whether further steps on its part are appropriate. Among the considerations that influence this determination are (1) evidence of sufficient bargaining by the parties themselves, including full use of conciliation and (2) evidence that the dispute involves an essential part of the atomic energy program.

If, in the opinion of the Panel, its procedures are appropriate in the instant dispute, it is understood that the parties will take no overt action that might interfere with the program as long as the Panel is acting on the case.

HISTORY OF CASES

In its first 6 months of existence, the Panel has had four cases submitted to it. The Panel referred one of the cases back to the parties for further bargaining and was instrumental in settling another case before the 15-day period of preliminary investigation had expired. In the two remaining cases, the Panel acted as mediator after first satisfying itself that the dispute threatened "an essential part of the atomic energy program" and that "the available agencies of conciliation" had been fully utilized. Both of these cases were settled in the mediation stage of the Panel procedure, thus obviating the necessity for the Panel to issue recommendations. A summary of these cases follows:

CASE NO. 1—AEC INSTALLATION: *Mound Laboratory*, Miamisburg, Ohio; PARTIES: Monsanto Chemical Co., United Gas, Coke, and Chemical Workers, CIO, Local No. 420.

Background of case. This dispute arose during negotiations over a first contract. The union was certified by a consent election. The certification was dated May 10, 1949. The first meeting of the parties was on May 20, 1949, at which time the union submitted a proposed contract.

At this meeting, the company asked and the union agreed to a postponement of further negotiations until after completion of contract talks between the company and another union covering the guards. But when, by June 3, it became apparent that the guard negotiation would be protracted, meetings were resumed between the company and the Chemical Workers.

The bargaining unit of the Chemical Workers includes 235 skilled and semiskilled workers. Total employment at the Mound Laboratory is 835. All employees outside of the CIO unit, other than guards, are on a salary status. Many of them are trained scientists.

Meetings were held June 7, 8, 14, 15, and 16. By the last date, the parties were in agreement over the bulk of the contract language. Wages, hazard pay, union security, the no-strike clause, shift differentials, and retroactivity were still

together. On June 23, the Federal Mediation and Conciliation Service was called in and a meeting with a commissioner from the Service was held on June 28. Since no appreciable progress was made on that day, on June 29 a letter was sent, signed by both parties, to the Panel asking it to take jurisdiction. After a preliminary investigation of the facts, the Panel officially assumed jurisdiction on July 15.

Issues in dispute at date of panel entrance:

(1) Union Security. The union wanted a union shop. The company refused to grant a union shop on the grounds that it was against company policy and that there was no union shop clause in any other atomic energy labor contract.

(2) Continuity of Operation. The union linked the no-strike clause to the union shop clause, refusing to make a no-strike pledge without assurance of union membership in the unit.

(3) Retroactivity. The union wanted the date of certification to be the retroactive date. The company wanted the new rates to go into effect the day the contract was signed.

(4) Shift Differential. The union wanted shift differentials of 7 cents for the first night shift, 14 cents for the late night shift. The company wouldn't mention any figure until after wage rates were in agreement.

(5) Wages. Company and union had reached agreement on an internal rate structure and job classifications. The wage disagreement was over the total cost of the increase. The last company offer averaged 15.3 cents and the last union demand averaged 22.3 cents, a difference of 7 cents.

Panel mediation. The Panel first met with the parties on July 29. At this meeting it soon became apparent that wages constituted the main obstacle to agreement and that if wages could be settled, the other items would wash out.

On the question of wages, it was also evident, after preliminary discussion, that the basic disagreement was over the facts on area wage rates. Both sides argued that their offer represented a true reflection of the area averages for comparable jobs. At a suggestion of the Panel, the parties agreed to work together on the preparation of a joint report on the area wage rates. For this task, the Panel offered the services of its executive secretary and undertook to secure from the Bureau of Labor Statistics the cooperation of George Vatova of the Chicago BLS office.

Meetings for this purpose were held in Miamisburg on August 2 and 3, and an agreed schedule of area wage rates was prepared.

On August 9, the parties reconvened with the Panel, bringing with them the agreed area wage exhibit. Working from this exhibit, the Panel was able to mediate a wage agreement after an all-day session. In recognition of the agreed area pattern, the company increased its offer. The upward revision was made by adding another progression step to the rates.

The other issues were quickly resolved with the aid of the Panel after the wage agreement was reached. The final settlement was: *Shift differential:* 5 cents and 10 cents. *Union security:* an irrevocable, voluntary checkoff for duration of contract. *Continuity of operation:* a standard no-strike clause. *Retroactivity:* to date when parties asked for Panel intervention.

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CASE NO. 2—AEC INSTALLATION: *Mound Laboratory*, Miamisburg, Ohio; PARTIES: Monsanto Chemical Co.; International Guards Union of America.

Background of case. This dispute arose during negotiations over a first contract. The union was certified on March 23, 1949. The bargaining unit covers all plant guards at the Mound Laboratory. The original certification named Mound Laboratory Patrol, Local No. 1, as the union.

Meetings between the union and company were held on May 4, 10, 11, 17, 18, 19; June 1, 2, 3, 8. By this last date, most of the contract language was in agreement. Wages were still unresolved. The company had made a dual offer of either retention of the 48-hour week at $1.33 per hour (plus, of course, overtime after 40 hours), or $1.40 for a 40-hour week. When this dual offer was presented to the membership, both proposals were voted down. When no progress was made at the June 8 meeting, the parties adjourned without setting a date for further discussions.

Representatives of the Federal Mediation and Conciliation Service were at the Mound Laboratory on June 28 and 29, in connection with another dispute. Through the medium of the Service, another meeting was scheduled for July 5. A series of further postponements occurred and, on July 14, notification was sent to the company by Walter D. Collins, president of the International Guards Union of America, to the effect that the Mound Laboratory Patrol had affiliated with the International. The letter contained a request for a meeting with Mr. Collins acting as the new representative. This request was granted by the company.

The first meeting between the International and the company was held on August 4. No progress was made at this time, and both parties invited the Federal Mediation and Conciliation Service to aid in breaking the deadlock. On August 5, with the aid of a representative of the Service, both sides agreed to consider a compromise rate of $1.43 per hour on a 40-hour schedule and no retroactivity. The only unresolved issue was the duration of the contract. The union wanted a wage reopener after 6 months. The company insisted upon a 1-year contract without a reopener. A compromise suggestion for a contract of approximately 9 months' duration, put forth by the conciliator, was turned down by the union. Both sides then withdrew their final offers and the union sent a letter to the Panel on August 10 requesting that it assume jurisdiction.

Panel mediation. It is the procedure of the Panel to investigate the factual background of a case before actively engaging in its settlement. This preliminary investigation provides the Panel with as complete a "second hand" picture of the dispute as possible before embarking upon actual mediation. It also gives them the facts upon which to determine whether or not to assume jurisdiction.

Ordinarily, this preliminary investigation is made by the Panel's secretary. In this case, a Panel member, Mr. Horvitz, accompanied the Panel secretary on this preliminary investigation. They went to Miamisburg on August 23, where they conferred with both parties—first separately and later jointly.

In the course of the talks, an agreement was reached based largely upon the compromise terms put forward during the August 5 meetings under the aegis of the Conciliation Service. Thus, technically, the Panel never officially participated in mediating this case.

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CASE NO. 3—AEC INSTALLATION: *Oak Ridge National Laboratory* (X–10), Oak Ridge, Tenn.; PARTIES: Carbide & Carbon Chemical Corp.; Atomic Trades and Labor Council, AFL.

Background of case. The relationship between the AFL and the various contractors who have operated the X–10 plant extends back to 1946. The history of this relationship has been complex. The main elements which have produced conflict are the following:

During the war, a differential in favor of the X–10 workers had developed in respect to both wages and fringe benefits.

When Oak Ridge was first opened to union organization, the AFL secured recognition at X–10 and the CIO Chemical Workers won bargaining rights at K–25. At that time, Carbide & Carbon Chemicals Corp. operated the K–25 plant and the Monsanto Chemical Co. was the contractor at X–10. The first contracts that were negotiated covering these two plants continued the differential established during the war years between X–10 and K–25.

In March 1948, the Carbide & Carbon Chemicals Corp. replaced Monsanto as the contractor at X–10. The new management believed that there was no longer justification, based on occupational hazard, for any differential between X–10 and K–25. Accordingly, the company attempted to negotiate identical wages and working conditions for both plants, and chose to follow the pattern established at K–25. This attempt ran into the head-long opposition of the AFL. The resulting deadlock was the cause of a Taft-Hartley injunction. The failure of the parties to reach agreement during the injunction period seriously threatened to interrupt operations at the X–10 plant. The eventual settlement came only after emergency measures were taken by the officials at the very highest levels of government, AFL, and company. All who participated in this experience were in agreement on at least one point: All possible avenues for avoiding a similar crisis in the future should be explored. It was this feeling that led to the appointment of the President's Commission on Labor Relations in Atomic Energy Installations and the eventual establishment of the Panel.

The contract terms of the 1948 agreement largely eliminated the fringe differentials, but left many differences between K–25 and X–10 wage rates.

The contract described above expired on July 1, 1949. Prior to its expiration, 14 negotiating meetings between the union and the company were held. In general, the company continued to pursue its long-range objective of making wages and working conditions identical in the K–25 and X–10 operations, and the union attempted to widen out the differential to its former extent.

While these negotiations were in progress, the company made and negotiated an agreement with the CIO union at the K–25 plant. This agreement embodied an 8 cents across-the-board wage increase.

On June 22, the Conciliation Service entered this dispute and eight meetings were held under its mediation efforts.

Commissioner Clyde Mills, acting for the Conciliation Service, was able to eliminate many of the issues still in dispute. On June 30, the company's last offer included a 7-cent wage increase. This wage offer, however, was not an across-the-board amount, but was rather distributed in such a way as to continue the company policy of narrowing the existing X–10 and K–25 differentials. For individual classifications, this 7-cent offer ran all the way from no increase up to 17 cents.

On July 1, the union sent a telegram to the Panel requesting its intervention. On July 7, a Panel representative made a preliminary investigation of the factual background of the dispute, at which time the union offered 14 further concessions not previously given to the company. These concessions, however,

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did not alter the fundamental issues in dispute. On July 15, the Panel
entered the case.

Involved in this dispute were 674 members of the bargaining unit. The
plant work force was approximately 2,000.

Panel mediation. The first meeting of the Panel with the parties
July 21. At this meeting, the Panel attempted to find a method for
the parties to continue negotiations along an agreed line of procedure.
the union's main arguments for a wage differential was based upon a
diversification of job assignments at the X–10 plant, a claim which was
by the company. It was suggested that a factual analysis of job
might help to resolve this conflict. The parties agreed to make an
to do this.

Accordingly, the parties met on July 26, 27, and 28. On July 29, they
further meeting with Aaron Horvitz, a member of the Panel, acting as
Although the parties failed to agree on a procedure for analyzing job
ments, in the course of these discussions there was a further narrowing
issues in dispute. Many of the fringe benefits were bargained out. In
the union agreed to leave the fringe benefits as they were in the old
which were in general identical to those of K–25. The wage positions
closer together in terms of money, but the union continued adamant in
mand for an across-the-board increase while the company was equally
desire to distribute this increase in such a way as to further iron
differences between K–25 and X–10. These series of meetings termina
the issues thus greatly narrowed.

On August 11, the Panel held a metting with company representatives
plore the possibility of their granting part of the increase across the
the remainder distributed in a manner to further narrow the K–25
differential. The company's reaction to this suggestion was
couraging to warrant the holding of another joint meeting on September

Sufficient progress was made at the September 13 meeting to continue
tions through September 14, 15, and 16. On September 16, an
reached based upon a proposal advanced by the Panel. The settlement
to an average increase of 5 percent. A few exceptions to this rule were
the case of certain crafts which were admittedly out of line with the
tice. These exceptions were more than 5 percent in some cases, less than
in other cases, thus retaining the average of around 5 percent for an
roll cost. This agreement was ratified by the union membership on

CASE NO. 4—AEC INSTALLATION: *Oak Ridge Construction*
PARTIES: Knoxville Building Trades Council, AFL; J. A. Jones
tion Co.

Disposition of case. On August 3, 1949, the Panel received a letter,
J. C. Kerr, business representative of the Knoxville Building Trades
outlining the circumstances of a dispute that threatened to interfere
progress of certain construction projects at Oak Ridge, and requesting
Panel intervene to aid in its settlement.

The Panel noted that this letter was signed by an officer of the local
Section 4b of the Report to the President states:

That, fully recognizing and safeguarding the primary responsibility
representatives for sound and stable relations at each Government-
vately operated atomic energy installation, provision be made for
bear upon the settlement of critical disputes all available experience
sponsibility of individuals at the very highest levels of management

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Accordingly, the Panel felt that this dispute had reached it prematurely. It referred Section 4b, quoted above, to the attention of the local union officers, with the suggestion that additional steps be taken to bargain toward an agreement at a higher level of both union and management. The Panel has received no further correspondence on this matter.

OTHER PANEL ACTIVITIES

On Monday, June 6, 1949, before the Panel was fully established, there was a threatened strike at the K–25 plant operated by Carbide & Carbon Chemicals Corp. at Oak Ridge. Mr. Davis, who was then chairman and the only member of the Panel, sent this telegram to the parties on June 7:

The Atomic Energy Labor Relations Panel is investigating the dispute at Oak Ridge plant K–25 between United Gas Coke & Chemical Workers of America (CIO) and Carbide & Carbon Chemicals Corp. The Panel calls upon you, and is likewise calling upon the corporation, in accordance with your respective pledges to the Atomic Energy Commission, to[1] refrain from any action to interrupt or to impede in any way production or services and to maintain without change in terms and conditions of employment existing when the dispute arose until the dispute is settled by mutual agreement or the Panel announces that it does not intend to take jurisdiction or that it has terminated its jurisdiction. In the meantime the Panel calls upon you to continue responsible collective bargaining and to cooperate fully with representatives of the Federal Mediation and Conciliation Service. If by Monday June 13 agreement has not been reached or if either party thinks negotiations are not proceeding satisfactorily, please report to me through your duly authorized representative at my office, 39 Pine Street, New York City, at 11 a. m., on that day.

WILLIAM H. DAVIS, *Chairman.*

That same day, both parties jointly signed the following telegram and sent it to Mr. Davis:

WILLIAM H. DAVIS,
39 Pine Street,
New York.

We wish to acknowledge receipt of your wire today and would like you to know that both the union and the company are making an earnest and sincere endeavor to achieve a settlement of this dispute ably assisted by the Federal Mediation and Conciliation Service and hope to reach an agreement before midnight Wednesday.

C. E. CENTER, *Carbide & Carbon Chemicals Corp.*
C. W. DANENBURG, *United Chemical Workers (CIO).*

Negotiations continued following this interchange of messages and at midnight, June 8, the 8-cent agreement referred to elsewhere in this report was signed.

The Panel has held several policy meetings in addition to its activities in connection with formal cases. It has met twice in Washington with members of the AEC labor relations staff. On October 18 the chairman attended a meeting of representatives from the labor relations staffs of contractors at Oak Ridge and spoke that evening at a dinner held in his honor. On this trip he was accompanied by the Panel secretary. Various informal meetings have also been held with union representatives.

As the chairman remarked on one occasion: "The Panel does not consider

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[1] In telegram to the contractor this sentence read: "To maintain without change the terms and conditions of employment existing when the dispute arose until the dispute is settled by mutual agreement or the Panel announces that it does not intend to take jurisdiction or that it has terminated its jurisdiction and to refrain from any action to interrupt or to impede in any way production or services."

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itself a fire engine. The whole concept of the Panel is to establish procedures which will give time for rational negotiations. The object is to permit bargaining to take place without the threat of an imminent strike hanging over the heads of those doing the negotiating."

With this purpose in mind, the Panel considers the job of creating a favorable atmosphere for successful collective bargaining to rank equally in importance with its job as a mediation agency.

WILLIAM H. DAVIS, *Chairman.*
AARON HORVITZ, *Member.*
EDWIN E. WITTE, *Member.*

JOHN T. DUNLOP, *Consultant.*
DONALD B. STRAUS, *Executive Secretary.*

NOVEMBER 8, 1949.

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