UNITED STATES ATOMIC ENERGY COMMISSION

Eleventh Semiannual Report

OF THE

ATOMIC ENERGY COMMISSION

January 1952

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

LETTER OF SUBMITTAL

WASHINGTON, D. C.
30 January 1952.

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

Respectfully,

UNITED STATES ATOMIC ENERGY COMMISSION
T. KEITH GLENNAN.
THOMAS E. MURRAY.
H. D. SMYTH.
GORDON DEAN, *Chairman.*

The Honorable
The President of the Senate.
The Honorable
The Speaker of the House of Representatives.

CONTENTS

PART ONE

PART TWO

PART THREE

APPENDICES

Part One

Major Activities in Atomic Energy Programs, July – December 1951

MAJOR ACTIVITIES IN ATOMIC ENERGY PROGRAMS, JULY-DECEMBER 1951

The past 6 months have been a period of intense activity in the Nation's atomic energy program, with three main lines of work proceeding simultaneously.

Existing plants have been operated at full capacity, and the existing research establishments have devoted extraordinary effort to the extension of basic knowledge and the solution of developmental problems in nuclear science and engineering.

At the same time the large expansion of plant, previously authorized, proceeded with 3 percent of the Nation's total building expenditure in the period going to atomic energy facilities, and nearly 2 percent of the Nation's construction force employed on AEC jobs.

Meantime, the Department of Defense and the AEC carried on an intensive study of the feasibility of undertaking a further important expansion of atomic energy production facilities. The report on this study was filed with the Joint Committee earlier this month.

This Eleventh Semiannual Report reviews major developments of the past 6 months in the atomic energy program that can be publicly reported without hazard to the national security. This appears as Part One of the Report. Part Two presents the condensed annual financial report for Fiscal Year 1951.

In Part Three is presented a brief review of developments in plant science research supported by the Atomic Energy Commission as part of its responsibility for determining the effects on all forms of life of the radiant energy released in atomic energy operations of a military, research, or industrial nature. Some results in plant research through the experimental use of radiation have pointed directly or indicatively to improvements in farming practice, and lowered costs of food and fibre production. Guidance for farmers in the application of such findings to their daily work is not the province of AEC research; this guidance is provided by Federal, State, local, and private agricultural authorities.

Major developments of AEC programs during the past 6 months may be summarized as follows:

Deliveries of uranium concentrates from the Belgian Congo and Canada continued according to schedule. Domestic production increased as a result of expanded exploration, higher prices for uranium ores and bonuses for initial production, the opening of new producing areas, and increased processing capacity. Various steps were taken for development of new sources of raw materials here and abroad.

The production of fissionable materials continued to increase with a lowering of unit costs. Unit cost reductions were made in spite of increasing labor and material costs and were the result of continuing improvement in production processes and expanded volume of operations. Construction proceeded on or nearly on schedule at most of the major new production facilities. Valuable time was lost, however, at the Savannah River, S. C., Dana, Ind., and Paducah, Ky., projects. Material shortages and labor disputes were the principal contributors to these delays.

Production of atomic weapons continued in accordance with schedules set by the President. Substantial advances were made in weapon research and development. These advances have been accelerated by the continuing test programs made possible by the activation and use of the Nevada testing site.

Progress toward new types of nuclear reactors for making fissionable materials and producing power for military and industrial purposes was signalized by a number of events. In this period the Experimental Breeder Reactor was put into operation at the Reactor Testing Station in Idaho. Utilizing heat energy produced by this reactor, small amounts of electric power were generated on an experimental basis. The Commission continued with the development of the reactor for the first nuclear-powered submarine, and new industrial contractors were enlisted in the work of developing a nuclear power plant for an aircraft.

The reactor development program is the frontier of a new technology in which American industry is showing a decided interest. The developments during the last 6 months were encouraging in this sector. Two reports resulting from the studies of the four industrial teams who have been appraising the possibilities of industrial participation in the reactor field on a competitive basis were received and are being studied by the Commission. Private industry was asked to undertake, on a competitive basis, the task of supplying AEC with zirconium, a material uniquely suited for reactor structures. Scores of industrial concerns began to take an interest in and to study on their own the possibilities of putting to work the large sources of radiation that now lie fallow in the wastes from reactors.

In August the Community Operations Panel submitted to the Commission its report and recommendations on private property ownership and municipal self-government in Oak Ridge, Tenn., and Richland, Wash., and these were issued to the public of the two communities.

The Commission has had sample appraisals made and will obtain the reaction of the residents before taking definite action. The Panel's report on Los Alamos is not yet completed.

A closer relation between physical research under contract and the immediate aims of the atomic energy program developed during this period. Six particle accelerators for research came into operation and five others were being constructed.

New knowledge was gained on the effects of radiation and an increasing variety of radioactive substances on life processes in man, animals, and plants. Development of methods of protecting people from radiation continued to be one of the major objectives. To better understand the hazards of atomic warfare, studies of the immediate and genetic effects of radiation on living tissues were continued.

In October, the Congress enacted an amendment to section 10, the first major revision of the Atomic Energy Act of 1946. This amendment will permit exchange of certain information with other friendly governments under adequate safeguards where such an exchange can be shown to be beneficial and not prejudicial to the national interest. Other proposed amendments were submitted by the Commission for the consideration of the Joint Committee on Atomic Energy.

Fifty-seven licenses were issued to industry to use the patents owned by the Commission. The Patent Compensation Board made its first award on a patent.

On December 15, 1951, Sumner T. Pike resigned as Commissioner. He was one of the original five commissioners of the AEC, and had served for slightly more than 5 years.

In the staff, Thomas F. Farrell was appointed an Assistant General Manager to coordinate and direct manufacturing programs of the AEC. Dr. Manson Benedict, on leave from his position as professor of chemical engineering at Massachusetts Institute of Technology developed a small Operations Analysis Staff for the General Manager.

Brigadier General James McCormack, Jr., who had been the Director of Military Application since the establishment of the Atomic Energy Commission, completed his tour of duty with the Commission in August 1951. Col. Kenneth E. Fields, Corps of Engineers, was appointed in his place. Colonel Fields had previously been associated with the atomic energy program both under the Manhattan Engineer District and later with the Commission.

In October Dr. Thomas H. Johnson, formerly chairman of the Physics Department at Brookhaven National Laboratory, was appointed Director of Research.

Raw Materials

Deliveries of uranium concentrates to the U. S. Atomic Energy Commission from the Belgian Congo and Canada during the past 6 months continued according to schedule. Domestic production in creased as a result of the expanded exploratory drilling program, higher prices for uranium ores, the bonus for initial production from domestic mines (effective March 1, 1951),[1] the opening of new producing areas, and increased processing capacity.

In South Africa construction of plants to recover uranium from gold ore residues is proceeding on schedule.

In Canada Eldorado Mining and Refining (1944) Ltd., has announced that at Beaverlodge, in northwestern Saskatchewan, construction of a mill to treat ores of the Lake Athabaska region will soon be started. Plant design is already well along and construction and installation will proceed through next summer.

In the domestic program, development of mining properties was stimulated and accelerated as a result of the bonus for initial production which was announced early in 1951. More than $200,000 in bonus payments had been made by November 30, 1951. An increasing number of phosphate fertilizer and chemical companies have been actively investigating the possibilities of recovering uranium from phosphoric acid produced in the manufacture of triple-superphosphate fertilizers and certain phosphate chemicals.

Planned rates of drilling in the expanded exploration program have been reached and drilling now is at the highest rate since the program began in 1947.

Domestic Production

Domestic plant production capacity was expanded in the second half of 1951 and still further expansion can be expected for 1952. A new ore-buying station is in operation near Shiprock, N. Mex. This depot serves the Lukachukai area, which shows promise of being an important source for domestic ores. In the area of Grants, N. Mex., the Atchison, Topeka & Santa Fe Railway and the Anaconda Copper Mining Co. are active in developing uranium production. An ore-buying station and processing plant are planned for this district.

Other areas are being developed and may turn into important sources of production. When volume in any area reaches the proper amount, ore-buying stations will be established. Under the Federal

---

[1] Printed in Appendix 6, Tenth Semiannual Report to Congress, July 1951, Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., 35 cents.

Aid Highway Act of 1950, the AEC is assisting in the planning of a program for the construction and improvement of access roads which will help to open up potential uranium-producing districts in the Colorado Plateau area.

A contract has been entered into with a phosphate chemical company for establishment of byproduct uranium recovery facilities. Other contracts have been made with several phosphate chemical and fertilizer companies for operation of pilot plants in furtherance of process studies and eventual construction and operation of additional uranium recovery plants (p. 9).

The Exploration Program

The AEC domestic exploration program has been concentrated in areas believed to be most favorable geologically for the occurrence of uranium. The major effort has gone into the Colorado Plateau area where the AEC and the U. S. Geological Survey, under contract to the AEC, are carrying out extensive exploration.

Approximately 1,200,000 feet of drilling is scheduled for the current fiscal year; the rate of drilling planned for the first half of fiscal year 1953 is still larger. In addition to the AEC-sponsored drilling, private mining interests are drilling at an increasing tempo. The mining industry and the public are actively participating in prospecting for, and investigation of, possible uranium production sources. The Defense Minerals Administration, as a part of its program of providing increased supplies of scarce minerals and metals, has approved a number of loans for uranium exploration.

Exploration by the AEC is by no means confined to drilling. A number of contracts have been made for underground exploration. This consists largely of drifting, crosscutting, and raising within mines to develop geological information and to investigate production possibilities. Both the AEC and the Geological Survey have also investigated promising surface occurrences by means of trenching and bulldozing.

Attention is being given to the phosphate deposits of Florida and the northwestern United States. The uranium content of these phosphates is very low but the enormous tonnage of phosphate rock being mined contains, in the aggregate, important quantities of uranium. Accordingly a systematic drilling and sampling program is continuing. A number of the phosphate companies are cooperating with the AEC in this program.

Thorium. The Special Minerals Investigation Branch of the U. S. Bureau of Mines and the Geological Survey, under AEC sponsorship, are continuing the search for United States reserves of monazite, the principal source of thorium and rare earths. The western United States monazite deposits contain somewhat less thorium than those of India and Brazil which have supplied most of the world's monazite.

AIDS TO URANIUM PROSPECTORS

The AEC with the Geological Survey and the Bureau of Mines maintain a free sample examination service for uranium prospectors. Anyone who believes he may have discovered uranium may submit samples to laboratories in the service program for examination.[2] Samples are tested without charge and a report is furnished on the results of the examination.

A program of technical and semitechnical information has provided useful information to those interested in prospecting. The booklet, "Prospecting for Uranium," first published in 1949 and recently revised, has sold more than 76,000 copies. A number of color illustrations of various types of uranium-bearing ores were included in the revision. It is available for 45 cents from the Superintendent of Documents, Government Printing Office, Washington 25, D. C. The AEC does not itself distribute this booklet.

A semitechnical booklet, entitled "A Manual of Analytical Methods for the Determination of Uranium and Thorium in Their Ores," has been published to aid assayers and others interested in analytical procedures for determining the uranium and thorium content of ores. It may be purchased from the Superintendent of Documents for 20 cents.

In October 1951 the AEC placed on open-file the first of a number of geological and mineralogical reports dealing with some of the results of domestic exploration by the AEC and the Geological Survey. These reports are not for sale or for distribution, but they are available for examination at a number of university libraries and depositories in 27 States and in the District of Columbia.[3] As issued, future reports will be made available at the depositories.

---

[2] Samples may be submitted for assay to the U. S. Geological Survey, Geochemistry and Petrology Branch, Building 213, Naval Gun Factory, Washington 25, D. C.; to the U. S. Bureau of Mines, Metallurgical Division, in care of the Chief, College Park Branch, College Park, Md.; Chief, Rolla Branch, Rolla, Mo.; Chief, Salt Lake City Branch, Salt Lake City, Utah; Chief, Tucson Branch, Tucson, Ariz.; Chief, Albany Branch, Albany, Oreg.; Chief, Tuscaloosa Branch, Tuscaloosa, Ala.; Supervising Engineer, Reno, Nev.; and to the U. S. AEC at Post Office Box 270, Grand Junction, Colo.; and P. O. Box 30, Ansonia Station, New York 23, N. Y., Attention: Division of Raw Materials.

[3] These reports can be examined at the following AEC installations: Atomic Energy Commission Library, 1901 Constitution Ave. NW., Washington 25, D. C.; Division of Raw Materials, 70 Columbus Ave., New York, N. Y.; Division of Raw Materials, Denver Exploration Branch, Room 127–129, Building 2B, Denver Federal Center, Denver, Colo.; Division of Raw Materials, Spokane Exploration Branch, S. 157 Howard St., Spokane, Wash.; Division of Raw Materials, Grand Junction Exploration Branch, Grand Junction, Colo.; at U. S. Geological Survey Offices: U. S. Geological Survey, Room 1033 (Library), General Services Building, Washington, D. C.; Information Office, Room 468, New Customhouse, Denver, Colo.; Library and Distribution Office, Room 504, Federal Building, Salt Lake City, Utah; University of Arizona, Room 10, Mines Building, Tucson, Ariz.,

Research and Process Development

Research in process development, mineral dressing, and beneficiation is an important part of the raw materials program. With increased emphasis on development of low-grade sources of ore these studies become more and more important. A major program of raw materials research in process development is continuing at the AEC laboratory at Watertown, Mass. This facility is operated by the American Cyanamid Co., under contract to the Commission. It is staffed and equipped to undertake the solution of the many problems incident to processing raw materials.

Although primarily concerned with improvement of existing processes the laboratory also undertakes the development of new processes. Assistance in process development and improvement is given to domestic processors and to suppliers of materials from foreign sources.

Research Contractors

A number of other companies, under contract to the AEC, carry on process studies—Dow Chemical Co. at its Pittsburg, Calif., laboratories; Sonic Research Corp., Boston; International Minerals & Chemical Corp., Armour Fertilizer Works, and U. S. Phosphoric Products Division of the Tennessee Corp., in Florida; Blockson Chemical Co., Joliet, Ill.; the Merrill Co., San Francisco; General Chemical Division of Allied Chemical & Dye Corp. at its North Claymont, Del., plant; Mathieson Chemical Corp., at its Pasadena, Tex., plant; and the U. S. Bureau of Mines at Salt Lake City, Utah, and Tucson, Ariz.

---

and at the following libraries: University of California General Library, Berkeley; University of California, Los Angeles; Denver (Colo.) Public Library; Yale University, New Haven, Conn.; Library of Congress, Washington, D. C.; Atlanta (Ga.) Institute of Technology; John Crerar Library and University of Chicago Library, Chicago, Ill.; and University of Illinois Library, Urbana; Purdue University Library, Lafayette, Ind.; Iowa State College Library, Ames; University of Kentucky Library, Lexington; Louisiana State University Library, Baton Rouge; Harvard University Library, and Massachusetts Institute of Technology Library, Cambridge, Mass.; University of Michigan Library, Ann Arbor, and Detroit (Mich.) Public Library; University of Minnesota Library, Minneapolis; Linda Hall Library, Kansas City, and Washington University Library, St. Louis, Mo.; Princeton University Library, Princeton, N. J.; University of New Mexico, Albuquerque; Cornell University Library, Ithaca; Columbia University Library, New York; New York City Public Library; and Rensselaer Polytechnic Institute, Troy, N. Y.; Duke University Library, Durham; North Carolina State College Library, Raleigh, N. C.; Cleveland (Ohio) Public Library; and Ohio State University Library, Columbus; Oklahoma Agricultural and Mechanical College Library, Stillwater; Oregon State College Library, Corvallis; University of Pennsylvania Library, Philadelphia; Carnegie Library of Pittsburgh, Pa.; University of Tennesse Library, Knoxville; Joint University Libraries, Nashville, Tenn.; University of Texas Library, Austin; University of Utah Library, Salt Lake City; University of Washington Library, Seattle; University of Wisconsin Library, Madison. Reports dealing with specific areas or deposits in a State, or including a State, will also be on file at the State geologist's office.

Production

The output of fissionable materials continued to increase during the last 6 months of 1951 and unit costs continued to decrease. The unit cost reductions were made in spite of increasing labor and materials costs and are the result of the continuing improvement in production processes and the expanded volume of operations.

Status of New Facilities

A substantial portion of the design is complete and construction is well under way on the new feed materials production center at Fernald, Ohio.

The K–31 addition to the gaseous diffusion plant at Oak Ridge was completed.

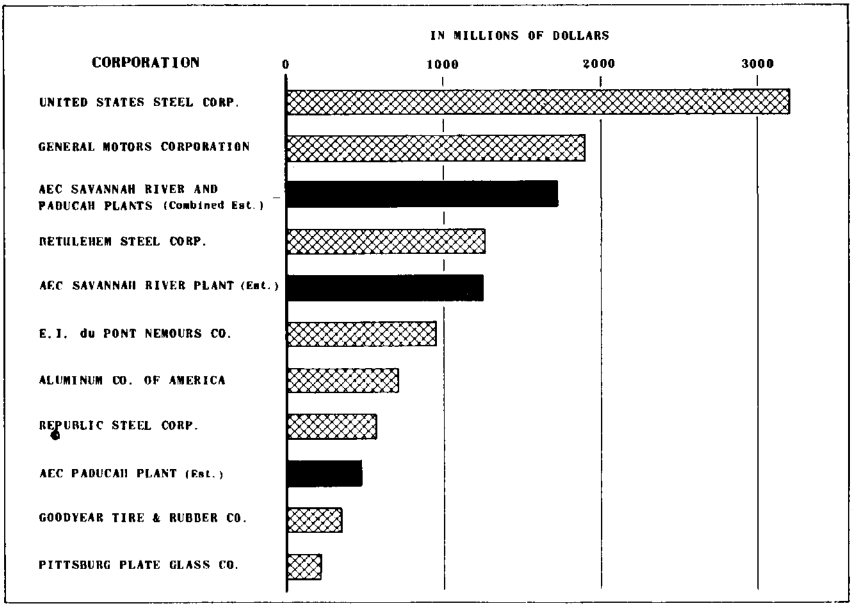
Savannah River. By the end of December, the Corps of Engineers had options on more than half of the 1,500 tracts of land to be acquired at the Savannah River site in South Carolina. Payments and closings had been completed on more than one-third of the total number of tracts involved. The total area to be acquired is about one and one-half times the area of the city of Chicago.

Employment of construction workers increased from 6,600 at the end of June to about 22,000 on December 31, 1951. Preliminary total cost estimates for this project, prepared with design still far from completion, indicated that more than 1.25 billion dollars will be required to pay for design and construction.

Paducah. Design and construction of the gaseous diffusion plant at Paducah, Ky., including auxiliary facilities and feed plant, proceeded at a fast pace despite a series of work stoppages during the summer and fall. It is hoped that with favorable weather and equipment deliveries some of the lost time can be made up. This plant, estimated to cost about 473 million dollars, is being constructed by F. H. McGraw & Co. Construction employment averaged 5,200 during June 1951 and exceeded 13,000 before the year ended.

The presently estimated costs of these two major projects are compared to the real estate, plant and equipment investment of eight major United States corporations in chart No. 1. The magnitude of the two jobs is brought out by the fact that both plants are to be constructed in a relatively short time but involve a total plant investment that a private company would normally accumulate over many years.

COST OF SAVANNAH RIVER AND PADUCAH PLANTS COMPARED WITH INVESTMENT IN REAL ESTATE, PLANT AND EQUIPMENT OF EIGHT MAJOR INDUSTRIAL CORPORATIONS



Source of Corporate Data: Balance sheets of corporations for December 31, 1950, as published in Standard and Poor's, 1951 edition.

One Year's Progress

It has been slightly more than a year since the selections of the Savannah River and Paducah plant sites were announced on November 28, 1950, and December 15, 1950, respectively. The total amount of earth excavated at the two sites by December 31, 1951, would build a solid wall 5 feet wide and 7 feet high reaching from New York to San Francisco. The structural steel erected at Paducah and Savannah River would be enough for another Chrysler Building. A total of 200 miles of roads has been built and 53 miles of underground pipe laid at the two sites. The amount of concrete poured at the two projects is equal to two-thirds of all the concrete in the Bonneville Dam on the Columbia River. One hundred and thirty-three miles of electric-power distribution lines have been strung and 78 miles of railroad completed. The total floor area of temporary office, store, and warehouse space constructed at the two sites is approximately equal to the total rental area in the Empire State Building.

980705—52——2

Housing and Services at New Plants

The AEC is relying on existing communities to furnish community facilities and services and on private development and financing to supply the housing for in-migrant personnel required for the construction and operation of the Savannah River and Paducah plants. As of the end of 1951, 60 percent of the persons engaged in AEC work at the Savannah River site and 50 percent of the workers at the Paducah site were in-migrant to the area.

Some Federal assistance is available for these areas, both of which have been designated critical defense-housing areas. Government credit restrictions pertaining to housing construction have been suspended and the National Housing Act has been amended to provide liberalized mortgage insurance for defense-housing requirements where critical defense-housing areas have been established. Federal assistance is also provided to communities in critical defense-housing areas for additional community facilities and services.

Housing. At Savannah River the in-migrants have been assimilated into the various communities near the project area, chiefly in Augusta, Ga., and North Augusta, Aiken, and Barnwell, S. C. Others are living in about 2,400 privately owned trailers scattered throughout the area. To induce private enterprise to provide and operate housing for construction workers, the du Pont Co. entered into contracts by which it guarantees payment of amounts equivalent to the revenue which normally would be required to amortize the investment in 4,000 family-type and 7,500 single-type temporary housing accommodations. The contract for the family accommodations runs for 5 years, and for the single accommodations for 2 or 3 years at du Pont's option. The Housing and Home Finance Agency programmed 3,600 houses to accommodate permanent operating-plant personnel. At the year's end, 1,000 of these programmed units were under construction as rental units, together with 250 houses which had been or were being constructed by individuals.

At Paducah about one-half of the in-migrants are living in trailers which they brought with them or purchased upon arrival. Other workers are living in rooms, apartments, and houses in the many communities and rural areas throughout western Kentucky and southern Illinois. While the AEC has depended primarily upon surrounding communities to absorb the influx of workers and their families, it has taken three steps to prevent a delay in the completion of construction or a slow-down of operations due to a lack of housing: Sale of 277 surplus prefabricated housing units located at Oak Ridge to be moved to the Paducah area and held for rent to project workers; authorization for the construction of two 500-man dormitories at the project site, one of which has been completed; and certification of the need for 500 rental-housing units under title VIII of the National Housing Act, as amended.

At both the Savannah River and Paducah plants, workers commute daily from living quarters as far as 60 miles away from the site.

Schools and community facilities. At the Savannah River site the U. S. Office of Education approved under the authority of Public Law 815, Eighty-first Congress, second session, 188 temporary classroom facilities in the various communities to serve the children of new families. The first of these classrooms is expected to be in use by March 1952. Augusta, Ga., is using funds placed at its disposal by the U. S. Office of Education to enlarge its permanent school structures. Funds for permanent buildings for several of the school districts in South Carolina also have been approved. Temporary classrooms have been approved for McCracken County in the Paducah area and assistance has been extended to the city of Paducah for rehabilitation of some classrooms.

Accountability for Source and Fissionable Materials

During 1951, the Commission further improved its system of accounting for source and fissionable materials. This was accomplished in part by preparing a manual of procedural standards for source and fissionable material accounting surveys.

Basis for accountability. As outlined in the Fifth Semiannual Report to Congress,[4] physical protection and accounting control are the two principal safeguards against loss or misappropriation of source and fissionable materials. Fissionable material, enriched uranium and plutonium, costs many times as much as gold.

Physical protection against loss of these materials is incorporated in plant design and operating methods and includes such measures as building fences and providing guards. Accounting controls provide an accurate record of materials that should be on hand to be compared with frequent, accurate and intricate measures of actual quantities which are on hand.

Manual of procedure standards. The procedure standards, prepared with the aid of two consultant firms, were a further step in a program to set up a uniform accountability system which would be sufficiently comprehensive but not excessively expensive. It was conceded at the

---

[4] Fifth Semiannual Report to Congress, January 1949, Superintendent of Documents, Government Printing Office, Washington 25, D. C., 45 cents.

outset that an absolutely fool proof system of accounting would be difficult to attain. Nevertheless, the system should disclose any significant loss with an accuracy and promptness commensurate with the value and strategic importance of the materials. With this goal, the Commission in 1947 established preliminary procedures for compiling and summarizing inventory and loss information. With experience, the Commission improved the procedures during 1948. The newest procedures, adopted in 1951, helped improve records and measurement and inventory techniques for all materials at all production stages. Consultants in the preparation and revision of the manual were the public accounting firm of Lybrand, Ross Bros. and Montgomery, of New York, and Hydrocarbon Research, Inc., a New York engineering consulting firm.

AEC Community Operations

On August 3, 1951, the special Community Operations Panel submitted to the Commission its report and recommendations on Oak Ridge, Tenn., and Richland, Wash. The report is the result of a year's work by a panel of four well-qualified individuals in the fields of real estate and municipal administration. The panel has not yet presented its recommendations on the Los Alamos community. The panel is headed by Richard G. Scurry, of Dallas, Tex., senior partner of the law firm of Scurry, Scurry & Pace and includes Frederick M. Babcock, a private consultant on housing from Washington, D. C.; George E. Bean, city manager of Grand Rapids, Mich.; and George Gove, vice president in charge of housing projects, Metropolitan Life Insurance Co.

The Commission has distributed the report within the communities affected and is planning to obtain the residents' reaction to the recommendations before taking further action.

To enable community residents to discuss and evaluate the merits of the recommendations, private appraisers have been retained at both Oak Ridge and Richland to make valuation appraisals of property that would be disposed of.

While studying the feasibility of instituting more normal American real estate and municipal practices in Oak Ridge and Richland, the Commission continued to operate the communities with increasing economy and to the extent possible, to institute some practices which normally prevail in American communities. Changes were made in the conveyance of land to churches to assist them in obtaining financing for building. Also it was decided to make land available on a long-term lease basis for the construction of rental housing by private developers where a deficiency of housing exists.

Rent Increases

A principal recommendation of the panel was that rents in Oak Ridge and Richland be brought to levels comparable to those for housing in the surrounding area. The Commission had adopted such a policy in February 1949, and in the summer of 1949 it corrected internal rental inequities, separated utility charges from shelter rent charges, and provided for an average increase of half the difference between existing rent and utility charges and those comparable to the surrounding areas. Shelter rents were not raised to full comparability at one time, to avoid a possible undue hardship on tenants. It was planned to bring shelter rents to full comparability on August 1, 1951, basing rates on reappraisals made by private appraisers during the fall of 1950. These increases would have raised the shelter rents in Oak Ridge an average of $10 and in Richland an average of $13 resulting in an average increase of 28 percent for Oak Ridge and 41 percent for Richland.

The AEC policy on rental rates conforms with the subsequently adopted Government policy on charging rents for Government quarters as announced by the Bureau of the Budget in July 1951.

Since it was evident that the Federal rent control law, which was to expire on June 30, 1950, would be extended and might be made applicable to federally operated and controlled housing, the AEC deferred the proposed rent increase to October 1, 1951. When Federal rent control was extended to June 30, 1952, it became necessary to study further its impact at Richland, Oak Ridge, and Los Alamos. As a consequence, the proposed rental increase actions in the three communities were deferred again until December 1, 1951.

Federal rent control now applies at both Richland and Oak Ridge. The Commission has deferred indefinitely rent increases at both Oak Ridge and Richland until an agreement is reached with the Office of Rent Stabilization on maximum legal rental rates which can be established consistent with the provisions of the Housing and Rent Act of 1947, as amended.

At Los Alamos, new rental rates went into effect on January 1, 1952. They amount to an average increase of about 4.8 percent, will correct previous inequities in the Los Alamos rental structure, and are intended to bring the rental level to full comparability with that prevailing in surrounding communities.

Los Alamos Community Expansion

The past 6 months have seen substantial completion of the program of rebuilding and expanding the Los Alamos community. This program was first planned and undertaken in 1947-48; it was subsequently enlarged as the program of the Los Alamos Scientific Laboratory was expanded. Now it has come to practically complete realization.

Oak Ridge Community Contractor

In July 1951 the Roane-Anderson Co., contractor for the operation and maintenance of the Oak Ridge community, notified the Commission of its desire to terminate its contract on or before January 3, 1952. The company indicated that it no longer found the contract profitable in view of the key personnel assigned to the operation as related to the recently reduced fee received for the work. In order to retain many of the experienced personnel employed by the contractor and to provide for continuity of operations, a no-fee contract was negotiated with a nonprofit corporation, Management Services, Inc., formed by a group of Oak Ridge residents. The new contract became effective December 1, 1951.

Housing at Hanford

At Richland, 300 new houses approved for fiscal year 1951 were completed by the end of December, and 300 more units were approved for construction with appropriated funds. However, constructing the latter units is being held in abeyance pending the outcome of attempts by private developers to supply privately financed and operated rental housing in Richland under the provisions of title VIII of the National Housing Act, as amended.

Construction and Supply

Such facts as can be publicly reported concerning progress in building appear in the sections of this report relating to the programs—production, military application, reactor development, research, and biology and medicine—to be served by the new facilities under construction during the last 6 months of 1951.

As a gauge of the size of the total construction program in atomic energy it may be noted that in July 1951, construction costs incurred by the Commission were 54.5 million dollars, and they rose steadily in accordance with plans to a level of about 79.8 million dollars in November. The total construction costs incurred for the 5 months ending November 30, 1951, were about 365.6 million dollars. During the same period the value of Nation-wide construction of all kinds, as reported by the Departments of Commerce and Labor, averaged approximately

2.45 billion dollars monthly. Accordingly, about 3 percent of total United States construction during the 5 months ending November 30, 1951, was for the national atomic energy program.

Construction Employment

Average construction contractor employment on all AEC-administered construction projects for the first 6 months of 1951 was 28,500 men. For the 5 months ending November 30, 1951 it averaged 50,000, or 1.8 percent of the estimated average contract construction employment of 2.75 million men on all projects in the United States.

PRIORITIES

Under the national priorities system, AEC continues to function as a claiming and allotting agency for the controlled materials (steel, copper, and aluminum) requirements of its construction and operations programs. Training of the AEC field staff in controlled materials plan operations was coordinated with the introduction of CMP by the National Production Authority and has facilitated the orderly operation of the plan within AEC.

AEC has also made special studies of its requirements for particularly critical products and services in order to assist NPA and other control agencies in their planning. Typical examples of these are power, valves, and electrical equipment.

The national supply-demand situation in materials of importance to AEC programs requires that AEC continuously review its requirements in these areas to identify points of significant impact and to assure the filling of these requirements.

Special Priorities Assistance

In order to meet the very tight construction schedules which have been established for AEC projects, deliveries of materials and equipment are usually required in less than current normal procurement time. In addition, the materials and equipment being purchased on these tight schedules are in direct competition with materials and equipment needed for other important defense programs. As a result, AEC and its prime contractors have not been able to obtain all required deliveries under the general priority devices established by the National Production Authority, such as defense order ratings and the controlled materials plan. To maintain some schedules it has been necessary to request special assistance from NPA, usually in the form of individual directive action by NPA on the manufacturer or supplier involved. As would be expected under conditions of tightening supply, the number of requests to NPA for such special assistance from July to November 1951, was much larger—nearly nine times in fact—than the number of requests made from January through June 1951. This sharp increase reflects the growing difficulties in securing timely delivery of critical materials and equipment. AEC has worked closely with NPA during the past several months in an effort to improve this situation and to meet current completion schedules on vital construction projects.

Supply

The design has been completed and actual construction started on the installation of the telephone system for the Savannah River plant. Upon its completion it will be one of the largest automatic telephone systems in the world serving only an industrial establishment.

A program for microfilming the important records of the Commission has started. All categories of records required for the operation of atomic energy projects have been microfilmed and are maintained under appropriate security safeguards.

Substantial savings in equipment and space have been made throughout the Commission's activities by the establishment and operation of records centers. Some 22,000 cubic feet of semiactive records are stored in these centers.

Transportation

Major efforts have been made to eliminate delays in transit and excessive transportation costs. Some of the results are:

a) A national weight agreement has been reached with the rail carriers. The value of this agreement is in the transit time saved on movement of articles which otherwise would be stopped in transit for weighing.

b) Arrangements have been made with the Railway Express Agency for the positive location of air express shipments identified as moving for the account of the AEC or its cost-type contractors. This will greatly facilitate tracing of shipments when necessary.

c) Through negotiations on freight rates the Commission has made savings in the last 6 months of approximately $300,000, of which $160,000 is an annually recurring saving.

Procurement

Arrangements have been made permitting AEC cost-type contractors, as agents of AEC, to issue purchase orders to suppliers holding current contracts with various Government purchasing agencies, such as General Services Administration, Armed Services Petroleum Purchasing Agency, Federal Prison Industries, and the Post Office Department. By this procedure, savings are realized in costs of material purchased and in the administrative effort required of the cost-type contractors' purchasing offices.

Military Application

Atomic weapons were produced at the rate authorized by the President for calendar year 1951, and significant advances were made in weapons research and development.

Construction continued at several locations to meet the needs of the expanding atomic weapons program. After site selection and some delay in acquisition of land, construction of a plant near Denver, Colo., was begun by the Austin Co., general contractor; construction proceeded on schedule during the last half of 1951.

Construction of additional facilities and rehabilitation of existing structures was well under way at the Pantex Ordnance Plant at Amarillo, Tex.; the construction work is being done on both a cost-plus-fixed-fee and competitive bid basis with the latter method used wherever practicable. Silas Mason Co. is doing the cost-plus-fixed-fee portion and lump-sum contracts have been awarded to several different contractors.

New field offices were established at Amarillo, Tex., at Denver, Colo., at the Nevada Test Site, and for the Pacific Proving Ground at Eniwetok, all under the Santa Fe Operations Office, which has primary field responsibility for atomic weapons work. Headquarters of the Santa Fe Operations Office were moved from Los Alamos to Albuquerque, N. Mex., where AEC-owned property was available for office space, to provide a measure of relief from crowded housing and office space at Los Alamos.

Test Activities

A series of experimental nuclear detonations was conducted at the Nevada Test Site in October and November 1951. Certain types of tests can be conducted at the Nevada location at considerably less cost than at Eniwetok. The program demonstrated the effectiveness of joint operations by an integrated test organization of qualified specialists of the Commission and its contractors, the Department of Defense, and other agencies of the Government.

One of the major objectives of the tests was to provide data for weapons development purposes. The Los Alamos Scientific Laboratory has made marked progress in the development of atomic weapons, and the tests contributed to the further advancement of the work. The primary technical responsibility for the test devices rested with the Los Alamos Laboratory. The Sandia Laboratory and several of the national laboratories of the Atomic Energy Commission played important roles in the operation.

A number of special services for the operation were provided by several units including the Special Weapons Command of the Air Force, the Armed Forces Special Weapons Project, the Air Weather Service of the Air Force, and several scientific organizations of the Department of Defense. Assistance was also given by the U. S. Weather Bureau and the Civil Aeronautics Authority. Representatives of the Federal Civil Defense Administration participated in the test program.

The other major purpose of the tests was to study various physical effects such as blast, radiation, and heat, including programs for the Armed Forces, the Federal Civil Defense Administration, the U. S. Public Health Service, other governmental agencies, industry, and biomedical researchers. The Department of the Army used the tests also for a combat troop training exercise, for the orientation of staff and instructional personnel, for studying the psychological reaction of troops, and for studying other tactical implications. The Sixth Army established a camp known as Desert Rock near the entrance to the test site for the accommodation of the military units participating.

The Atomic Energy Commission and the Department of Defense are giving continued consideration to the most effective method of integrating the requirements of both agencies for full-scale test operations.

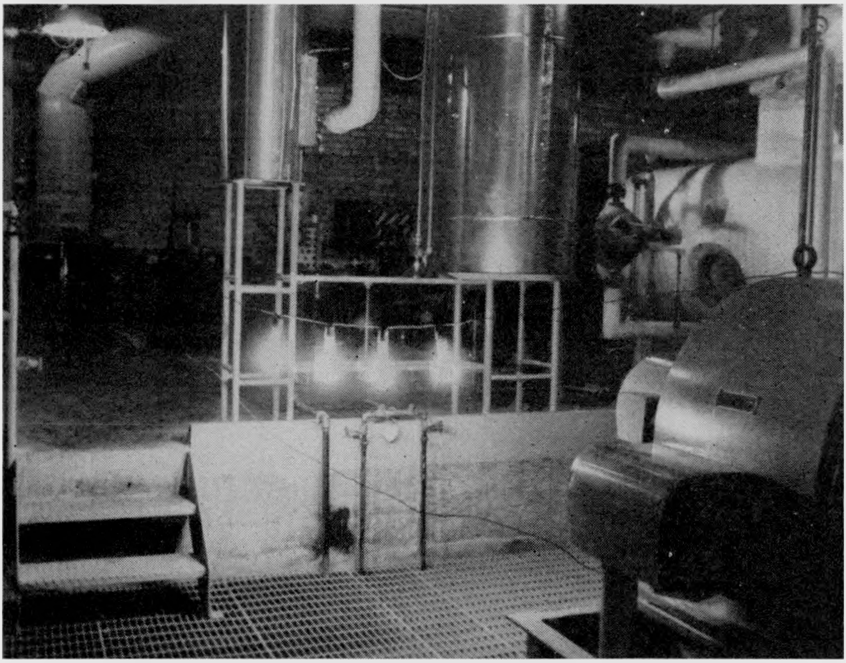
Reactor Development

New Reactors

In the period under report, the construction of the Experimental Breeder Reactor was completed by the Bechtel Corp., at the National Reactor Testing Station in Idaho and the reactor was brought up to criticality by the operator, the Argonne National Laboratory.

This is the first reactor of appreciable size to operate with fast neutrons, the first fast reactor being a very small unit at the Los Alamos Scientific Laboratory. Already, valuable information has been obtained on the new design and more data will be secured from operating experience. It will be months, however, before the feasibility of breeding can be determined. Many factors will have to be considered, such as the investment of fuel required in a large breeder reactor and its plants for processing and fabricating fuel elements, the time required to double the amount of fuel invested, and construction and operating costs.

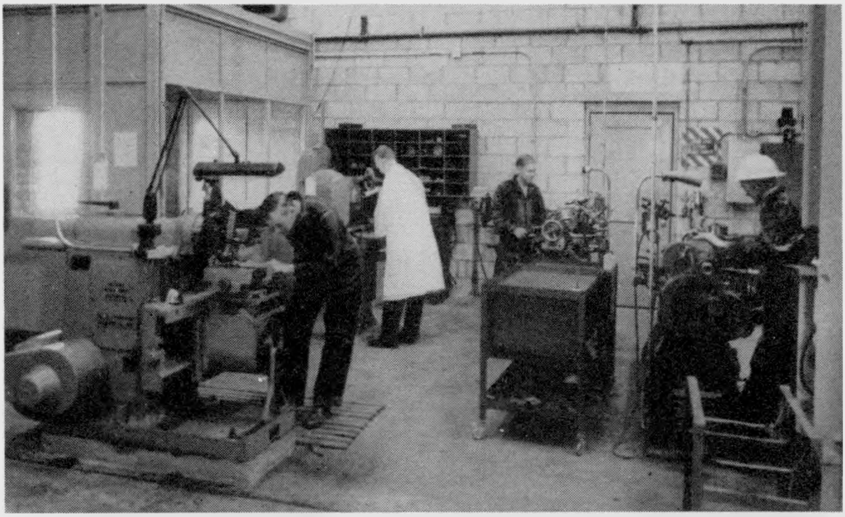
Power generating experiment. The reactor's small experimental power plant—heat exchanger, steam turbine, and electric generator—was operated in trial runs on December 20, 21, and 22, 1951. Electrical power was generated at the rate of more than 100 kilowatts and used to operate the pumps and other reactor equipment and to provide



The glowing electric light bulbs in this photo show the first known use of electric power from atomic energy. The bulbs are lighted by electricity from the generator at the right which, in turn, operates on heat from the Argonne National Laboratory's Experimental Breeder Reactor at AEC's National Reactor Testing Station in Idaho.

light and electrical facilities for the building that houses the reactor. The heat energy produced in the reactor was removed by a liquid metal at a temperature high enough to generate steam to drive the turbine. Test operations were resumed in January after further adjustments of the reactor system.

Power generation is incidental to the main experimental purpose of the reactor. The power studies are being carried out to secure information on the handling of liquid metals at high temperatures under radioactive conditions and on the extraction of heat from a reactor in a useful manner. The power plant of this reactor can never generate large amounts of electrical power but it does provide



The machine shop in the building housing the newly completed Experimental Breeder Reactor at the AEC's National Reactor Testing Station in Idaho is shown lighted by and operated on electric power produced from the heat energy of the reactor. The reactor and its power plant were designed by and are now being operated by the Argonne National Laboratory.

a useful tool for carrying out such experimental studies. The power experiment is in no way intended to establish the feasibility of producing electrical power economically from nuclear sources. The technical information gained, however, may be useful in the design of future reactors aimed at generating electricity at a competitive cost.

The Materials Testing Reactor

Construction of the Materials Testing Reactor facilities and structure at the testing station by the Fluor Corp. continued. Engineers of the Phillips Petroleum Co., operating contractor, after training at Oak Ridge with a pilot model of the MTR, took up their assignments at the testing station.

The MTR is expected to produce a neutron flux more intense than any now available. A schedule for the first few months' use of this new and much needed facility to make some two-score irradiation tests of the highest priority for a number of laboratories and contractors was established with the guidance of a policy board representing the AEC program divisions.

The Naval Reactors

Construction at the testing station of buildings and facilities for a land-based prototype of the Submarine Thermal Reactor power plant (STR) was advanced. Installation of machinery is to be by Electric Boat Co., of Groton, Conn. Both the construction contractors and Electric Boat are subcontractors to the Westinghouse Electric Corp. which will operate the nuclear power plant in consultation with the Argonne National Laboratory.

Contractual arrangements are being made for the submarine thermal reactor which is to go into the first nuclear-powered submarine. By agreement between AEC and Westinghouse, the latter will furnish the reactor for the submarine, which the Navy has named the U. S. S. *Nautilus*. The Navy's Bureau of Ships has contracted with Electric Boat to construct the hull of the *Nautilus* and with Westinghouse for the propulsion machinery.

Work continued by the Knolls Atomic Power Laboratory on design and development for the Submarine Intermediate Reactor (SIR). The first installation is to be a land-based prototype of a nuclear power plant suitable for a submarine. Though similar in power specifications to the Submarine Thermal Reactor, this reactor will operate in the intermediate neutron energy range and is being designed along substantially different lines.

Chemical Processing Plant

Construction of a chemical processing plant at the testing station drew nearer to completion. The plant will be used for the separation of unused fuel from used fuel units. Construction was expedited by nearly two-score field engineers from the Foster-Wheeler Corp., New York City, architect-engineer, and Oak Ridge National Laboratory, who gave direct supervision at the site. The construction contractor is the Bechtel Corp. of San Francisco.

Progress was made in laboratory development work for additions to the plant. Investigations of other methods of recovering unused nuclear fuel were also pressed.

Long Range Program

In the long range program of developing new reactor designs, studies and investigations looking toward production reactors were intensified. Significant studies of new reactor designs are being carried on by Argonne, Oak Ridge, and Brookhaven National Laboratories; the Knolls Atomic Power Laboratory; North American Aviation, Inc., Downey, Calif.; and H. K. Ferguson Co., New York City.

Development of Fluidized Reactors

The Homogenous Reactor Experiment was brought nearer completion at the Oak Ridge National Laboratory. This is a pilot reactor, a step in the study of fluidized reactors. Although an "experiment" by comparison with large reactors, the HRE will have greater power than the only existing fluidized reactor, the Los Alamos Water Boiler, or the water boiler under construction at North Carolina State College. Like the Experimental Breeder Reactor, it will ultimately operate a small turbo-generator for heat transfer and power studies.

Aircraft Nuclear Propulsion

Acting under a letter contract of June 30, the Aircraft Gas Turbine Department of the General Electric Co., began design and development leading toward aircraft propulsion by nuclear power. Facilities at Oak Ridge, formerly occupied by the Nuclear Energy for Propulsion of Aircraft Division of the Fairchild Engine and Airplane Corp., were taken over by General Electric and modification of buildings at Lockland, Ohio, near Cincinnati, began. Plans call for the GE staff at Oak Ridge to move to Lockland by June 1952. This nuclear development is paralleling development of associated propulsion devices by General Electric and preparation of the air frame by Consolidated Vultee Aircraft Corp., of Fort Worth, both under Air Force sponsorship. The Air Force also entered into contract with the Pratt & Whitney Division of the United Aircraft Corp., East Hartford, Conn., for work on an atomic aircraft engine. The AEC is cooperating in nuclear phases of this work.

Industrial Participation Studies

The privately financed studies of reactor technology by the four industrial groups[5] progressed. The Detroit Edison-Dow Chemical group and the Pacific Gas & Electric-Bechtel group submitted reports which are being studied by the AEC. More than 100 engineers and scientists, cleared for access to restricted data, have been giving full or part time to the studies, examining literature, visiting AEC installations and consulting with people who have been working in the field. Thus new talent is being brought into the program to develop improved reactors and electric public utilities are entering this field since 5 of the 8 participating firms are electric utilities.

---

[5] Monsanto Chemical Co. and its associate, Union Electric Co. both of St. Louis; Detroit Edison Co., of Detroit, and Dow Chemical Co., of Midland, Mich.; Commonwealth Edison Co. and Public Service Co. of Northern, Ill., both of Chicago; and Bechtel Corp. and Pacific Gas & Electric Co., both of San Francisco.

It is expected that additional reports will be received by early summer, 12 months after the last agreement was signed. As outlined in the Tenth Semiannual Report, the agreements provide for surveys and studies by the companies to (*a*) determine the engineering feasibility of their designing, constructing, and operating dual-purpose reactors to produce fissionable materials and power; (*b*) examine the economic and technical aspects of building such reactors in the next few years; (*c*) determine the possible research and development needed; and (*d*) recommend industry's role in designing, building, and operating such reactors.

Training for Reactor Engineering

In September 1951 the School of Reactor Technology operated by the Oak Ridge National Laboratory graduated its first regular class of 43 engineers. Twenty-three were experienced people from the AEC and its contractors and the military services, and 20 were recent college graduates employed by the laboratory during the course.

Immediately after the graduation of the first class, a second class of 67 students began the 12-month course, which is largely classified. Thirty-eight of these are recent college graduates employed by the Laboratory, 23 are from industrial organizations, 2 are from the Navy, and 4 are from the Air Force. A new laboratory to serve the enlarged enrollment was completed in December.

The experienced engineers sent by industrial firms continue to receive their salaries while studying at Oak Ridge. Since experienced engineers are not enrolling for this course in the numbers needed by the reactor development program, consideration is being given to sponsoring evening courses at industrial centers and short summer courses at educational institutions.

Industrial Participation

One objective of the reactor technology studies by the four industrial groups is to give opportunity to industry to invest private funds in reactors and to build and operate them with profit in proportion to efficiency and improvements rather than on a cost-plus-fixed-fee basis. Another program with the same general objective—smaller but promising accomplishment in less time—is the production of zirconium.

Competitive Zirconium Production

In developing the program for the manufacture of zirconium in privately owned facilities on a unit-price basis, a meeting was held in Chicago, July 18, with representatives of 31 firms who responded to AEC's invitations. The specifications, processes, and needs were discussed.

The major steps now used in obtaining pure metal from commercial grade zirconium tetrachloride are: (1) Separation of hafnium from the zirconium in commercial grade tetrachloride; (2) chemical purification of the separated zirconium; (3) calcination and rechlorination of the purified zirconium; (4) reduction of purified tetrachloride using the basic Kroll-type process, which yields "sponge" metal; (5) refining the reduced "sponge" using the basic deBoer-type process, which yields "crystal bar" metal.

As a result of the meeting, representatives of 20 interested and qualified firms were given security clearance and during October and November visited several research and development and production facilities. On November 5 invitations were issued for bids to be submitted on zirconium production and to be opened in January 1952.

New Uses for Fission Products

Results of the Stanford Research Institute's technical and economic survey were published as a 100-page book, "Industrial Uses of Radioactive Fission Products." [6]

The book reports that present commercially feasible industrial uses include the activation of phosphors for self-luminous signs and markers and the reduction of starting voltage requirements in fluorescent light tubes. Static eliminators for a variety of industrial processes and process control instruments which incorporate a source of radiation are also listed.

Possible future uses for fission products, where the technology and desirability of use will require at least 2 to 5 years for development, include industrial radiography, cold sterilization of drugs and foods, and portable low-level power sources. In the highly speculative area where basic technical knowledge is lacking, possibilities exist for uses in radiation chemistry and flame propagation.

The study emphasizes that the possible industrial advantage in the use of fission products lies in their potential ability to produce certain types of radiation at less cost or in more convenient forms than presently available sources.

A program to ascertain basic technical information was started during the past 6 months. Brookhaven National Laboratory furnished a 1-kilocurie cobalt 60 source, prepared in the laboratory's reactor, to the University of Michigan, another to Columbia Univer-

---

[6] Can be purchased from Project 361, Stanford Research Institute, Stanford, Calif., for $1.50, the cost of reproduction.

sity and a 1.5-kilocurie source to Massachusetts Institute of Technology. General Electric's General Engineering Laboratory is to be supplied with a 1.5-kilocurie source and the Stanford Research Institute with a 5-kilocurie source. A kilocurie cobalt 60 source is about 25,000 times as potent in radioactivity as the amount of radium used in a typical medical treatment. Such special cobalt 60 sources are to be used until specifications are determined for fission product sources and methods of preparing them developed.

Several fundamental investigations are being financed by the AEC. During December negotiations were in progress with Schering Corp., a pharmaceutical firm of Bloomfield, N. J., for that firm to finance its own program to determine the feasibility of sterilizing its products with radiation from fission products. AEC would furnish the radiation source.

Sixteen firms, representing the antibiotic industry, are planning a program supported by private funds which would use a 5- to 10-kilocurie source.

SANITARY ENGINEERING

During the past 6 months useful data were obtained from investigations on the safe disposal of radioactive wastes. Some of the new information has already been applied at atomic energy installations. Developments include:

Sewage treatment methods. To ascertain the practicality of utilizing sewage treatment methods for removing radioactivity from high-volume, low-level radioactive wastes, investigations were started at the University of California and at New York and Johns Hopkins Universities. At California, extensive studies are being made of the activated sludge process while New York University started experimental work on trickling filters. Johns Hopkins began investigating economic methods for handling low-level wastes, such as those resulting from laundering contaminated clothing worn by atomic energy workers. These studies promise to decrease the cost of disposing of low-level wastes.

Adsorption by plumbing metals. At Johns Hopkins valuable information was developed on the adsorption of radioactivity by metals used in plumbing systems. It was found, for example, that alloys containing lead and copper are much more susceptible to contamination by iodine 131 than galvanized iron or stainless steel. Such information should prove useful in the design of drainage systems for laboratories using radioactive materials.

980705—52——3

Water supply treatment. Massachusetts Institute of Technology completed studies of the removal of certain radioactive elements from water supplies by conventional methods of treatment. This work has already proved of value to the photographic industry in attacking the problem of treating water slightly contaminated by the fall-out following weapon design tests.

Air cleaning evaluation. A group at Harvard University brought nearly to completion a testing program to evaluate commercial air cleaning equipment in the light of AEC requirements and completed a "Handbook of Air Cleaning," which is to be published. The group conducted training and information courses for engineers of the Commission and its contractors which were also attended by representatives of the National Research Council of Canada from the reactor installation at Chalk River, Ontario.

Other investigations are in progress by A. D. Little, Inc., Cambridge, Mass., on a new high-temperature, acid-resistant air filter; by New York University on the feasibility of reproducing certain atmospheric phenomena in a wind tunnel; and by the University of Illinois on aerosols.

Solidifying incinerator ash. The Bureau of Mines Station in Pittsburgh completed work on the fluxing of ash from an incinerator in which radioactive materials are burned. The ash is fluxed into a lump of sodium hydroxide so that this concentrated radioactive waste can be more easily handled and disposed of. The station is also well along on laboratory studies of a small incinerator being developed primarily for non-AEC users of small amounts of radioactive materials. Results will also be applicable to installations of the Commission.

Surveys at new installations. The U. S. Weather Bureau and the U. S. Geological Survey assisted in evaluating the meteorologic, hydrologic, and geologic aspects of environmental problems of new AEC installations. The evaluations included estimates of the extent of the distribution and disposition of radioactivity in the atmosphere and surface and ground waters.

Two new river groups. Advisory groups were established for the Mohawk and Savannah Rivers, similar to the group for the Columbia River. These groups, which include representatives of Federal or State public health services, the AEC, its contractors, and local agencies, are apprised by the Commission of plans for releasing wastes in the rivers. In turn the groups provide local consulting services so that the disposal can be carried out safely and efficiently.

Physical Research

About 37 million dollars was allocated to the support of basic and applied research for fiscal year 1952, 75 percent devoted to research in AEC laboratories and the rest to contracts with universities and private research institutions. In the latter category, 2.8 million went into contracts administered through a joint program with the Office of Naval Research.

A closer association between physical research under contract and the immediate aims of the atomic energy development program progressed during the last 6 months of 1951 on such matters as raw materials problems, zirconium production, radiation damage to materials, and the measurement of neutron cross sections.

During this period six particle accelerators came into initial operation. Four new machines in various universities and one at Brookhaven National Laboratory were under construction or being installed. Operation is expected some time in 1952.

Research Program

The AEC's university and private laboratory contractors have cooperated fully in the program to align their research more closely with the operational and developmental aims of the atomic energy program.

Given below are some examples of the types of research being conducted under AEC contract for application to particular problems.

Raw Materials Problems

During the past 6 months research on raw materials problems was expanded to include nine new projects. Work in this field is now under way at the University of Arkansas, California Institute of Technology, Columbia University, Illinois Institute of Technology, Massachusetts Institute of Technology, Pennsylvania State College, Princeton University, Syracuse University, University of Tennessee, University of Wisconsin, and the U. S. Geological Survey. The present annual level of support of these raw materials projects is $828,210. (See Appendix 5.)

The raw materials group of the Materials Chemistry Division at Oak Ridge National Laboratory has been increased, and smaller groups at Ames Laboratory and Argonne National Laboratory are also active in this research.

Zirconium Research

The properties of zirconium make it a desirable reactor construction material, and new methods of production and purification are being sought in order to improve its availability and utility (see p. 26).

Research on improved and economical methods of obtaining zirconium metal is being conducted at Columbia University; Graham, Crowley and Associates, Inc.; and Horizons, Inc. In August, representatives of these three organizations met at Columbia University to coordinate the research on the electrolytic production of zirconium metal. The representatives of Horizons indicated that some success had been obtained in their electrolysis of potassium zirconium fluoride in a fused salt bath. Graham, Crowley and Associates are studying the electrolytic reduction of zirconium in aqueous and organic media, and the group at Columbia is making an investigation of molten chloride systems.

Radiation Damage Research

During the past 6 months, a considerable expansion was accomplished at institutions outside of AEC installations in studies of the effects of radiation on metals. Particle accelerators are being utilized for this research at private laboratories and at the University of Illinois, Purdue University, Carnegie Institute of Technology, and Massachusetts Institute of Technology. The results of these projects will be correlated with research at the national laboratories, where both particle accelerators and reactor irradiations are utilized. The annual value of this type of research at outside institutions totals approximately $200,000. (See Appendix 5.)

Neutron Cross Sections

Data on neutron cross sections [7] of the elements play a vital part in atomic energy development. Without accurate measurements of these values, calculations on the usefulness of various materials in reactor shielding and on improved design of reactors are not possible. The AEC is contracting for more research in neutron cross sections as an aid in the development of better experimental techniques and the advancement of nuclear theory.

---

[7] The efficiency or probability of a nuclear reaction can be defined in terms of the number of particles emitted, or of nuclei undergoing transmutation, for a specified number of incident particles. A more general, uniform method, which has been widely adopted, is to express the relative efficiency by means of a quantity called the *nuclear cross section*. It represents the effective area, or "cross section" of a single nucleus of a given species for a particular reaction.

Cross sections of the various elements for fast and slow neutrons are often very different, and for given energies of neutron impact the cross sections of isotopes of the same element may differ considerably. The nucleus of a particular form of an element generally has a different cross section for each type of neutron reaction in which it can take part. For each isotope of each element there is a cross section for elastic scattering and one for inelastic scattering; another for radioactive capture; one for proton emission, and one for alpha particle emission, and so on. Fission cross sections are of great importance for elements of high atomic number such as thorium, uranium, and plutonium.

Thus in order to have a proper understanding of the subject a complete study of the cross sections of a given nuclear species for interaction with neutrons of various energies must be made. But 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. This, of course, would be a tremendous undertaking. The AEC concerns itself only with the forms of elements and the neutron velocities of immediate practical interest in atomic energy development.

These measurements are carried out in some of the contracting universities as well as in the majority of the national laboratories. In the past few years more of these measurements have been made in the universities, due to the fact that a number of particle accelerators, either partially or wholly financed by the AEC are coming into operation at these institutions.

Particle Accelerators

During the past 6 months, the construction of the 63-inch cyclotron at Oak Ridge National Laboratory was completed, and initial testing started in early January 1952. This cyclotron will accelerate ions heavier than helium.

In August, the AEC authorized the construction at Brookhaven National Laboratory of an 18-inch cyclotron which will accelerate deuterons and protons. Construction is proceeding as rapidly as materials and components can be delivered. Completion is expected in the spring of 1952.

During this period the synchrotrons at California Institute of Technology and at the University of Michigan, the cyclotron at the University of Washington, and the synchrocyclotron at Carnegie Institute of Technology came into initial operation. Also, a Van de Graaff generator, purchased with AEC funds, was delivered to Duke University and is in the initial stages of operation.

Construction started on four new accelerators with operation scheduled in 1952. The Van de Graaff generator at the University of Notre Dame will produce electrons of 2 Mev energy, and the one at Rice Institute will accelerate protons to 5.5 Mev. The linear accelerator at the University of Minnesota will accelerate protons to 68 Mev. These three machines are owned by the AEC and loaned to the universities. The Van de Graaff at the University of Texas, partially supported by the AEC, is expected to accelerate protons to 4 Mev.

The years 1950 and 1951 were productive years for the particle accelerator program—20 and 21 machines respectively came into operation in these years. Because of the increased number now in operation, more research requiring accelerators can be done outside of the national laboratories. Such research is by no means limited to the physical sciences; a number of these accelerators are devoted to biological and medical studies.

Progress in the Studies of the Nucleus

Research to bring to light the relatively unknown forces which hold neutrons and protons tightly together to form the nuclei of atoms is being pursued in the AEC laboratories and in universities. An approach to the nature of these forces is the study of the actual energy involved in the formation of a nucleus and the various energy states in which it can exist, if only momentarily. Such research, leading possibly to greater energy releases from the atom, is being actively continued.

During the past 6 months, Brookhaven physicists have succeeded in bringing together all of the known information regarding the properties of certain types of atoms called isomers.[8] They have developed a classification scheme which has made it possible to explain many previously inconsistent observations and to predict the existence of several new isomers. These will be used to expand knowledge of the nucleus.

At the University of California's Radiation Laboratory the energy states of the helium 4 nucleus were studied by bombarding helium gas with protons from the linear accelerator. It was found that the helium 4 nucleus cannot be raised to a higher energy state with less than 23 Mev. In addition, observations showed that some of the

[8] A nucleus which has been given extra energy usually gets rid of it almost immediately after receiving it by emitting gamma rays. The structure of some nuclei, however, permits them to retain the extra energy for longer periods of time. These nuclei are called nuclear isomers.

bombarded helium 4 atoms were transformed to helium 3 by the emission of deuterons, a previously unobserved reaction. Further research on this reaction is under way.

Fellowship Program

No new fellowship awards will be made by the AEC in view of the contemplated National Science Foundation fellowship program for the academic year 1952–53. The National Science Foundation program will be supplemented by renewals by AEC to qualified fellows now on the rolls.

Isotopes

Isotope Production Survey

In August 1951 Bendix Aviation Corp. and Tracerlab, Inc., made arrangements with the AEC to conduct studies on the problems of chemical processing of radioistopes, and to determine the desirability of designing, constructing, and operating a nuclear reactor for the production of radioistopes. These organizations conducted the surveys at their own expense with the AEC supplying advice and information. Both organizations sent representatives to Argonne, Brookhaven, and Oak Ridge National Laboratories and other sites to discuss matters related to their surveys. Final reports will be furnished in 1952.

Stanford Pricing Survey

In planning the future of the radioisotopes program and in discussions of increased commercial participation in the program, the AEC recognized the need for an analysis of the factors influencing the costs of isotope production and accordingly the prices of isotopes. The present prices for isotopes have evolved from the application of an overall pricing policy adopted at the beginning of the distribution program, namely, that the total income from isotopes sales should equal approximately the total expenses of radioisotope production. In attempting to determine production expenses it has been necessary to make some arbitrary decisions concerning the apportionment of certain costs. It may be that the present pricing policies and the manner of apportionment of costs and sales prices are not entirely equitable. Therefore, in September the AEC made arrangements with Stanford Research Institute of Stanford, Calif., to study the cost and pricing structure of the present isotope distribution program.

Results of this study will help in establishing the basis for radioisotope prices in the future.

Distribution of Helium 3

To facilitate research studies on the properties of matter at temperatures near absolute zero, the Commission, on November 1, 1951, raised the limit on the amount of helium 3 that can be distributed to private researchers. It is now possible for an investigator to receive for a single project up to 20 cubic centimeters of contained helium 3 as 88 to 96 percent material, or 2,000 cubic centimeters of 2 percent material.

Biology and Medicine

New knowledge has been gained in the last 6 months on the effects of radiation and an increasing variety of radioactive substances on life processes of man, animals, and plants. A major objective continued to be to investigate and develop methods of protection from radiation. To understand better the hazards of atomic warfare, studies of the immediate effects of radiation on living tissues and of the possible effects on future generations through changes in the genes or units of heredity were continued. Recent noteworthy accomplishments in connection with spleen and partial body shielding are described briefly below. More data on the genetic effects of ionizing radiation are reported.

The Construction Program

Considerable progress was made in the construction of laboratory facilities for the biological and medical research program. While no great expansion over existing facilities has been made or is contemplated, the completion of buildings now under construction will increase the effectiveness of the present laboratory facilities.

Total value of laboratory facilities for the biological and medical research program completed or approved for construction will approximate 30 million dollars. At the end of December, the value of completed facilities was about 16.5 million dollars. Construction status of projects under way, totaling about 13.5 million dollars, was as follows:

Argonne Biological Laboratory. Construction was 70 percent completed with estimated date of completion, July 1, 1952. The estimated cost is $5,450,000.

Argonne Cancer Hospital. Construction was progressing rapidly with 70 percent completion; estimated date of occupancy around May 1952, total estimated cost, $4,275,000.

Brookhaven Biological Laboratory. Construction on the second of two biological laboratories has begun under a lump-sum contract. The estimated percentage of completion by December 31, 1951, was 25 percent, with occupancy anticipated by September 30, 1952. The cost is estimated at 1 million dollars.

Hanford Aquatic Laboratory. Construction progressing rapidly with 25 percent completion; tentative conclusion date is set for April 1952, at an estimated cost of approximately $500,000.

Los Alamos Biomedical Laboratory. Bids were opened for the construction of this facility, estimated to cost 2.3 million dollars and scheduled to be completed in May 1953.

Selection of Research Projects

Support of university sponsored research projects involving radiation and the effects of radioactive materials is an essential part of the program of the AEC. In biology these AEC-supported contracts may lie in almost any field, but the areas of plant and animal metabolism, development and genetics, parasitism and disease have been found to be most frequently concerned with radiation problems.

Specially qualified investigators are sometimes invited to undertake studies that the AEC believes to be pressing, but most projects originate with the investigators themselves, and their own attainments strongly influence decisions on AEC support. Under sponsorship of the institutions that employ them, they submit proposals for research studies, indicating over-all scientific significance and importance for the atomic energy program, together with budgets and plans for sharing the costs with the institution. Graduate students frequently work part time on the projects so that advantages accrue to the institutions and to the AEC which are not reflected in the financial arrangements.

A uniform formula for cost sharing would not fit the variety of circumstances encountered in these contracts, but the research institution normally pays the salaries of the principal investigators, and provides laboratory space and standard equipment. AEC provides the cost of extra scientific and technical personnel and special supplies and equipment. In the smaller contracts, equipment which is left after the completion of the work usually becomes the property of the institution. In order to stimulate many different lines of research and to give many different investigators experience in the field of atomic energy, AEC usually limits consecutive support for research contracts to 3 years.

Biology research contracts. During the period, new research contracts and renewals of existing contracts in biology totaling approximately $889,000 were approved. The largest contract, $69,000, went to the University of California at Davis, Calif., for studies on the effects of radiation on the longevity and work capacity of dogs. Such studies may contribute results which may be extrapolated to man. The contracts provide for studies of radiation effects on life processes in animals, plants, and bacteria; physiological studies, such as the mode of action of drugs, mechanisms of transfer from mother to fetus; and a number of genetic studies concerned with the rate and mechanism of production of mutations by radiation.

Accomplishments in Research

At Brookhaven National Laboratory, corn, tomatoes, potatoes, cotton, and other plants are being irradiated over the growing season in a field centered on a cobalt 60 source. In addition to furnishing basic information on the effects of radiation on plant growth, this is a means of increasing the number of mutations which may aid in breeding improved crop varieties. The first and second generation offspring of irradiated plants are being studied for the occurrence of desirable mutants or characteristics which might then be developed on a commercial scale. North Carolina State College is getting similar results in large scale experiments with peanuts irradiated at Oak Ridge National Laboratory. (Research in atomic energy and plant science is reported more fully in Part Three.)

ORNL has used the rate of chromosome breakage in the pollen of the plant Tradescantia as an accurate measurement of alpha or neutron radiation. This method was used successfully in measurements of radiation dosage for the tests at Operation GREENHOUSE.

Excretion of radioactive elements. Important progress has been made at the University of California Radiation Laboratory at Berkeley in developing solutions which when taken internally help to speed up the removal of radioactive elements which have become fixed in the animal body. Such chemicals are called chelating agents. A very promising substance, ethylenediamine tetracetic acid (trade name, Versen), forms very stable compounds with metal ions and therefore has a strong tendency to remove such ions from previously insoluble combinations. Versen has a low level of toxicity when used as a calcium salt, and it is rapidly excreted intact via the kidneys. Versen will also take up, or "chelate," a large number of metals—such as plutonium fission products—which displace the calcium and form new stable combinations. These also are excreted by the kidneys.

These results are of particular importance since radioactive metals when ingested are frequently immovably fixed in some particular part of the body and can eventually cause injury if they are not removed. Although to date these studies have been made only on animals, it may be possible to use chelating agents to remove radioelements ingested by humans.

Immunization studies. Studies have been made at the Brookhaven National Laboratory on the effects of radiation on immunization against diseases. Tests involving more than 600 mice show that gamma radiation from a Co 60 source has no detectable effect on antibodies already previously formed. However, irradiation before and during the immunizing injections can almost completely inhibit antibody formation. Irradiated mice are not protected from infection by passive immunization, that is transfer of antibodies from another animal which has responded to immunizing injections.

Dextran as a blood plasma substitute. Dextran is a complex sugar produced by the bacterium *Leuconostoc mesenteroides* which has proved to be an effective and useful blood plasma substitute. It is particularly interesting for possible use in the event of a large-scale catastrophe when natural blood plasma supplies would be limited. Using carbon 14 labeled dextran, the best analytical procedures have accounted for only about half the material injected into the animal body, and it is desirable to determine whether dextran is stored or eventually metabolized. At Argonne National Laboratory a program has been initiated to biosynthesize a uniformly labeled carbon 14 form of dextran in cooperation with the Commercial Solvents Corp., Terre Haute, Ind., and the U. S. Public Health Service. Dextrans of two different levels of carbon 14 activity have been produced; the higher activity lot is to be used for small animal experiments; the lower activity lot with human patients.

Studies using radiocarbon. Counting techniques for C 14 are being continually improved. The organic group at the Radiation Laboratory of the University of California is using counters consisting of ionization chambers with a vibrating reed electrometer for routine counting of C 14. They can count one disintegration per minute per milligram of barium carbonate to an accuracy of 1 percent. The minimum amount of radioactive carbon that can be detected is 0.01 disintegration per minute per milligram of barium carbonate.

This accuracy in routine counting of C 14 permits the use in human experiments of drugs and other organic compounds at such low levels of activity that little radiation harm is possible. For instance, short-term human experiments can be performed with as little as 1 microcurie of activity taking into consideration the large biological dilution. In spite of the rapidity of elimination, activity from 100 microcuries of C 14 labeled glycine fed to a human can be followed for 9 months.

Shielding of the spleen. Experiments made at Argonne National Laboratory have shown that shielding of the spleen of mice markedly reduces the injury from whole body irradiation. In order to understand the nature of this protective effect, tests have been made to determine the radiation dosage to the spleen alone which will inhibit the corrective effect of shielding after exposure of the remainder of the body to 1,025 *r* of X-radiation. The survival was greater even when as much as 600 *r* were delivered to the spleen.

Some mice survived even after five repetitions of 600 *r* (3,000 *r* total) of total body X-irradiation when the spleen was shielded. The control mice were all dead after the second dose. Experiments following removal of the spleen showed that its presence in the circulation for only 1 hour increased survival by 75 percent. Shielding of other organs showed similar but less marked protective effects. Administration of cell-free splenic extracts provided no protection to the irradiated animals.

Total body X-irradiation reduced the ability of rabbits to produce immunizing antibodies when antigens were injected shortly before or after radiation. Shielding of the spleen or appendix permitted animals to retain the immunizing ability.

Implantation of spleens from new-born mice increased the survival of irradiated mice after total body irradiation but not as much as did spleen shielding.

Atomic Bomb Casualty Commission

The Atomic Bomb Casualty Commission is administered through the National Academy of Sciences and is currently supported by a contract with the AEC. Its object is to study delayed radiation effects on the populations of Hiroshima and Nagasaki, Japan. An advisory committee, known as the Committee on Atomic Casualties, including representatives of the National Research Council, the AEC, and distinguished scientists in the fields of internal medicine, pediatrics, radiology, hematology, biochemistry, pathology, genetics, and biophysics has been established to work with the ABCC. The committee met in Washington in September and November to hear current reports of ABCC activities. The casualty commission's scientific staff includes 17 M. D.'s and Ph. D.'s, 4 nurses and 42 technicians of allied nations, and a larger number of Japanese. The proportion of Japanese is expected to increase when the peace treaty becomes effective.

Current data indicate a definite increase in the incidence of leukemia among the 2,000 or more people from Hiroshima who were within 2,000 meters of the explosion center. Since the exact incidence of leukemia among a normal Japanese population is unknown, the extent of the increase over normal is uncertain.

For the genetic studies, data are being taken on all completed pregnancies in both Hiroshima and Nagasaki (about half of which involve parents one or both of whom were exposed within the 1,500-meter zone). It is found that detectable malformations appeared in 1.18 percent of the offspring of parents who showed no immediate effects of radiation, while among offspring of parents who showed immediate evidences of radiation injury, the figure was 1.40 percent. Since the actual numbers are still small, the result is not as yet statistically significant. Though data on sex ratios must always be accepted with caution, it is of interest that among the offspring of women exposed within the 2,000-meter zone, the percentage of male births has been significantly lowered.

Genetic Studies

The extensive study of radiation-induced mutations in mice at the Oak Ridge National Laboratory continued to give important and significant results which warrant tentative conclusions on the nature of the mutations and on the over-all mutation rates. The mice used in the study were first generation hybrids of two inbred lines and carried the dominant and recessive genes for seven easily recognized gene pairs. The study is concerned particularly with mutations in these particular gene pairs (or loci) but all other dominant or recessive mutations are studied. The hybrid males were exposed to a single whole body dose of 600 *r* of 250 kilovolt X-rays and were mated after recovery from their temporary sterility.

Successive litters fathered by these males now total 48,000 from irradiated lines and nearly 38,000 from unradiated control mice. Among the offspring of the irradiated fathers a total of 53 recognized mutations have been found to date. The controls have given only 2. Assuming that all genes mutate at the same rate and that mice have about 20,000 different genes, this result indicates 1 new mutation for every 200 mice per *r* of radiation.

The distribution of the mutations among the seven gene loci clearly showed that these are not equally affected. There were none at one locus; as many as 28 at another. It seems likely that the over-all total represents a minimum figure, since some mutations may have caused death *in utero*. If the result is a fair sample of the effects of irradiation on all genes, it suggests that about 30 *r* of radiation cause mutations at double the rate that would occur in mice without irradiation. Mice have a considerably higher sensitivity to induction of mutations by radiation than was found in the fly Drosophila, on which previous radiation tolerance levels for humans were based. The findings with mice so far suggest that in so far as genetic effects are concerned, humans are more sensitive to radiation than previous estimates have indicated.

Mortality curves on X-irradiated mice of two different strains in other experiments have indicated that the females of both strains are slightly more resistant to radiation than the males.

Effects of Radiation

Studies of inbred strains of mice exposed to a range of X-ray doses during critical stages in embryonic development show clear abnormalities at dosages as low as 25 *r*. Reduction in oxygen content in the atmosphere before and during irradiation of pregnant mice has been found at Oak Ridge to provide a measure of protection for the embryos. The reduced oxygen alone had no effect on the mice. The result opens up possible methods for use of X-rays or other ionizing radiation during pregnancy.

Radiation experiments with bacteria. Studies of the radiation effects in bacteria indicate that the increase in the number of mutations is independent of the number of cell divisions which occur, and is related rather to the amount of synthesis of proteins and their building blocks which has taken place. It has been shown at the Oak Ridge National Laboratory that alcohol protects bacteria against radiation damage. The result has been confirmed with Drosophila flies at Oak Ridge and with mice at the Argonne National Laboratory.

Other substances which give some protection against X-ray damage are sodium hydrosulfite and dimercaptopropanol (BAL), para-dinitrobenzene, as well as morphine.

It was demonstrated at Oak Ridge that individual chromosomes in isolated pollen grains of the plant Tradescantia exposed to 50 to 100 percent oxygen showed breakage even more uniformly than from radiation. This rather surprising finding may indicate the instability of the chromosomes in isolated pollen grains and suggests how slight a disturbance may cause breakage or mutation.

Air Radon Measurements

In order to protect the health of workers in the Colorado-Utah uranium mines, the Division of Occupational Health, U. S. Public Health Service, is cooperating with the Health and Safety Division of the New York Operations Office on an evaluation of health hazards in the uranium mining industry.

Previously, radon samples had to be sent to one of three laboratories equipped to analyze them. The Health and Safety Division at New York developed and furnished the Public Health Service with instruments which now make it possible to analyze air radon samples inside a uranium mine within 30 minutes.

Civil Defense Liaison

In response to the request of Millard F. Caldwell, FCDA Administrator, that AEC appoint a staff member to work closely with FCDA in the discharge of mutual statutory responsibilities under the Civil Defense Act of 1950, Chairman Dean on March 30 designated Dr. Shields Warren, Director of the Division of Biology and Medicine, to fulfill this function. Mr. Robert L. Corsbie, Chief, Civil Defense Liaison Branch, was named as alternate on June 27, 1951.

At the invitation of the Commission, FCDA Administrator Caldwell and members of his staff met with the Commission and principal staff to discuss informally the FCDA program to date, to evaluate the usefulness of information and materials provided by AEC, and possible means of assistance by AEC in the future.

Design criteria for protective construction. The Civil Defense Liaison Branch has continued to work with the responsible program divisions of the AEC to formulate criteria of design for new AEC plants and facilities, taking into consideration the possibility of enemy attack in event of war, and including an assessment of the vulnerability of proposed sites and component locations.

Loan of instruments and radiation sources. The AEC continued to lend radiation detection instruments and radioisotopes for calibration of these instruments to State and local civil defense organizations. Instruments were lent to 28 State and local groups, the FCDA Regional Training Center, the Food and Drug Administration, and the Ninth Coast Guard District. Radioisotopes were provided to 25 organizations and the U. S. Public Health Service Environmental Health Center at Cincinnati, Ohio. Several civil defense agencies have been lent instruments or radioisotopes on two or more occasions. In many cases the individuals responsible for radiological defense training in these groups attended one of the five radiological monitoring instructor training courses given last year by the AEC in cooperation with the NSRB.

Instruments have been lent to Alabama, Connecticut, Georgia, Kentucky, Maine, Nebraska, Nevada, New Jersey, New Mexico, New York, North Dakota, Ohio, Oregon, South Dakota, Utah, Washington, and Wyoming; and to Milwaukee, Wis.; Berkeley, Calif.; Tacoma, Wash.; Greenville and Charleston, S. C.; Hopewell, Va.; Rock Island, Ill.; Minneapolis and Duluth, Minn.; Phoenix, Ariz.; and St. Petersburg, Fla.

Radioisotopes have been furnished to California, Connecticut, Georgia, Kentucky, Iowa, Maine, Nebraska, New Jersey, North Dakota, Ohio, South Dakota, Tennessee, Texas, West Virginia, Wisconsin, and Wyoming; and to the District of Columbia; Chicago and Rock Island, Ill.; Milwaukee, Wis.; Norfolk, Va.; Minneapolis and Duluth, Minn.; Phoenix, Ariz.; and St. Petersburg, Fla.

Legislative Proposals

The Commission has for some time been studying the provisions of the Atomic Energy Act of 1946, as amended, in the light of actual operational experience, and has recommended several amendments to the act.

Personnel Security Clearances Requirements

The first of these amendments relates to the requirements of the act for security investigation and clearance of participants in the Commission's program. Section 10 (b) (5) (B) (i) of the Atomic Energy Act contemplates a full background investigation of all individuals who will receive access to restricted data from Commission contractors, prospective contractors, and prospective licensees regardless of the degree of its security significance and the nature of the access which will be had.

This has resulted in an extremely large number of investigations, which has placed a substantial burden upon the investigative facilities of the Federal Bureau of Investigation. Reducing this burden by eliminating full background investigations of individuals who are not to have access to information of real security significance should speed the clearance of those who do require such access in order to carry out the Commission's urgent programs.

At the same time, the provisions of section 10 (b) (5) (B) (i) have the effect of limiting the two-way exchange of restricted data between AEC contractors and personnel engaged in related programs of the Armed Services, since under this section AEC contractors must agree not to permit any individual (including personnel of the Armed Services and their contractors, even though they may have been granted security clearance in accordance with the procedures of the agencies of the Department of Defense), to have access to restricted data until he has been investigated by the FBI and granted security clearance by the Commission.

To meet these problems, the Commission has drafted a proposed amendment to the act which would authorize the Commission to relate the scope and extent of the investigation required under the act to the nature and significance of the access to restricted data which will be had, and which would facilitate interchange of restricted data between Commission contractors and personnel engaged in related programs of the Armed Services. This amendment has been submitted to the Joint Committee on Atomic Energy for its consideration.

AEC's Internal Organization

The Commission has proposed, and submitted to the Joint Committee on Atomic Energy, other amendments to the act which fall into two broad categories. The first of these categories includes amendments designed to assist the Commission to better meet its responsibilities in connection with the expanding atomic energy program with greater organizational flexibility. Thus, it is proposed that section 2 (a) (4) (B) of the Atomic Energy Act be amended to eliminate the statutory requirement for certain divisions in the Commission organization, the statutory rate of compensation for the directors of these divisions, and the present limitation upon the authority of the Division of Research to enter into contracts for the conduct of research and development activities.

The other proposed amendment in this category would authorize the Commission to issue general regulations to effectuate the purposes of the Atomic Energy Act. Although the Commission considers that it has implied authority to issue such regulations, authority of this sort is usually expressly granted to Government agencies.

Strengthening Security

The other category of amendments relates to the strengthening of the security of the AEC program. One of these amendments would expressly authorize the Commission to arm its guards and couriers. Although such authority is undoubtedly implied in the Atomic Energy Act, it is believed that express statutory authority, similar to that

980705—52——4

possessed by the Federal Bureau of Investigation, the Central Intelligence Agency, and other agencies to carry firearms is important to allay the uneasiness which may be felt by some Commission personnel now carrying arms in the performance of their duties.

A second proposed amendment in this category would grant the Commission permanent authority to import, free of customs duty, emergency purchases of certain materials abroad. The Commission now has this authority under Executive Order 9829 but since the authority is based upon war legislation, it will expire no later than 6 months after the official termination of the war.

A third proposal in this category would grant the Commission authority essentially identical to that granted the Secretary of Defense and the Director of the National Advisory Committee for Aeronautics under section 21 of the Internal Security Act of 1950, to issue security regulations relating to protection of Commission property and facilities, violation of which would constitute a misdemeanor.

Another proposed amendment would extend the period of limitations for indictment for violation of sections 10 (b) (2), 10 (b) (3) and 10 (b) (4) from 3 to 10 years, to parallel a similar extension of the period of limitations for indictment for violation of the Espionage Act made in section 19 of the Internal Security Act of 1950.

Patents

Since 1949, more than 175 licenses have been issued to American industry to use the 372 patents owned by the AEC and available to industry on a royalty-free, nonexclusive basis. Fifty-seven licenses were issued in the past 6 months. Abstracts of the patents issued to the AEC are published regularly in a number of standard and professional journals; those issued up to Nov. 20 are listed in Appendix 9.

The expansion of the Commission's research program has resulted in a marked increase in the number of inventions submitted for patent consideration; from some installations, the number has doubled in the past year.

Patent Compensation Board

On November 20, 1951, the Patent Compensation Board made its first award on a patent application to Cyril E. McClellan, of Glen Burnie, Md. The award of $7,500 was for a patent application on the "Method and Apparatus for Effecting the Separation of Atomic or Molecular Species of Different Mass, Such as Isotopes," useful in separating isotopes of different mass on the principle that the time of flight varies with the mass of the respective ions. The findings and determinations are reported in the U. S. Patent Quarterly, volume 91, page 278.

The Patent Compensation Board has heard and disposed of five other claims.

Technical Information Services

The Commission's technical information operations are designed to serve two purposes: First, to provide to scientists, engineers, physicians, architects, and technicians working in the atomic energy program for contractors or the AEC essential classified and unclassified informational materials and services; and secondly, to discharge the Commission's obligation to disseminate unclassified information to those in the general scientific and technical community who are interested in the scientific and technical developments of the AEC program.

To a large extent, the products of technical information operations are cumulative as more and more information is collected, processed, disseminated and indexed. But to assure maximum usefulness, many special informational programs are necessary.

Publications

The contribution that the Commission's research activities make to scientific progress can be measured in part by the unclassified technical information rising within the project that is released and published. The AEC encourages project scientists to make their own arrangements for publication in established, privately supported scientific periodicals. The volume of material contributed for publication in this manner has helped to create a grave financial problem which threatens a breakdown of these channels of scientific communications. In recent months, the AEC has moved to help solve this problem by paying page costs for publication of material contributed by the project, whenever such costs are regularly assessed by the journals.

As other examples of action in this field, the Commission has entered into contracts with the American Chemical Society for publication in the Journal of the Society of a limited number of papers on the synthesis of radioactive compounds; and with the American College of Physicians for the publication of a monograph on "The Acute Radiation Syndrome in Man." In both cases the publication costs are being borne by the Commission.

In its centralized publishing program, the AEC has arranged for the publication of a number of books and documents. Some are distributed by the Superintendent of Documents, Government Printing

Office, while others are issued by private commercial publishers. A complete list of the publications now available is given in Appendix 8.

The major scientific book publishing program undertaken by the Commission is the National Nuclear Energy Series. During the past 6 months 4 books totaling 1,713 pages have been completed and published by the McGraw-Hill Book Co. under this program. In addition, the AEC Technical Information Service prepared a number of classified NNES volumes which were distributed only to authorized project personnel.

Report Distribution

To supplement the primary publications described above, the Commission endeavors to make available to the public that information which is contained in the AEC unclassified and declassified report files. Essentially complete sets of such files, together with the index materials, have been deposited in 40 scientific libraries throughout the country. Distribution of this material was completed during the past 6 months and copies of all future reports will be sent to these libraries concurrently with the official distribution. Smaller collections of selected reports are sent to numerous other libraries that have requested AEC documents. Also, a number of suitable reports which have not been otherwise published, are offered for sale at nominal cost by the Office of Technical Services, Department of Commerce. As of December 31, 1951, 1,478 such reports were available.

Cooperation with Government Agencies

The exchange of information among Government agencies and affiliated groups has received considerable study. During the past 6 months, a committee of representatives from the Army, Navy, Air Force, National Advisory Committee for Aeronautics and the AEC has developed standard procedures for cataloging and abstracting research and development reports, and for distributing reports, catalog cards, and abstract bulletins. Substantial progress was made in solving such problems as the standardization of microphotography, the establishment of interagency distribution lists, and the development of new techniques for rapid reproduction and dissemination of research results.

Research in Technical Information Methods

The Commission has worked with other Federal agencies and the National Research Council in the devolpment of new codes for record-ing material, electronic sorting devices, and facsimile transmission systems for the rapid transit of information between laboratories and libraries.

During the past 6 months, the AEC has completed a system for coding nuclear data suitable for use with the "Rapid Selector," an electronic sorting machine which operates with coded microfilms of documents. This machine was developed by the Department of Agriculture and is currently being modified for tests using atomic energy information.

A facsimile machine for transmitting printed information, in much the same manner as wire-photo transmission, has been used for operational analysis at Oak Ridge during the past year. The results have interested Government agencies and scientific libraries, and a number of Government libraries including the Library of Congress, have indicated their willingness to participate in further tests with the AEC. An interagency test operation in Washington has been arranged, using unclassified information. The results of these tests will be made freely available to all who are interested.

Information for Industry

The Commission, aware of the possible value to American industry of inventions and "know-how" developed within the atomic energy program, is making publicly available the information about equipment, apparatus, and techniques that is no longer deemed restricted data and that may be useful in general research and industry. Such technological information is not so readily suited for systematic publication and dissemination as are the laboratory research results. For this reason, the Commission has sponsored a program for collecting and distributing industrial technological information.

An Ad Hoc Committee on Technological Information for Industry was formed in September 1949. This committee, composed of 12 representatives of professional engineering societies and industrial publications (see Appendix 2) was asked "to test ways and means of providing American industry with technological information originating in the atomic energy program that is of use to industry generally, the dissemination of which will enhance our national security by increasing our industrial potential and productivity."

After a study of certain phases of the problem, this committee concluded that the Commission's declassification procedures are reasonably effective in dealing with the clearance of classified technological information and that no huge amount of declassifiable information of interest to industry was being held in the AEC files which the committee inspected. However, certain specific fields of information of probable value were noted and recommended for release. On the recommendation of the committee, a technical information officer was appointed to the staff of the AEC.

In November 1951, the Ad Hoc Advisory Committee met with representatives of the AEC and major contractors to consider ways and means of further expediting the dissemination of technological information on an AEC-wide basis. Beginning early in 1952, the Advisory Committee will visit various AEC sites to observe and evaluate specific activities in the field of information dissemination to the engineering societies and the technical press.

Engineering Education

Recognizing the problems brought to the field of engineering education by the rise of the atomic energy industry, the American Society for Engineering Education has tried to work out, through a system of committees on atomic energy, a program to incorporate nuclear science data in engineering curricula. The AEC is cooperating particularly in providing information for the preparation of teaching materials and facilitating the flow of such information to the engineering schools. At the suggestion of the ASEE, the AEC is preparing a "Sourcebook on Nuclear Engineering" for educators.

Architectural Training

Another profession which has felt the need for atomic energy information is that of the architects who are being called upon to design laboratories and other structures where radioactive materials are used. While considerable information in this field is readily declassifiable, there remains the problem of collecting, organizing, and disseminating the data. The American Institute of Architects has formed a Committee on Architecture in Nuclear Science, addressed to this task, which is collecting information from all sources. The Commission is giving its cooperation and support to this Committee. The AEC and the AIA sponsored jointly a "Symposium on Radioactivity Laboratory Design," which was conducted in Washington, November 27–29, 1951, by the Building Research Advisory Board of the National Research Council. Participants in this symposium included men who have played a key role in designing AEC facilities, and the attendance of some 300 was drawn from a wide cross section of U. S. design and construction experts. The complete proceedings of this conference will be issued by the Building Research Advisory Board.

Organization and Personnel

Reorganization in the General Manager's Office

In view of the increased workload required by the expanded program during the past year it became advisable to establish the position of Assistant General Manager for Manufacturing to coordinate and direct the manufacturing programs of the AEC including the functions performed by the Divisions of Production, Raw Materials, and Construction and Supply. Thomas F. Farrell, former deputy to the chief of the Manhattan Engineer District, joined the Commission on July 27, 1951, on this assignment.

A small Operations Analysis Staff was established for the Office of the General Manager by Dr. Manson Benedict. The members of the staff possess advanced training and experience in the physical sciences and detailed knowledge of the technical programs of the Commission. Their job is to provide the General Manager with analyses of technical problems which cut across the fields of two or more AEC operating divisions. The group examines matters of this type, suggests solutions, and recommends courses of action to carry out decisions made by management. The work they have done has already proved of extreme value.

Employment in the AEC Program

The number of workers in the atomic energy program continued to increase during the 6 month period. In construction work employment accelerated. Much of the growth reflects increased employment on the Savannah River and Paducah construction projects. All AEC construction and design contractors employed 45,735 workers on July 1. By December 31, 1951, this figure had risen to about 66,000. Employment in operations and research and development advanced at a slower rate, from 47,745 on July 1 to approximately 52,400 on December 31, an increase of about 10 percent. Direct AEC employment expanded from 5,646 to 5,750 during the same period.

Labor Management Disputes

The growing construction program has been attended by some interruptions arising out of labor management disputes. During 1951, up to November 30, an estimated 96,115 man-days were lost through work stoppages [9] on the Paducah construction project. This equaled 5.7 percent of man-days worked.

During the same period 32,288 man-days were lost on construction of the plant at Dana, Ind., as a result of work stoppages, or 3.7 percent of man-days worked.

Lost time at other construction projects was somewhat less. At Hanford, where the average number of workers employed on construction up to November 30, 1951, has been almost as great as at Paducah, 17,189 man-days were lost as a result of work stoppages, or 1.1 percent of man-days worked. The percentage of estimated working time lost during 1951 on construction of the new gaseous diffusion plant at Oak Ridge was 1.2. Almost no time was lost as a result of work stoppages on other AEC construction. Experience at the Savannah River project was exceptional. Employment increased rapidly from February, when construction started, to more than 22,000 workers at the end of December. During this period there has been no significant work stoppage.[10] Similarly, experience was excellent during an 18-month construction period at Arco, Idaho, where contractors employed a peak force of 2,112 workers on Reactor Testing Station construction. No significant work stoppage occurred after construction contractors and AF of L building trades unions executed a project agreement in July 1950.[11] No serious interruptions have been encountered on construction of the feed materials production center at Fernald, Ohio, since construction started in May 1951.[12]

Vital nonconstruction operations of the Atomic Energy Commission have continued free of interruptions from work stoppages. There has been no stoppage which threatened to interfere with atomic energy production. In one case involving 18 striking truck drivers employed at the Knolls Atomic Power Laboratory, considerable inconvenience was experienced by the contractor in maintaining essentially normal operations. Since operations at this location were not seriously affected during the period involved, November 15 to December 18, it was unnecessary for the AEC Labor Relations Panel to intervene in this dispute, despite a request from the union to do so.

---

[9] The Bureau of Labor Statistics definition of work stoppage has been used in measuring time lost. In its reports BLS includes work stoppages involving six or more workers and continuing as long as a full day or shift.

[10] Two unauthorized stoppages occurred, resulting in a loss of 1,162 man-days.

[11] Two short stoppages in August and November 1951 resulted in a loss of 117 man-days.

[12] 30.5 man-days have been lost or 0.02 percent of man-days worked.

Atomic Energy Labor Relations Panel

The Panel intervened in 8 disputes during the period from June 1 to December 1, 1951 (see Appendix 7).[13] Its services were invoked four times in disputes involving construction contractors and building trades unions. Two of the cases were controversies relating to payment of travel allowances, one at the Paducah project, the other at Dana. The other two cases involved negotiations of contract renewals between unions and contractors on Hanford construction. The other disputes involved employees of operations contractors. The Panel intervened in contract negotiations between Carbide and Carbon Chemicals Co. and A. F. of L. and CIO unions representing production and maintenance employees at three plants in Oak Ridge, Tenn. In these cases the contractor and the unions accepted Panel recommendations of uniform wage rate and progression schedules in the three plants. The remaining dispute was between Sandia Corp. and A. F. of L. unions representing separate bargaining units of production workers and office employees at Albuquerque, N. Mex. This case was still unresolved at the time this report was made.

In one other labor management controversy the disputes settlement authority of the Wage Stabilization Board was invoked. The President's Executive Order 10233 of April 21, 1951, provides that WSB may make binding settlements in disputes voluntarily submitted by the parties. The first voluntary submission of this sort accepted by WSB was a dispute over an increase in isolation pay between Atkinson-Jones Construction Co. and Pasco-Kennewick Building Trades Council, representing employees on construction work at Hanford. WSB had not issued its decision at the time this report was made.

AEC Nondiscrimination Policy

In line with Government policy, contracts entered into by the Atomic Energy Commission contain a clause prohibiting discrimination in employment because of race, color, sex, religion or national origin. Numerous conferences have been conducted with operating personnel and with the home offices of AEC contractors on compliance with this nondiscrimination clause. The Commission has recently assigned a personnel officer to aid in placement of qualified Negroes in AEC and contractor jobs.

---

[13] The Panel's report to the President on its activities during the period from June 1 to November 30 appears in Appendix 7. A report on the origin and functions of the Panel appeared in the Ninth Semiannual Report of the Atomic Energy Commission, January 1951, Superintendent of Documents, Washington 25, D. C. 40 cents.

Retention of Military Reservists and Draft Eligibles

The Commission has been allowed in most cases to retain the services of essential employees who have received calls to military service. The basic criterion used by the AEC in its endorsement and support of such deferments or delays is the individual's contribution to the atomic energy program and the extent to which the individual's loss would hinder the progress of the defense program.

Safety and Fire Protection

At the beginning of 1951, it was anticipated that because of the large amount of construction to be undertaken there would be a decided increase in the number and severity of accidents to personnel and in other interruptions in AEC operations. The total of AEC construction accidents has resulted in a frequency (accidents per million man-hours) of (4.38) at the end of November, as compared with 8.35 during 1950 and with last year's national average of 19.3 for all United States construction as published by the National Safety Council. The severity rate has increased from 1.06 in 1950 to 1.22 (days lost per 1,000 man-hours) in 1951 as compared to the 1950 National Safety Council average of 2.72. This is satisfactory experience in view of the tendency of accidents to increase in the early stages of construction jobs.

Accident experience among operations contractors has decreased from 3.31 in 1950 to 2.82 at the end of November. Frequency rate for Government employees decreased from 2.05 to 1.83 in the same period. The National Safety Council all-industry average frequency rate for 1950 was 9.30.

When related to insurance experience, the continued reduction of accidents is reflected in an average compensation insurance rate of 59 cents per $100 of payroll. In a typical group of 13 contractors, the actual loss rate in this group's experience is 37 cents per $100 of payroll, and amounts to a recoup of slightly under 8.5 million dollars on premium expenditure. This insurance savings is of course only a fraction of the dollars saved and time saved through the improved safety performance.

The over-all AEC fire loss experience continues to be far below comparable national averages. The marked decrease in fire risks in AEC activities has been accomplished by the dispersion of production facilities, modification of process methods to utilize less hazardous materials, and effectuation of many program improvements.

Part Two

Condensed AEC Annual Financial Report
Fiscal Year 1951

CONDENSED AEC ANNUAL FINANCIAL REPORT

FISCAL YEAR 1951

The financial position of the U. S. Atomic Energy Commission at June 30, 1951, and June 30, 1950; the results of operations for the fiscal years ended on those dates; and other financial data appear in the statements on pages 56–60. These statements and the accompanying comments constitute a condensed version of the AEC annual financial report for Fiscal Year 1951. As condensed, it contains only information that can be released without endangering the Nation's security. The first published annual financial statements of AEC appeared in the Commission's Tenth Semiannual Report to the Congress.

Practically all of the atomic energy program is carried out by private contractors and other Federal agencies working on a reimbursable-cost basis under the direction of AEC and using AEC-owned facilities. Most of the major contractors maintain for their AEC work separate accounting records which are an integral part of the AEC accounting system. The financial statements presented here are a consolidation of the statements of these contractors with those of the AEC itself and thus give a comprehensive financial picture of the atomic energy program.

The balance sheet and statement of operations have been prepared in conformity with the generally accepted accounting principles used by industry except that for security reasons certain data have been omitted. Chief among these omissions is that the statements give no recognition to inventories of source and fissionable materials and atomic weapons and weapons components. This results in an understatement in the balance sheet of inventories, total assets, and AEC equity, and means that production costs included in the statement of operations represent costs incurred during the year, i. e., input, rather than the cost of products completed during the year. These inventories are, of course, rigorously controlled and meticulously accounted for by AEC; but even their dollar amount cannot be publicly disclosed without divulging information that might endanger the Nation's security.

AEC auditors examine on a continuing basis the accounts of those contractors whose accounting records are an integral part of the AEC accounting system, and customary internal controls are maintained for direct AEC financial transactions. The Audit Division of the General Accounting Office independently audits the receipts and expenditures of AEC and its cost-type contractors. In January 1951 the GAO Corporation Audits Division started a survey of the Commission's operations preliminary to making a comprehensive audit of AEC similar to its audits of Government corporations. The survey is still in process and some phases of the audit are under way.

The condensed Comparative Balance Sheet, pages 56 and 57, sets forth the assets, liabilities and AEC equity at June 30, 1951 and June 30, 1950. Comments on this statement appear on pages 61–63.

The condensed Comparative Statement of Operations, page 58, shows costs incurred for the operating programs, other expenses and other income, and extraordinary charges for the years ended June 30, 1951 and June 30, 1950. Comments on this statement appear on pages 63–67.

The condensed Statement of Resources Received and Applied for the Year Ended June 30, 1951, page 59, indicates the total volume of business done by showing both capital and operating receipts and their expenditure or disposition. The excess of all such receipts over the sums applied during the year amounted to $1,161 million. This increase in cash working capital resulted from the adoption by the Congress of the policy of substituting cash appropriations for contract authority in providing for AEC's commitments.

The summary of U. S. Government Investment in the Atomic Energy Program, page 60, shows the amounts invested since the National Defense Research Council started the project in 1940 and the total amount charged to operations through June 30, 1951. It does not include any funds expended by the military departments of the Government on the application of atomic energy to their purposes since the establishment of AEC.

COMPARATIVE BALANCE SHEET AS

ASSETS	1951	1950
Cash and working funds:		
U. S. Treasury	$1, 454, 005, 609	$329, 842, 953
Contractors	102, 765, 861	34, 527, 486
Other Federal agencies	56, 842, 291	28, 941, 982
	1, 613, 613, 761	393, 312, 421
Accounts receivable less reserves	5, 412, 417	5, 783, 284
Inventories at cost less reserves	79, 587, 721	68, 196, 653
Prepayments	12, 928, 112	10, 730, 756
Properties, plant, and equipment at cost:		
Land and land rights	13, 961, 508	12, 117, 799
Production and research facilities	1, 484, 337, 431	1, 424, 046, 562
Community facilities	286, 806, 624	268, 850, 518
General facilities	139, 706, 417	104, 630, 099
Construction in progress	591, 202, 190	294, 787, 749
	2, 516, 014, 170	2, 104, 432, 727
Less reserve for depreciation and obsolescence	597, 538, 205	414, 940, 563
	1, 918, 475, 965	1, 689, 492, 164
Collateral funds and other deposits	50, 315, 338	48, 972, 131
Total assets	$3, 680, 333, 314	$2, 216, 487, 409

NOTES:

Inventories of source and fissionable materials and atomic weapons and their components have been excluded from the balance sheet.

Since 1943 the atomic project has had on continuous loan from the U. S. Treasury a substantial quantity of silver bullion which is installed as electrical connections in production facilities. The value of this silver, 362 million dollars at June 30, 1951, has not been included in the balance sheet.

As part of the domestic uranium program, the Commission has guaranteed minimum prices through March 31. 1958, for refined uranium and for uranium-bearing ores and mechanical concentrates. In addition, bonuses are payable under certain circumstances to encourage the discovery of new uranium resources. (See Domestic Uranium Program Circulars No. 1 through No. 6.) The Commission also has long-term commitments for the procurement of foreign ores.

OF JUNE 30, 1951, AND JUNE 30, 1950

LIABILITIES AND AEC EQUITY

	1951	1950
Liabilities:		
Accounts payable	$95, 501, 835	$52, 433, 201
Accrued leave	3, 588, 688	3, 527, 581
Working funds from other Federal agencies	18, 834, 712	5, 849, 504
Employees' and other funds on deposit	4, 713, 050	2, 621, 277
Deferred credits	411, 028	497, 221
Total liabilities	123, 049, 313	64, 928, 784
AEC equity:		
Equity, beginning of year	2, 151, 558, 625	1, 868, 509, 614
Additions:		
Congressional appropriations	2, 032, 143, 000	702, 930, 769
Transfers from other Federal agencies without reimbursement	4, 093, 772	7, 041, 582
	4, 187, 795, 397	2, 578, 481, 965
Deductions:		
Net cost of operations and extraordinary charges (see Comparative Statement of Operations)	622, 051, 692	416, 250, 145
Transfers to other Federal agencies without reimbursement	3, 461, 505	8, 642, 845
Collections paid to U. S. Treasury	4, 998, 199	2, 030, 350
	630, 511, 396	426, 923, 340
Equity, end of year	3, 557, 284, 001	2, 151, 558, 625
Total liabilities and AEC equity	$3, 680, 333, 314	$2, 216, 487, 409

NOTES—Continued

In addition, AEC and its cost-type contractors had the following commitments for construction and other services and materials not received at the balance sheet date:

	June 30, 1951	June 30, 1950
	(In millions)	
Fully covered by funds and receivables	$1, 458	$282
Against unfunded contract authority granted by the Congress	398	522
Total commitments	$1, 856	$804

Unobligated funds available to AEC were 41 million dollars at June 30, 1951, and 56 million dollars at June 30, 1950. No funds have been obligated to pay accrued annual leave of AEC employees.

COMPARATIVE STATEMENT OF OPERATIONS FOR THE YEARS ENDED JUNE 30, 1951, AND JUNE 30, 1950

	1951	*1950*
Production, research, and development:		
Source and fissionable materials [1]	$138, 272, 654	$112, 449, 129
Weapons [1]	141, 515, 021	93, 800, 063
Reactor development	40, 572, 011	27, 596, 200
Physical research (net) [2]	31, 488, 918	31, 128, 252
Biology and medicine	20, 615, 908	17, 687, 416
	372, 464, 512	282, 661, 060
Community operations:		
Operating costs	21, 030, 405	21, 356, 977
Less revenue	16, 993, 319	15, 551, 590
	4, 037, 086	5, 805, 387
Program direction and administration	23, 800, 838	22, 092, 169
Total program costs and expenses	400, 302, 436	310, 558, 616
Other current expenses and income:		
Depreciation	93, 734, 815	97, 019, 242
Projects abandoned	860, 727	7, 013, 312
Other charges	1, 072, 429	1, 148, 097
	95, 667, 971	105, 180, 651
Less other income	1, 331, 955	973, 242
	94, 336, 016	104, 207, 409
Net cost of operations	494, 638, 452	414, 766, 025
Extraordinary charges (net):		
Provision for obsolescence of certain facilities and inventories net of adjustment to depreciation accruals of prior years to reflect increase in estimated service lives of certain other facilities	126, 170, 958	----------
Other adjustments applicable to prior years' operations (net)	1, 242, 282	1, 484, 120
	127, 413, 240	1, 484, 120
Net cost of operations and extraordinary charges	$622, 051, 692	$416, 250, 145

[1] During 1951 certain types of costs previously charged to the source and fissionable materials program were charged to the weapons program. Costs for 1950 reported in this statement have been reclassified accordingly for comparative purposes.

[2] Costs have been reduced by proceeds from sales of isotopes aggregating $453,352 for the fiscal year ended June 30, 1951, and $222,130 for the preceding year.

STATEMENT OF RESOURCES RECEIVED AND APPLIED FOR THE YEAR ENDED JUNE 30, 1951

Resources received:			
Appropriations by the Congress			$2, 032, 143, 000
Reimbursements for work done for others			18, 902, 252
Community operations revenues			16, 993, 319
Sales of isotopes			453, 352
Interest and other income			1, 331, 955
Salvage on inventory disposals			674, 081
Transfers from other Federal agencies			4, 093, 772
Adjustments to prior years' operations increasing net cash working capital as of July 1, 1950			5, 370, 205
Total resources received			2, 079, 961, 936
Resources applied:			
Construction			459, 192, 206
Operating programs (gross)			417, 749, 107
Other current expenses			402, 700
Cost of work done for others			18, 902, 252
Excess of inventory procurements over issues			9, 905, 460
Increase in prepayments			2, 197, 356
Increase in insurance and other deposits			1, 343, 207
Transfers to other agencies			3, 461, 505
Collections paid to U. S. Treasury			4, 998, 199
Total resources applied			918, 151, 992
Excess of resources received over those applied added to cash working capital:	*June 30, 1951*	*June 30, 1950*	
Cash and working funds	$1, 613, 613, 761	$393, 312, 421	
Accounts receivable (net)	5, 412, 417	5, 783, 284	
Total cash working capital	1, 619, 026, 178	399, 095, 705	
Less liabilities	123, 049, 313	64, 928, 784	
Net cash working capital	$1, 495, 976, 865	$334, 166, 921	$1, 161, 809, 944

NOTE.—The substantial increase in cash working capital resulted from the adoption by the Congress in 1951 of the policy of providing cash appropriations, rather than contract authority for AEC's obligational requirements.

980705—52——5

U. S. GOVERNMENT INVESTMENT IN THE ATOMIC ENERGY PROGRAM AND THE CUMULATIVE COSTS OF OPERATIONS FROM JUNE 1940 THROUGH JUNE 1951

Appropriated funds disbursed, net of reimbursements:		
National Defense Research Council		[1] $468,000
Office of Scientific Research and Development		[1] 14,624,810
War Department (Manhattan Engineer District):		
Fiscal year 1943	$77,098,355	
Fiscal year 1944	730,321,470	
Fiscal year 1945	858,571,646	
Fiscal year 1946	366,355,447	
Fiscal year 1947 (part)	186,337,067	
		2,218,683,985
Atomic Energy Commission:		
Fiscal year 1947 (part)	146,092,939	
Fiscal year 1948	478,986,553	
Fiscal year 1949	627,873,553	
Fiscal year 1950	534,308,839	
Fiscal year 1951	920,467,872	
		2,707,729,756
Net disbursements		4,941,506,551
Unexpended balance of appropriations, June 30, 1951		1,434,602,201
Total appropriated funds		6,376,108,752
Less:		
Collections paid to U. S. Treasury	[2] 10,931,380	
Property and services transferred to other Federal agencies without reimbursement, net of such transfers received from other Federal agencies	[3] 2,482,232	
		13,413,612
Total investment through June 30, 1951		6,362,695,140
Less AEC equity at June 30, 1951 (see Comparative Balance Sheet)		3,557,284,001
Cost of operations June 1940 through June 1951 including (1) depreciation and obsolescence, and (2) inventories of source and fissionable materials and atomic weapons and components at June 30, 1951		$2,805,411,139

[1] Based on published reports.
[2] From Jan. 1, 1947, to date. Prior data not available.
[3] For the fiscal years 1949, 1950, and 1951. Prior data not available.

NOTE.—The total appropriated funds through June 30, 1951, accounted for in this statement consist of (1) funds invested in the atomic bomb project before the Atomic Energy Commission started operation of the atomic energy program and (2) funds appropriated to AEC through June 30, 1951, including unexpended balances transferred by the War Department to AEC. The statement does not cover funds that the Armed Services have expended on the application of atomic energy to military purposes since the establishment of AEC.

Comments on the Comparative Balance Sheet

Cash in U. S. Treasury consists almost entirely of the unexpended balance of congressional appropriations. The large increase over the balance at June 30, 1950, arose chiefly from the increase in outstanding commitments for construction projects for which funds have been provided by the Congress.

Funds with contractors are (1) the unexpended cash advanced to contractors whose contract accounts are an integral part of the AEC accounting system and (2) the net outstanding advances to other contractors. The increase over the balance at June 30, 1950, reflects a general acceleration in contractor construction and operational activities plus substantial advances to two new contractors.

Accounts receivable arise chiefly from rentals and other community services and from refunds due from contractors under interim or final contract settlements.

Inventories consist of stores (mainly materials, supplies, and parts normally used or consumed in operations or maintenance work) special reactor materials, and other special materials. These are carried in the accounts at cost, and reserves are established to provide for estimated losses that will be incurred upon disposal of excess or obsolete stores. For security reasons no amounts have been reported for inventories of source and fissionable materials, production work in process, and finished atomic weapons and weapons components. Inventories of construction materials and supplies are included in construction in progress.

The largest single item of *prepayments* represents amounts advanced for the purchase of foreign ores and concentrates not yet received in this country.

The investment in *properties, plant and equipment* increased substantially during the year. Net construction costs incurred during the fiscal year 1951 amounted to 459 million dollars as against 256 million dollars for the fiscal year 1950.

The original cost of completed plant as of June 30, 1949, was determined by contractor and AEC personnel under the supervision of engineering and accounting consultants. All additions to plant since that date have been recorded at cost as acquired.

Depreciation of plant and equipment is recorded in the accounts on the basis of engineering estimates of the useful service life of each type of facility. Because the bulk of the production facilities are unique and without precedent in industry, the accuracy of service-life estimates is admittedly uncertain. The estimates are periodically reviewed and revised as experience indicates. Allowance for obsolescence is made after a decision has been reached that a facility has become obsolete. During fiscal year 1951 adjustments were made in the accounts to reflect an increase in the estimated service lives of certain important facilities and to provide for the estimated loss on certain other facilities unused for some time and now considered definitely obsolete.

Collateral funds and other deposits consist chiefly of funds invested in United States securities and placed in escrow for the protection of certain contractors against financial loss in the event of catastrophe. The contingent liabilities thus provided for relate to workmen's compensation claims, employee benefit plans, and general public liability.

These collateral funds were established early in the atomic energy program when the hazards of atomic energy work were unknown and normal casualty insurance could not be purchased. Demands for establishing this type of fund lessened as it became clear that the safeguards set up for protection against personal injury and property damage were effective.

The 43-million-dollar increase in *accounts payable* during the fiscal year resulted from the establishment of a new installation and a general acceleration in activities.

Commitments, shown as footnotes on the Comparative Balance Sheet, increased greatly during the year. The increase in contractual commitments arose chiefly from the expanded construction program.

Congressional appropriations account for the principal increase in *AEC equity*, and the net cost of operations explains the principal decrease. The congressional appropriations made to AEC for fiscal year 1951 were provided in four separate acts as follows:

TITLE OF ACT	*Amount appropriated*	*Date of approval of act*
General Appropriation Act, 1951	$647,820,000	Sept. 6, 1950
Supplemental Appropriation Act, 1951	260,000,000	Sept. 27, 1950
Second Supplemental Appropriation Act, 1951	1,065,000,000	Jan. 6, 1951
Fourth Supplemental Appropriation Act, 1951	59,323,000	May 31, 1951
Total	$2,032,143,000	

The initial appropriation for 1951 included $414,000,000 cash to liquidate obligations incurred under contract authority granted by the Congress in prior years. At the same time the Congress authorized AEC to enter into contracts up to a total amount of $300,150,000 for which funds will be appropriated in future years. Commencing with the first Supplemental Appropriation Act of 1951, however, the Congress discontinued the practice of granting contract authority and provided funds in the full amount estimated to be necessary for obligational requirements. As a result the AEC carried substantial unexpended balances of appropriations into fiscal year 1952. The Atomic Energy Act of 1946 provides that funds appropriated to the

AEC shall, if obligated by contract during the fiscal year for which appropriated, remain available for expenditure during the 4 succeeding years. Recently the Congress adopted the practice of merging with the current year's appropriation to AEC the unexpended balances of prior years' appropriations. This consolidation of appropriations has facilitated the application of industrial accounting practices to AEC's work.

Comments on the Comparative Statement of Operations

This statement shows the net cost of operations of the various AEC programs, other current expenses and income, and extraordinary charges for the fiscal years 1951 and 1950. For reporting purposes the production, research, and development activities of the Commission are classified into five programs—source and fissionable materials, weapons, reactor development, physical research, and biology and medicine. In addition to its costs for these five major programs, AEC incurs costs for community operations and for program direction and administration. The total cost of the major and supporting programs in 1951 amounted to $400,302,436, an increase of 29 percent over 1950, and reflected the expansion of AEC activities. These costs do not include depreciation of plant and equipment which is reported as a single item under *other current expenses.* Net cost of operations for 1951 amounted to $494,638,452, an increase of 19 percent over 1950. During 1951 certain extraordinary allowances and adjustments were made for obsolescence and changes in depreciation accruals, amounting to a net charge of $126,170,958. No similar charge occurred in 1950. After giving effect to this charge and other adjustments applicable to prior years' operations, the net cost of operations and extraordinary charges carried to the AEC equity account for the year 1951 was $622,051,692.

Source and Fissionable Materials and Weapons

The operating costs for the source and fissionable materials program cover the materials and operations required to produce the fissionable materials, uranium 235 and plutonium. The major activities are exploring for and procuring uranium ores; processing the ores into feed materials for the plants at Oak Ridge and Hanford; and there completing the manufacture of uranium 235 and plutonium. In addition, research and development work is conducted to improve the efficiency of the manufacturing processes.

The weapons program comprises weapons research and development and the manufacture, testing, storage, custody, and surveillance of atomic weapons.

The operating costs of these two programs in 1951 amounted to $279,787,675—approximately 70 percent of the total program costs and expenses.

Reactor Development

The costs of reactor development related to four operations: research and development on specific reactors, research and development on reactors in general, the operation of specific reactors and processing plants, and the operation of the Reactor Testing Station in Idaho. The sharp increase in the cost of reactor development in 1951 indicates the greater scientific and technical effort applied to developing reactors designed for propulsion of military craft and to developing more efficient reactors for producing fissionable materials.

Physical Research

The program of research in the physical sciences is designed to continue and increase the world leadership of the United States in the field of atomic energy by providing an expanding background of basic scientific knowledge, to which the fundamental sciences of physics, chemistry, metallurgy, and mathematics contribute. The program also includes the production of radioisotopes at Oak Ridge for use in research, medical therapy, and industrial processes. Increased revenue from isotope sales and the curtailment of stable-isotope production resulted in a decline of 35 percent in the net costs incurred for the isotope program in 1951 as compared with 1950.

The following table shows the costs of the major activities that make up the physical research program:

	1951	*1950*
Physics	$16,614,038	$16,766,072
Chemistry	9,790,583	8,563,540
Metallurgy and materials	3,078,114	3,423,467
University training and cooperation	961,056	999,528
Isotope production (net)	850,978	1,310,323
Other costs	194,149	65,322
Total	$31,488,918	$31,128,252

Biology and Medicine

The biology and medicine program includes the establishment and use of standards to protect the health of people who are or may be exposed to radiation; the promotion and direction of research utilizing atomic energy and its products in biology, biophysics, and medicine; and the dissemination of related information that can be released without endangering the Nation's security.

All activities in the field of biology and medicine except fellowships increased in 1951, as shown by the following table:

	1951	1950
Cancer research:		
Medical	$964, 684	$848, 509
Free distribution of isotopes	386, 585	335, 267
	1, 351, 269	1, 183, 776
Medical research—general	6, 301, 037	4, 950, 616
Biological research	8, 771, 079	7, 926, 339
Biophysics research	3, 415, 294	2, 769, 066
Fellowships	487, 731	568, 784
Special training	289, 498	288, 835
Total	$20, 615, 908	$17, 687, 416

Community Operations

In support of its facilities for the manufacture of fissionable materials and weapons, the Commission operates the towns of Oak Ridge, Tenn.; Richland, Wash.; and Los Alamos, N. Mex.; and in addition, provides some housing at other locations. The net cost of this program includes the cost of the operation of housing, commercial facilities, and all of the usual municipal functions, offset in part by revenues.

Because of decreased operating costs and increased revenues, the net cost of operating the AEC communities in 1951 declined by more than 30 percent to $4,037,086, from the preceding year's $5,805,387. Depreciation of community plant and equipment, a substantial item of expense, has not been included in the costs of community operations. Depreciation accruing on all AEC facilities appears under *Other Current Expenses and Income* in the Comparative Statement of Operations.

Operating data for the three AEC communities and the housing at other locations follow:

	1951			1950
	Costs	Revenue	Net costs (net revenue)	Net costs (net revenue)
Oak Ridge	$9, 157, 200	$7, 613, 040	$1, 544, 160	$2, 989, 072
Richland	6, 235, 640	4, 822, 990	1, 412, 650	1, 015, 109
Los Alamos	5, 393, 080	4, 183, 123	1, 209, 957	1, 873, 837
Sandia	208, 093	317, 152	(109, 059)	(81, 050)
Colorado	36, 392	57, 014	(20, 622)	8, 419
Total	$21, 030, 405	$16, 993, 319	$4, 037, 086	$5, 805, 387

In 1951 the net revenues secured from real estate operations and utility services were more than offset by the net costs of municipal services and operation of the hospitals. Real estate and utility revenues increased sharply, and the net costs of hospital and municipal services were reduced below the level of the preceding year.

The following table shows comparative data for each of the major services in 1951 and 1950:

	1951			1950
	Costs	Revenue	Net costs (net revenue)	Net costs (net revenue)
Real estate operations	$7, 211, 969	$10, 908, 940	$(3, 696, 971)	$(2, 564, 517)
Utility services	3, 278, 195	3, 682, 994	(404, 799)	(135, 716)
Hospital services	2, 951, 788	2, 111, 101	840, 687	1, 031, 767
Municipal services	7, 588, 453	290, 284	7, 298, 169	7, 473, 853
Total	$21, 030, 405	$16, 993, 319	$4, 037, 086	$5, 805, 387

Program Direction and Administration

The costs of program direction and administration during 1951 and 1950 are sumarized in the following table:

	1951	1950
Salaries	$18, 176, 005	$16, 296, 388
Other	5, 624, 833	5, 795, 781
Total	$23, 800, 838	$22, 092, 169

The increase in the 1951 cost of program direction and administration was proportionately smaller than the increases in total program costs and expenses. The fact that the cost of program direction and administration constituted only 5.9 percent of total operating program costs and expenses in 1951, compared with 6.9 percent in 1950, is especially significant in view of the added workload resulting from the increased tempo of AEC activity. At June 30, 1951, the total number of full-time AEC civilian employees engaged in all programs was 5,646.

Other costs consist of travel, office supplies, rents, and such services as communications, printing, shipping, certain guard services, and utilities. The amount for 1950 includes a nonrecurring expense of $715,468 for financial assistance to off-site schools near Hanford. Assistance to such schools by AEC was made unnecessary when Public Law 874, Eighty-first Congress, was enacted to provide financial assistance by the U. S. Commissioner of Education for local educational agencies in areas affected by Federal activities.

Other Current Expenses and Income

Current expenses not distributed to operating programs consisted of depreciation of plant and equipment, write-off of abandoned projects, and other charges. In 1951 these other charges included such items as property donated to off-project schools, undistributed service costs, and write-downs on property transferred between installations. Income not applicable to programs amounted to $1,331,955 in 1951 and included interest on collateral funds, royalties, and rentals.

Extraordinary Charges

The allowance for obsolescence less certain depreciation adjustments amounted to $126,170,958 in 1951. The depreciation and obsolescence policy under which these adjustments were made has been discussed on page 61. No similar adjustments were made in 1950.

Other entries during 1951 applicable to prior years' operations resulted in a net charge of $1,242,282. Major items included in this amount were inventory and plant adjustments, return of unexpended funds by another Federal agency, and refunds of excess overhead and insurance premium payments.

As in any large enterprise, it is impracticable and undesirable to hold open the accounts and delay the reports for each year until all accrued assets and liabilities applicable to that year can be exactly determined. In this year's financial report such adjustments to prior years' operations are shown at the end of the Comparative Statement of Operations rather than as a direct charge or credit to AEC equity. The operating statement thus shows all the operational factors affecting AEC equity between the two balance-sheet dates regardless of whether they are financial transactions actually occurring during the year of the report or adjustments of amounts reported in prior years.

Part Three

Atomic Energy and Its Applications in Plant Science

ATOMIC ENERGY AND ITS APPLICATIONS IN PLANT SCIENCE

The Atomic Energy Commission has two broad objectives in fostering and supporting certain research in plant science. The first is to determine the effects of radiation and radioactive products upon plants in order to broaden scientific understanding and to aid manufacturers and users of atomic energy in adopting measures to safeguard life and property. As a result of such studies, AEC and other users of atomic energy products have gained knowledge that enables them to carry out their present operations with confidence that they can protect crops and other property from damage.

Research on the effects of radiation on plant growth and reproduction is necessary to cope with circumstances that may follow atomic explosions. Research on soils, fertilizers, and movement of minerals in plants is carried out to evaluate the effect of fission products from atomic explosions and from production operations. At present fission products are being deposited on the earth in minute amounts. For present and future operations, it is necessary to understand their distribution in the soil, their uptake and concentration by plants, and their effect upon animals which might eat the plants.

The AEC's second broad objective in fostering plant science research is to help in the application of atomic energy products and techniques to fundamental and applied research with plants, as in other fields, and in encouraging projects which may benefit the Nation's people or industries.

AEC financial support of research into farming practice problems is confined to fertilizer studies using radioactive materials. The studies themselves are carried on by other agencies. AEC helps finance preparation of the radioactive materials. The bulk of AEC expenditures on plant science research goes into fundamental studies of plant genetics, physiology, and pathology. The results may eventually yield knowledge that the agricultural experimenters may employ in creating new plant strains, improving pest controls, or otherwise increasing the return per acre and per man in agriculture. The AEC contribution comes in the main in these fundamental fields of scientific knowledge, not in the fields of immediate application which are the province of Federal, State, and private agricultural establishments.

AEC has reported briefly on research in plant life in its regular semiannual accountings to the Congress, particularly in the Sixth

Semiannual Report [1] which covered the broad field of the life sciences. The present report deals more fully with the effects of radiation and atomic energy fission products on plants and specifically the advances in farm practice, actual and prospective, from plant science research. It is not intended to be a report on the AEC's fundamental basic research on the effects of radiation on the genetics and biochemistry of living organisms. This is another and equally large field which holds promise of eventual aid to more efficient production of crops.

Scope of the Program

During the fiscal year ended June 30, 1951, AEC devoted to research on plant life 1.3 million of 20.6 million dollars allocated to the entire field of biology and medicine. The money was spent:

a) $800,000 for research carried out in laboratories owned or financed by AEC: Argonne National Laboratory, operated by the University of Chicago; Brookhaven National Laboratory, operated by Associated Universities, Inc.; Oak Ridge National Laboratory, operated by Carbide and Carbon Chemicals Co., a division of Union Carbide and Carbon Corp.; the University of California's Radiation Laboratory at Berkeley and Atomic Energy Project at Los Angeles; and the Hanford Plutonium Works, operated by General Electric Co.

b) $500,000 for cost-sharing contracts with universities, colleges, and private institutions and one cooperative project with the United States Department of Agriculture. (See p. 64 for more detailed statistics on the scope of the biology and medicine program for 1951 fiscal year.)

Under AEC's cooperative agreement with the USDA, radioactive fertilizers were prepared and distributed for research use at 29 state experiment stations and in Puerto Rico and Canada. During 1951, AEC allocated $185,000 to this project, which includes also the operation of certain facilities at USDA's Beltsville, Md., Experiment Station. About $320,000 was spent under 48 smaller cost-sharing contracts for plant life research projects at 33 universities, colleges, and private institutions in 26 states.[2] (See Appendix 5 for a list of these contracts.)

[1] Sixth Semiannual Report to Congress, July 1949, Superintendent of Documents, Government Printing Office, Washington 25, D. C., 45 cents.

[2] Statistics as of Nov. 30, 1951.

Selection of Research Projects

Research studies for AEC laboratories are chosen with primary emphasis on problems of the atomic energy industry, such as the effects of radiation and radioactive materials on plants and other organisms and the biological synthesis of materials that incorporate radioactive "tracer" atoms. The AEC laboratories also study major applications of atomic energy in fundamental and practical research, especially those applications that require the nuclear reactors, particle accelerators, special laboratories, and other equipment available only in large, Government-owned institutions.

Several factors are considered in choosing the second group of research projects, which are performed in universities and other institutions under contracts in which AEC underwrites part of the cost. Projects are preferred which supplement and enrich the atomic energy industrial studies of AEC laboratories, or which bring atomic energy into areas of scientific investigation where it has not been used before, or which give promise of developing new techniques in the use of atomic tools.

The professional attainments of scientists who will direct the work enter strongly into decisions on support for particular projects. Specially qualified investigators sometimes are invited to undertake studies that the atomic energy industry particularly needs. The greater part of AEC-supported research in plant science originates with the investigators themselves and is on subjects they have selected in line with their professional interests. Under sponsorship of the institutions that employ them, they seek AEC aid by submitting descriptions of the proposed studies and their scientific or practical significance, together with budgets and plans for sharing the costs.

The part of the cost that the sponsoring institution proposes to carry is considered. A uniform formula for cost-sharing could not fit the variety of circumstances encountered in these contracts, but on the average AEC contributes about half the direct cost of those studies in plant life for which it provides support. The research institution typically pays the salaries of the principal investigators and provides laboratory space, existing facilities, and standard laboratory equipment, while AEC carries the cost of extra personnel and special supplies and equipment.

Most of the accepted projects cover basic work that requires several years to finish, but AEC usually allots funds to them for 1-year periods. If they continue to bear sufficient promise and funds are available, renewals for additional periods are considered. To stimulate many different lines of research and to give as many researchers as possible experience with the tools of atomic energy, AEC does not assure continued support to a particular plant research project beyond the third year.

Aids to Research

Apart from such direct support of selected projects, AEC produces stable and radioactive isotopes and other research materials and sells them at incentive prices to investigators (see Appendix 12).[3] Short courses in the use of isotopes in research were given under AEC auspices, principally at Oak Ridge. Seventy-one researchers in the field of plant science have completed the Oak Ridge course. Their fields of work have ranged from plant biochemistry and microbiology to work with cotton, corn, pecans, tropical plants, naval stores, golden rod, peanuts, and fruit trees.

As a companion service to the isotopes program, qualified researchers may have material they are studying exposed to radiation in AEC-owned nuclear reactors. Argonne, Brookhaven, and Oak Ridge National Laboratories grow medicinal and other important plants under conditions that cause them to build radioactive materials into their structures, thereby producing compounds useful in biological and medical research. AEC also sold isotopes to eight independent institutions that synthesize and sell isotope-tagged compounds (see page 133).

Research Policy

The Atomic Energy Act of 1946 directs AEC "to exercise its powers in such manner as to insure the continued conduct of research and development activities" in several stipulated fields, and "to assist in the acquisition of an ever-expanding fund of theoretical and practical knowledge in such fields. To this end the Commission is authorized and directed to make arrangements (including contracts, agreements, and loans) for the conduct of research and development activities relating [among other things] to utilization of fissionable and radioactive materials for medical, biological, health, or military purposes," and "the protection of health during research and production activities." The law calls for "a program of federally conducted research and development to assure the Government of adequate scientific and technical accomplishment" and also "a program of assisting and fostering private research and development to encourage maximum scientific progress."[4]

---

[3] AEC-produced isotopes are sold at direct costs plus shipping charges, with nothing added for capital costs, depreciation or interest. A single exception is isotopes destined for cancer research and treatment, on which the users pay only transportation costs.

[4] Atomic Energy Act of 1946, Sections 1 and 3.

Effects of Radiation on Plants

Atomic radiation affects all living things. The degree of effect depends on the kind of radiation, the amount and rate of exposure, and the ability of the species and individual specimen to withstand radiation. In its work with plants, the atomic energy program studies the effects of radiations on all aspects of plant life, on development, growth, yield, and heredity, on particular organs, on micro-organisms and fungi that influence growth or that feed upon plants, on cells and on hormones and enzymes of the plants.

Experiments have yielded fundamental knowledge of the behavior of plants and plant materials after exposure to radiation. There is no sharp division between many processes of plant and animal life; and the knowledge gained from plants frequently can be applied directly to research on radiation effects in animals and man.

The work has confirmed that damage in plants is directly related to the amount and rate of exposure to radiation, that when radiation is heavy enough it retards growth, reduces yield, and causes malformations. It has confirmed that the less complex organisms have greater resistance to radiation than more complex creatures. Some evidence has been found that small, controlled dosages of radiation may eventually prove effective in treating certain plant diseases. It is possible that genetic changes induced by radiations can improve strains of crop and forage plants.

Intense Radiation and Plant Development

Limited studies of the effects of heavy radiation exposure upon plants were made before the advent of AEC. Since 1947, much of the work in this field has been carried on at Brookhaven National Laboratory, Upton, Long Island, N. Y. Potatoes, corn, tomatoes, and other plants have been exposed to radiation of various kinds, intensities, and rates, and the gross effects on the plants evaluated.

The work with seed and plants of white potatoes is typical. Three kinds of radiation were used: *a*) Seed potatoes were exposed to *X-rays*[5] and the plants observed through two growing seasons; *b*) other seed potatoes were exposed to beams of *neutrons*[5] from a

[5] The atomic energy industry deals with several kinds of radiations. X-rays are generated in the electrons that circle the nuclei of atoms. *Gamma rays* behave like X-rays but are produced by disturbances within the nuclei, and they generally have shorter wave lengths and greater penetrating power than X-rays. Both X-rays and gamma rays are waves of electromagnetic energy, as are light and radio waves, but have a much shorter wave-length.

Other radiations from nuclei are *alpha particles,* comparatively heavy bits of subatomic matter that carry positive electrical charges; *beta particles,* much lighter and carrying negative charges; and *neutrons,* particles whose absence of electrical charge enables them to penetrate deep in solid matter.

980705—52——6

nuclear reactor; *c*) potato plants were grown in a field where they were constantly exposed to varying amounts of *gamma* radiation.[5]

Effects of X-rays on Seed Potatoes

Brookhaven's first pilot experiments in exposing seed potatoes to radiation were designed to test their radiation tolerance. Seed pieces containing "eyes" were given various doses of X-rays up to 38,400 roentgens (*r*),[6]—a very heavy exposure—more than 60 times the amount fatal to people when their entire bodies are exposed to radiation. After exposure, the pieces were planted.

There was no observable effect among the pieces that received up to 300 *r*. Above 300 *r*, plants were delayed in emerging from the soil and in flowering. The growing plants were smaller than normal and those from the more heavily exposed pieces of potato tuber had malformed leaves. The malformed leaves were thickened and crinkled and withered off or were shaded out in later growth. Leaves that were formed later were not malformed, but the whole plants were dwarfed at higher radiation levels (see photo). Above 2,400 *r*, the survival rate fell off rapidly, and the most heavily exposed pieces failed to sprout.

Most of the delayed plants seemed to catch up with nonirradiated "control" plants toward the end of the season, but the heaviest exposed seed that germinated attained a height of only a few inches. The yield of mature potatoes fell off in proportion to the amount of radiation exposure.

After the harvest, seed pieces that failed to sprout were dug up. Normally, potatoes that fail to sprout would rot; these tubers, heavily exposed to radiation, were still fairly firm even after months underground. The reason for their state of preservation has not yet been determined.

Results of second season. In the 1949 season, potatoes grown from 1948's irradiated seed pieces were planted, but were not themselves exposed to radiation. The plants appeared normal, and the harvest showed no consistent relation to the amount of radiation the original potatoes had received. Apparently the stock that survived had recovered physically from the original exposure.

---

[5] See foot note on page 75.

[6] Roentgen is a unit, named for the scientist who discovered X-rays, which is a measure of the ionizing effect of X-rays. X-rays, like other radiations discussed here, have the power to separate electrons from atoms. When this happens, the atom is no longer electrically neutral. With the loss of the negatively charged electron, the remainder of the atom carries an over-all positive charge. The separated electron and the positively charged remainder are known as an *ion pair*. A roentgen is roughly that quantity of X-rays that will produce 2 billion ion pairs in a cubic centimeter of dry air at standard pressure and temperature.

After the first year of pilot experiments, Brookhaven planted a larger number of potatoes under more precisely controlled conditions. Half of each seed potato was irradiated, and the other half left unexposed as a control. The halves were then planted in a random scheme to minimize the effects of variations in soil, water, and other conditions in the field on the experimental results. The resulting crop was harvested by hand. This test indicated that X-ray exposures below 300 *r* had no significant effect on yield, that 1,200 *r*

Inserted by each row of potatoes is the number of roentgens of X-ray radiation the tubers in this row received before planting. Above 1200 roentgens the growth was significantly reduced and above 4800 roentgens little or no growth occurred. Brookhaven National Laboratory.

caused a significant decrease, and that yields at 4,800 *r* were extremely low.

Neutron Irradiation of Seed

In a further experiment, seed potatoes were irradiated with neutrons in the nuclear reactor at Oak Ridge National Laboratory,[7] and Brookhaven planted and harvested the crop in the same manner as in

[7] This experiment was performed before the completion of Brookhaven's own reactor, which was first operated in mid-1950.

the X-ray experiments. It appeared that for the same radiation dosage neutron irradiation produced about four times the effect on yield as X-rays. The unusually damaging effects of neutrons also have been observed with animals, and are a subject of extensive investigation. Perhaps an understanding of the lethal effects of neutrons may lead to a better understanding of the mechanism of radiation damage.

Experiments with hemp seed. At Argonne National Laboratory an important series of tests has been made on the effects of neutron irradiation of seed of the hemp plant (*Cannabis sativa*). This is a dioecious species (one having separate male and female plants). In normal populations the male and female plants occur in a one to one ratio. The seeds were exposed to thermal neutrons in the Argonne heavy water reactor for 2 to 16 minutes.[8] The most interesting result noted among the plants grown from these neutron irradiated seeds and among their first and second generation offspring was a significant influence on the sex ratio. This was consistently in favor of females. For example, plants of the 4-minute neutron exposure showed a final ratio of 142 females to 81 males. Apparently selective death of male plants occurs between the time of irradiation and emergence of seedlings from the soil. These plants were then intercrossed and their unirradiated seeds planted. Significantly, their offspring still showed the predominance of female plants though at a somewhat lower point than for the directly irradiated ones. Apparently the predominance of female plants would gradually disappear in subsequent generations.

Irradiation of Growing Plants

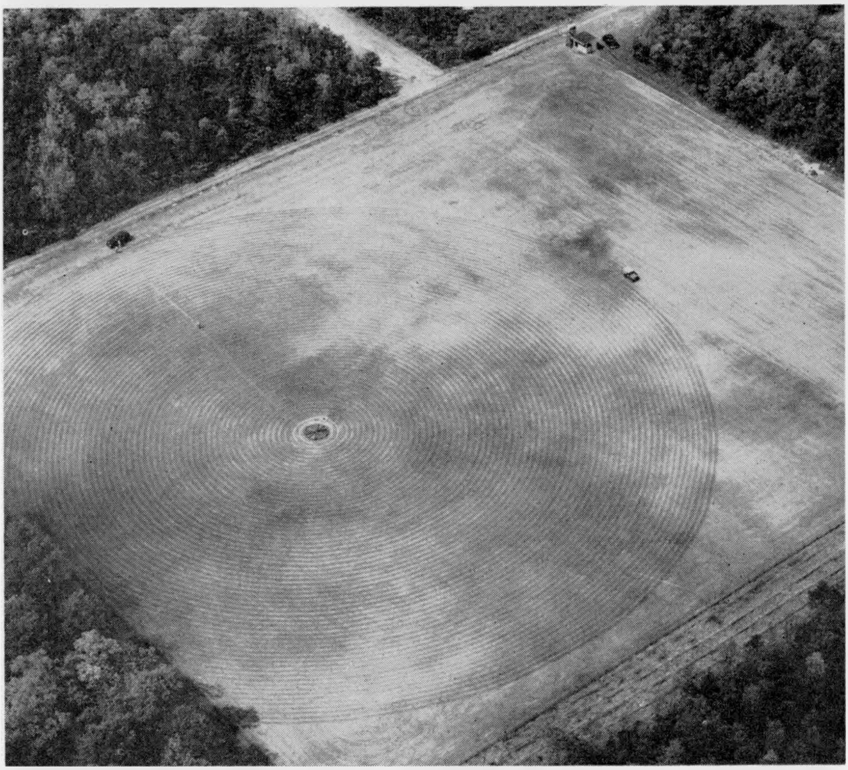
In another experiment, Brookhaven exposed many varieties of plants to gamma rays throughout the growing season. The total amount of radiation was less than the maximum that had been administered to the X-ray potato slices, but the dosages were heavy and continued day after day instead of being given in a single brief burst. To provide the gamma rays, a 16-*curie*[9] source of cobalt 60, a radioactive isotope, was suspended on a post in the center of a large field. Various crops were planted in concentric circles at various distances from the center so that the growing plants would receive varying exposures (see photos p. 79 and p. 80).

---

[8] Neutron flux of 5.8×10^{10} per square centimeter per second at the position of the seeds was used.

[9] The curie is a unit of the rate of radioactivity of any substance, assumed equivalent to the rate of radioactive decay of one gram of pure radium, in which some 37 billion atoms break down each second. The 16-curie cobalt 60 source is roughly equivalent in level of radiation to that from about four-fifths of an ounce of pure radium.

Potatoes. When potatoes were planted in this radiation field, men could enter the field for cultivation only when the "hot" cobalt was lowered, by remote control, into an underground lead vault. At all other times plants 2.5 meters from the source received 79.7 roentgens of gamma radiation a day, a total of 8,529 *r* during the growing season. Plants 40 meters away received a total of about 28 *r*— only a few times the amount a man might receive in undergoing an X-ray examination.



Aerial photograph of the cobalt radiation field *without* any plants growing. Brookhaven National Laboratory.

Exposure of this outermost row of potatoes was at a rate of one-quarter roentgen a day, which is about five times the maximum rate at which persons employed in the atomic energy program are permitted to receive radiation.

Plants near the center of the field, which received the heaviest radiation, averaged as high yields of potatoes as those farther out. There was no visible difference in size or apparent vigor of the plants. The experiment demonstrated that when radiation is spread over a protracted period living organisms can tolerate a total exposure which would cause serious injury if the exposures were concentrated into a short time.

This corn is growing near 200 curies of radioactive cobalt 60, a fission product. The stalks in the foreground are four meters away from the source, at which distance their growth has been stunted by a radiation dosage of about 370 roentgens per day. The corn in the next row behind is five meters distance from the source, where the dosage is approximately 240 roentgens per day, which is sufficiently low to insure more regular growth. Brookhaven National Laboratory.

Other plants. Findings similar to those with potatoes were obtained from tests of tomato, corn, and other plants in the Brookhaven gamma field. Tomato plants that received 20,000 *r* at a rate of 150 *r* an hour lost the chlorophyll that gives plants their green color and were retarded in development. Removed from the radiation, they greened and resumed normal growth but did not regain lost growth.

While there is some difference among varieties of plants in radiation sensitivity, the evidence was that all kinds of plants are affected by sufficiently high exposures.

The flowering herb spiderwort, cut back to 2 inches above ground line at the time of setting out in Brookhaven's gamma-ray field, was allowed to grow under exposures ranging from 5 *r* to 128 *r* per day. Growth was apparently normal at 10 *r* per day. At higher exposures, growth declined. A characteristic group of physical abnormalities developed at each exposure level, and at 128 *r* there was no growth. At each exposure level there was a specific and recognizable difference in the form of the flowerhead.

Growth and flower development were inhibited in lily plants by exposures above 60 *r* a day, but the plants showed no obvious structural abnormalities.

In the broad bean, growth and fruiting seemed normal at exposures of 5 *r* per day. Plants growing at 22 *r* per day flowered but bore no fruit. Above 34 *r*, seeds germinated but growth and flower development were inhibited. Leaves in the more heavily exposed bean plants were thickened and abnormal in shape.

The end result of these experiments is that radiation interrupts biochemical processes in plants but only with gross effects at high levels of radiation.

Radiation and Plant Disease Control

To test the possibility that radiation could be used to kill or inactivate parasites that cause plant diseases, the Connecticut Agricultural Experiment Station undertook a series of experiments under an AEC research contract. Tomato plants and *Fusarium locyperdaceae*, a fungus that causes a kind of wilt in tomato plants, were exposed to radiation in Brookhaven's gamma-ray field. Uninfected tomato plants receiving 5,400 roentgens in a 36-hour period showed no visible harm from the radiation. Those receiving 9,600 *r* spread over the growing season produced heavier vines and less fruit. Plants removed from the field after 20,000 *r* resumed growth, but no such recovery occurred in plants subjected to 100,000 *r*. However, the fusarium could withstand much more radiation than the tomatoes. When cultures of fusarium were exposed in the radiation field, only above 20,000 *r* were any spores killed. Half the fungi survived even at 125,000 *r*. Thus one cannot kill the fungi by irradiating the plant without also killing the plant.

Other experiments with these materials all showed that the plant was more sensitive to radiation damage than were the fungi. Healthy and infected plants were exposed side by side in the gamma field. Within a few weeks, the infected plants receiving the strongest radiation were either severely injured or dead from the wilt whereas the fungi were not destroyed.

Tomato plants were also inoculated with fusarium spores after the plants had been irradiated. They all developed wilt, and the severity of the infection a month later bore no relation to the amount of radiation individual plants had received. Radiation had neither raised nor lowered the resistance of tomato plants to fusarium infection.

Dutch elm disease. One aim of the Connecticut work is to find some way to check Dutch elm disease, a fungus infection that threatens American elms with extinction. The tomato-fusarium tests were, in part, a pilot experiment in this search. *Ceratostomella*, the Dutch elm fungus, also was exposed in the Brookhaven gamma field, and results indicated tentatively that it is twice as sensitive as fusarium to radiation.

While radiation had worsened the lot of tomato plants attacked by wilt, some exposed fusarium developed new strains that showed sharply reduced virulence when subsequently grown on tomato plants. Following this lead, the Connecticut group will use radiation in an effort to develop nonvirulent strains of *Ceratostomella*, and to test the possibility that inoculating healthy elms with these strains will make them immune to Dutch elm disease.

Effects of Moderate Radiation

While heavy radiation is damaging to plant life, some people once thought that moderate exposures would stimulate plant growth. Experiments sponsored by the U. S. Department of Agriculture and AEC show, on the contrary, that while small amounts of radioactive material may cause no readily discernible harm, they also confer no benefits.

Claims that radioactive fertilizers would increase crop yields have been discredited by repeated tests. Even small amounts of radioactive material used for "tracer" [10] research in plant studies may—unless care is taken—damage the plants, and cause error in observed results. Radiation at moderate rates of exposure causes greatest damage at root and stem tips, where new plant growth is normally most rapid. Other experiments demonstrated that, although radiation in "tracer" amounts may kill some soil micro-organisms which help plants to grow, the result is not adverse to plant health.

Tests With Radioactive Fertilizers

For 50 years or more there have been recurrent claims that crop yields could be increased by including weakly radioactive materials, such as uranium ore, in fertilizers. As long ago as 1914, the U. S. Department of Agriculture concluded that the available evidence did not support such a view. But interest in the possibility of increasing crop yield by radioactivity persisted, and further tests with various vegetables were made under USDA auspices in 1944. They did not provide "a very optimistic case" for radioactive fertilizers, the USDA

[10] "Tracers" are helping scientists to understand life processes and mechanisms which have been only partly understood for lack of such a key to unlock their secrets. Radioactive carbon, for example, enters into life processes almost exactly like stable, or natural, carbon. By means of counters or photographic film to record carbon's emission of beta particles, scientists can "trace" the movement of the element through living tissues and through complex chemical reactions.

found, but, because some instances of increased growth were observed, the possibility remained that "further experimentation may prove that certain crops grown on particular soil types under specified conditions may respond beneficially to additions of radioactive materials."

Agricultural scientists took renewed interest in the question after publication of reports of greatly increased crop yields in the vicinity of the Hiroshima and Nagasaki atomic bombings. Investigation of these claims fully established that the stimulation came not from radioactivity but from a combination of other causes. The need remained, however, for some reasonably exhaustive work.

No stimulus to crops. Accordingly, with financial assistance from AEC, the USDA in 1948 commenced a 2-year study of the influence of radioactive materials on the growth of plants. Seventeen common crops were grown in plots to which low concentrations of radioactive material were applied. Three naturally radioactive materials were used: radium, uranium, and a commercial preparation said by its manufacturer to derive its radioactivity principally from actinium.

At the end of the first year, results observed at 13 State experiment stations cooperating in this project led to the tentative conclusion that "the farmer cannot expect increased yields from money invested in radioactive chemicals." The second season's results confirmed those of 1948, and the USDA concluded that "no effect of the radioactive material was found, either beneficial or harmful."

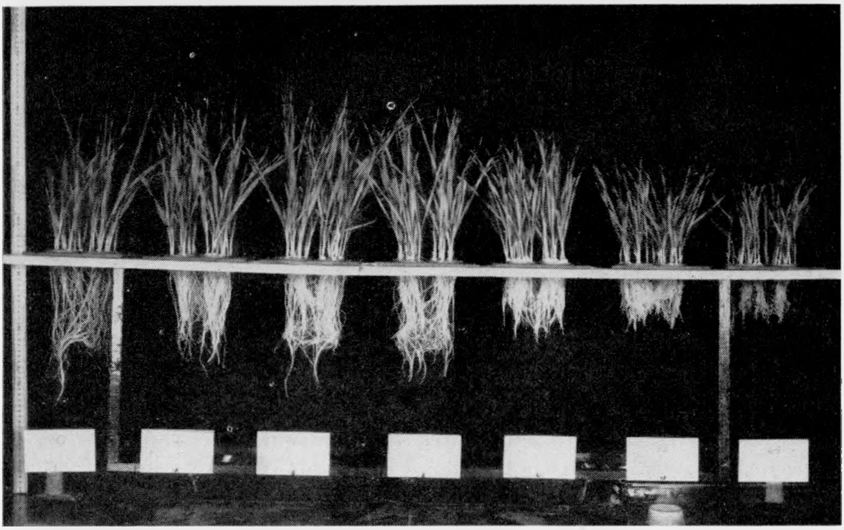
An Experiment With Internal Radiation

Though the radioactive fertilizer tests showed neither benefit nor harm to crop yields, a laboratory-scale experiment conducted under joint USDA-AEC auspices indicated definite possibilities of harm. All radioactive isotopes emit nuclear radiations. While amounts of radioisotopes used in most experiments are normally very low, the possibility that they could cause radiation damage that would distort the experimental results could not be discounted.

A group of plant scientists at the USDA's Beltsville, Md., Experiment Station grew young barley plants in nutrient solutions containing various amounts and proportions of P 32, a radioactive isotope of phosphorus (see photo p. 84). They found that even comparatively small amounts of radioactive materials would, when taken up by the plants, affect their growth adversely. Where the total amount of available phosphate was low, the roots and leaves were greatly retarded by the presence of radioactive material. When the proportion of nonradioactive phosphorus was increased, visible radiation damage became correspondingly less.

Effects of Internal Radiation on Growing Tips

In the same series of experiments, microscopic examination disclosed that the growth-inhibiting effects of moderate radiation operated primarily in the root tips and in the apex bud at the top of the stem. These regions contain rapidly dividing cells, and it is in these limited sites that most of a plant's growth upward into the air and downward into the soil takes place.



These barley plants were grown in nutrient solutions containing a total of 0.00005 moles of phosphate and from left to right 0, 2, 4, 8, 16, 32, and 64 microcuries of radioactive P 32 per liter. U. S. D. A., Beltsville, Md.

Radiation injury to these so-called meristematic regions appears as a reduction and disruption in the normal course of cell division. Healthy new cells are in an embryonic or juvenile condition, with thin walls and high potential for further development. Damage by radiation causes them to show characteristic evidences of old age. They enlarge in size, their walls thicken, and their semi-liquid contents become thinner. Since fewer new cells are formed, further growth of the plant slows down.

A quantitative measure of radiation injury to plants was developed by measuring the length of 10 cells along the periphery of the growing tip. These microscopic measurements showed cell enlargement even at low radiation levels that produced no changes visible to the naked eye. These tests indicated that the level of radiation which damages plants is very low. Fortunately, at the levels normally used in radioactive isotope tracer experiments *in vivo*, such low levels of radiation result that the physiological effect is essentially nil.

AEC sponsors continuing research on practical applications of this concept, such as the fixing of maximum permissible limits of radiation exposure for atomic energy workers.

Damage in root tips. A further clue to what takes place when radiation strikes meristematic tissue developed from work at Argonne National Laboratory in which plants were grown in atmospheres containing radioactive carbon in the form of carbon dioxide gas. Even when the radiation was moderate, root tips of onion plants showed broken chromosomes. Chromosomes—so named because they take up certain dyes that make them visible under the microscope—are rod-shaped bodies which become visible in the nucleus of a cell at the time when it divides to duplicate itself.

The fact that the damaging effect of radiation was highly localized in the growing tips was confirmed by a second test at Argonne in which onion leaves were grown in radioactive carbon dioxide. The cells of the leaves were not actively dividing. So long as they were exposed to light, these leaves continued to build up plant sugars from carbon dioxide and other nutrients. This process of photosynthesis continued at a normal level even when the leaves were exposed to radioactivity 400 times the intensity of that which had caused definite damage in root tips.

Speeding up maturity. When K 42, a radioactive form of potassium, was fed to seedlings, investigators working at Oklahoma Agricultural and Mechanical College under an AEC contract noted that the walls of skin and bark cells were converted to a cork-like tissue. These and other observations confirmed that the weak internal radiations hasten maturity in developing plant cells, with the result that both the rapid division of cells and the further sensitivity of cells to radiation decline. The experimenters found also that radiation-exposed cells at certain stages of duplicating themselves, unlike normal cells at these stages, tended to clump up and stick together.

In addition to such experiments with plants, AEC-financed studies proceed on the effects of radiation on aging and longevity in animals. This area of radiation biology needs thorough exploration in an age when atomic energy promises to come into more varied and extensive use.

Effects of Radiation on Soil Micro-Organisms

Since the welfare of plants depends in considerable degree on the activity of bacteria and other micro-organisms in the soil, USDA scientists in cooperation with the Iowa Agricultural Experiment Station set out to determine whether radioactive phosphorus used in research on the efficiency of fertilizers would affect these minute things. This project was carried out without direct AEC assistance but in cooperation with the USDA's radiation project, which is partially financed by AEC.

At the highest level of radioactivity used in the tests, the radioactive phosphorus did not influence the amount of carbon dioxide which was set free by the developing micro-organisms in a silt loam normally low in phosphates. After 21 days of incubating, the most highly radioactive soil samples showed 67 percent less nitrogen in the form of ammonia and 4 percent less in the form of nitrates—a harmful effect so far as plant life is concerned. Presumably the radioactivity harmed the soil micro-organisms which fix nitrogen (see page 108). The amount of radioactivity causing this effect, however, was considerably above the concentration used normally in fertilizer research.

Handling Atomic Energy Wastes

Various processes of the atomic energy industry create radioactive materials that could damage vegetable and animal life. This is particularly true of the 60-odd radioactive elements created in the fission, or splitting, of uranium atoms, one of the industry's basic processes. As a step in controlling these potentially hazardous materials, several AEC-sponsored groups study the effects of fission products and other radioactive materials on plant life.[11]

Research on the uptake of radioactive materials by plants is conducted at the Hanford Works, at Oak Ridge, and at the Atomic Energy Project of the University of California at Los Angeles—also under AEC research contracts with the University of California at Berkeley, the University of Arizona, and Michigan State College. An investigator at the University of Texas is experimenting with the use of algae for the safe disposal of radioactive wastes. A group at North Carolina State College makes studies of mineral movements in soil that contribute to the safe management of fission products and radioactive isotopes.

Products of Nuclear Fission

Radioactive fission products are created in the operation of nuclear reactors and in the explosion of nuclear weapons. Thorough controls are used to prevent the escape of any significant amount of radioactive material at the plutonium plants, and bomb tests are held in remote places where the effects of fission products will be at a mini-

[11] Methods by which the atomic energy industry holds its releases of radioactive materials within safe limits are described in the AEC Eighth Semiannual Report to Congress, July 1950, Superintendent of Documents, Washington 25, D. C., 55 cents.

mum. To prepare against contingencies, however, AEC sponsors a number of studies on the soil movements of fission products and their biological effects on plant and mineral life. Fission products present an industrial waste problem everywhere that nuclear reactors are operated.

Beginning in the days of the Manhattan Engineer District, original operator of the atomic energy program, and continuing under AEC, a group at the University of California tested the uptake by plants of radioactive strontium, yttrium, cesium, columbium, ruthenium, tellurium, calcium, barium, lanthanum, cerium, and plutonium. Today these problems are being investigated by the Hanford Biology Laboratory, Tennessee Valley Authority, and several universities. All these minerals were taken up by plants even when they were present only in trace amounts, but only strontium is carried upward from roots to leaves in any significant quantity. Thus, 1.6 percent of an initial dose of strontium applied to the soil appeared in leaves of barley and peas, whereas only 0.00045 percent of a dose of plutonium was translocated to the leaves.

Strontium. Several evidences indicate that strontium is potentially the most biologically hazardous of the fission products. As far as plants are concerned, strontium is similar to calcium, an essential plant element, and plants will draw the one out of the soil as readily as the other. Furthermore, the radioactivity in radiostrontium has a half life of about 25 years. Tests by the Hanford botany group showed that red kidney bean plants took up strontium in proportion to its concentration in a nutrient solution over a broad range of 0.0001 to 100 parts per million. The plants built up strontium in their leaves until they assayed 5 to 10 times as high a concentration as was present in the nutrient. If animals should eat plants containing large quantities of radioactive strontium, the material would lodge in their bones and injure their blood-forming organs. It would appear in cow's milk and, from this source and from leafy vegetables such as spinach, could be taken in directly by human beings.

All aspects of the biological utilization of radioactive strontium and other fission products are studied in the AEC research program, from their original production to their absorption by plants and utilization by animals to their final effects on animals. Such research will enable scientists to determine what levels of radioactive strontium may safely be released.

While plants readily take up strontium from soil, tests at the University of California indicated that applying abnormally high concentrations of calcium to the soil would inhibit this action. The ratio of strontium to calcium taken up is determined by their respective concentrations in the soil.

There is reason to believe that strontium carried in dusts or sprays would be absorbed by leaves. An investigator at Michigan State College is testing this presumption for AEC. The University of California at Los Angeles has found that strontium appears in all parts of crop plants tested. UCLA and the University of Arizona are currently measuring strontium uptake by various edible plants.

Yttrium. Lesser amounts of radioactive yttrium occur in association with radioactive strontium, and are taken up by plants on a proportionate scale.

Cesium. Radioactive cesium presents similar but lesser problems than the strontium-yttrium complex. UCLA is studying the uptake of all three minerals by barley, beans, carrots, lettuce, and radishes. Plants took up large quantities of strontium from each of several soils tested, and smaller amounts of cesium.

Hanford data on the uptake of cesium by red kidney bean plants indicated that it was directly proportional over a wide range to the concentration of this mineral in a slightly acid solution. The plants built up the percentage of cesium in their leaves to two or three times the concentration in the nutrient medium. While plants will take up strontium indiscriminately in place of calcium, this is not true of cesium.

Even in trace amounts, strontium, yttrium, and cesium have no apparent role in plant nutrition. They are studied, rather, with the idea of preventing or minimizing their adverse effects.

Iodine. Hanford botanists expose plants to radioactive iodine vapors in the laboratory and study the absorption through leaves. They also make routine tests for radioiodine and other fission products in vegetation near the Hanford Works. The escape of these materials in the plutonium extraction process is held to such low limits that they are not a hazard to animal and vegetable life in the vicinity.

Reactor Cooling Water

Small amounts of radioactive materials are produced from minerals in Columbia River water as it passes through cooling ducts in the Hanford reactors. After standing in catchment basins to allow the shorter-lived materials to lose their radioactivity, the water flows back into the river with minute amounts of radioactive sodium and manganese, still smaller amounts of radioactive phosphorus, and bare traces of radioactive iron and calcium.

As a check on the safety of Hanford's operations, botanists each month test more than 500 samples of vegetation, soil, and mud. Though the simple aquatic plants called algae have the ability to build up phosphorus concentrations to 500,000 times the level present in the surrounding water, no harmful effect of the Hanford operations has been found in Columbia River algae—or in plankton and fish.

Hanford has operated a small experiment station in which a variety of fruits and vegetables were irrigated with water drawn from the Columbia below the reactor cooling outlets. The amount of radioactive material appearing in the soils and crops has been insignificant.

Absorption of Minerals by Plants

The AEC is also supporting a project of the Tennessee Valley Authority for the study of the plant and animal ecology of the White Oak Lake watershed, a small area adjacent to the Oak Ridge National Laboratory, where the lake receives some radioactive wastes. By autoradiographic and analytical means, the botanist working with this project is making a study of the uptake and degree of concentration of fission product elements, especially strontium, in the shoreline plants. This program is a part of the general study of the safe management of wastes around Oak Ridge.

Absorption of Minerals by Algae

Algae have a marked capacity to take up certain minerals from the water in which they live and grow. Means might be developed whereby algae would be used to extract radioactive material from liquid wastes of atomic energy centers and isotope users. An investigator under AEC contract at the University of Texas is exploring this possibility.

Work to date has concentrated on determining what particula species of algae are best adapted to growth in large quantities, car best tolerate a radioactive environment, and can most easily be harvested and stored after they have done their job. Most work ha been done with *Chlorella pyrenoidosa*, a common single-cell algae The experiments have demonstrated that this species requires manganese and iron to maintain normal growth, but it apparently doe not need boron, copper, cobalt, and molybdenum—other element that higher plants require in trace amounts.

Work is getting under way at Texas to determine the ability of alga to take up and store strontium, yttrium, and cesium, and the heavie minerals such as uranium and plutonium.

Movement of Minerals in Soil

AEC sponsors research to clarify the ways in which fission products and other minerals move through soils and into plants. The subjects of study here are ions, electrically charged atoms, and combinations of atoms into which chemical molecules break down under conditions encountered in solutions, in soils, and in plant tissues.

Most mineral elements in their ionized state carry positive charges. In the soil, they adhere to particles of clay carrying negative charges. A mineral ion travels through the soil by being transferred from one clay particle to another through an exchange reaction in which each particle gives back a hydrogen ion to the preceding particle. Plant roots, too, produce hydrogen ions. When a mineral ion reaches a clay particle in direct contact with a root, the root takes in the mineral and surrenders hydrogen in exchange for it.

Soil tests. To hold down the heavy expense of providing tanks for all radioactive wastes, Hanford Works runs materials containing low radioactivity into the soil in such a way that they do not reach the supply of ground water. Continuing tests have shown that the soil at this location is remarkably efficient in binding fission products so that they travel only small distances through the ground. Studies of soil and underground water conditions played a large part in selecting the Idaho site for AEC's Reactor Testing Station. Soil monitoring is performed at all major atomic energy centers.

Studies of isotope movements in soils. To supplement the work at AEC manufacturing and research centers, a group at North Carolina State College is exploring ion movements in clay containing soil minerals and tracer amounts of radioisotopes. They found that phosphorus movement speeded up when the water and phosphorus content of the soil were raised.

A relatively high content of hydrated iron and aluminum—a condition encountered in many soils—markedly slowed down phosphorus movement. Even when an abnormally high concentration of phosphorus was tested in such a soil, the radioactive phosphorus tracer material moved only 9.5 inches in 30 days, and its subsequent movement was very slight. This inhibiting effect was apparently connected with the fact that minerals such as iron and aluminum form insoluble complexes with phosphorus.

In contrast with the behavior of phosphorus, calcium moved more rapidly when the water content of the soil was reduced. The reason remains to be determined.

Retention of isotope wastes. From the limited movement of phosphorus, the experimenters concluded that a small amount of soil could be used to hold radioactive phosphorus wastes until its radioactivity had died out to a safe level. As to disposal of radioactive calcium in soil, it has been suggested that first it can be converted to calcium carbonate or hydroxide, both of which are relatively insoluble—second, it can be added to a soil that already contained nearly as much nonradioactive calcium as it would hold.

In addition to continuing its work with phosphorus and calcium, the North Carolina group plans to test other radioactive isotopes and fission products for their ionic mobility and waste-disposal properties: antimony 125, iron 55 and 59, mercury 203, nickel 59, selenium 75, silver 110, strontium 89 and 90, sulfur 35, and zinc 65.

Biochemical Effects of Radiation

To account for retarded growth and other physical changes that radiation and radioactive materials cause, scientists look for underlying chemical changes in the plant's tissues. The basic chemical effect of radiation is that it disrupts complex molecules within living cells, blocking or distorting their functions, altering their chemical composition, and sometimes killing the cells.[12] Experiments are conducted at AEC laboratories to gain clearer understanding of important biochemical alterations in irradiated plants.

Radiation and Growth Regulators

Since radiations inhibit plant growth, biochemists at Argonne made special studies of the plant hormones called *auxins*, which control growth throughout the plant. Auxins are complex organic compounds, produced naturally in the apex buds of plants—that is, in a meristematic region which experiments have shown to be especially sensitive to radiation. The auxins amount to perhaps only one-millionth of the total mass of the plant, but have a profound effect on its development.

Argonne experimenters subjected kidney bean, cocklebur, and cabbage plants to X-rays and then analyzed their auxin content. Expo-

---

[12] Radiation splits electrically neutral molecules into postitive and negative fragments called *ions*, which then combine anew into neutral materials. In living cells, these recombinations do not produce the same materials that existed before the splitting. A protein molecule containing 5,000 or more atoms of a half-dozen elements linked together in a certain way may, for example, become something very different after ionization. The specialized function of the original molecule is disturbed or destroyed, and sometimes the chemically scrambled contents poison the whole cell.

980705—52——7

sures to as low as 25 and 100 roentgens brought an immediate drop in auxins, and this effect increased as exposure was stepped up.

Other evidence indicated that the decrease might not result primarily from direct radiation damage to the auxins themselves. Pure auxin dissolved in water proved fairly sensitive to radiation, but when it was combined with other organic compounds, these materials absorbed many of the damaging ions and thus had the effect of making the auxin content comparatively resistant to radiation. Since the proportion of non-auxin compounds in living plants is very high, this experiment indicated that direct auxin destruction alone could not account for the sensitivity of plant growth to radiation. The experimenters therefore adopted a working hypothesis that the system of enzymes that enables the plant to produce auxins—not the auxins themselves—must be particularly sensitive to radiation.

In further tests, they found that plants exposed to small amounts of radiation recovered in a few days to normal auxin levels and that the immediate inhibition of growth that normally would have resulted could be checked and reversed by applying synthetic auxins to the growing tip. There was no recovery of auxin level after heavier exposures, and applications of synthetic auxin failed to prevent the stoppage of growth. This was further evidence that the injury was more deeply seated than direct destruction of the auxins.

Auxins and structural change. Other experiments demonstrated that damage to the auxin system caused other structural changes in plants beside inhibiting growth. Growing tips of cocklebur plants were exposed to small doses of X-rays while the rest of the plants were shielded in lead. After this treatment, the terminal bud stopped growing, and lower buds on the plant developed. Auxin spreads out from the terminal bud of a growing plant and normally suppresses growth of all other buds, but when this top bud is cut off or injured, the dormant buds begin to grow. This applies equally to physical damage and radiation injury. When auxin was applied to the growing tip immediately after irradiation, the terminal bud continued growing and other buds remained dormant.

Localizing the damage. Finally, the fact that damage was localized in the growing tips was confirmed by observing the difference of behavior between the terminal bud and adjacent plant tissue. Plant growth takes place not only in the meristematic tip, where cells are rapidly dividing, but also just below the tip, where cells already produced become longer. Growth in this area of cellular elongation is in direct proportion to the amount of auxin sent down from the terminal bud. Despite the closeness of this interrelationship, direct radiation exposures up to 10,000 roentgens had no apparent effect on growth in the region of cellular elongation, whereas exposures in the order of 100 *r* to the terminal buds stopped the elongation. The Argonne investigators attributed this striking difference to the radiation sensitivity of the enzyme that controls the production of auxin in the growing tip.

Other Biochemical Studies

Studies of the effects of radiation on various biochemical processes of plants are under way. So far, none has been found which is so sensitive as the mechanism by which auxin is synthesized. Many key physiological processes are little affected even by comparatively high exposures to radiation. This is apparently true, for example, of photosynthesis, the vital process by which green material in leaves takes in energy from light, builds carbon dioxide, water, and nutrients into plant tissue, and releases free oxygen into the air.

Radiation and Plant Genetics

To broaden their understanding of radiation, scientists study not only its growth effects on plants but also its genetic effects. Each living cell contains thousands of specialized chemical units called *genes*, strung together into a smaller number of rod-like bodies called *chromosomes*. This genetic apparatus serves two purposes:

a) It determines the physical inheritance of offspring. This is true whether the offspring are whole plants or animals resulting from sexual reproduction, or new body cells within existing organisms. Each individual gene determines a particular characteristic of the species.

b) It acts as a basic regulator of processes involved in life, growth, and health of each living thing. There is evidence, for example, that the genes control enzyme activity, which in turn regulates life processes.

Each of the multitude of genes normally reproduces faithfully from generation to generation except about one time in a million or less when a chemical or physical change occurs which results in a changed individual or mutation. High-energy radiation can step up this rate of genetic mutation to 10, or 100 or more, in a million. It does this by disturbing one or more genes, or by breaking chromosomes, or by producing foreign chemical products from other components of the cell that act as gene poisons.

Using radiation, the geneticist can induce in a short period a variety of mutations that might appear normally only in the course of centuries. For genetic studies, such increase in the variety of different strains is an end in itself. Since valuable plants sometimes result from mutations, radiation-induced changes also have practical aims. A good example is hybrid corn now familiar to all. There is a good chance that a greater diversity of genes responsible for the hybrid vigor may be induced by radiation, thus giving the plant breeder many more genes to work with. Such an eventuality might make it unnecessary to comb various parts of the world for specific genes of disease resistance or drought resistance. A good example of this type of search is the Hope Wheat which got its disease resistance from Yaroslav Immer, a variety of Russian wheat. Radiation may ultimately provide a useful shortcut for these protracted searches.

Scope of the Work

AEC conducts genetics research with various kinds of organisms at Argonne, Brookhaven, and Oak Ridge, and contributes to the support of 35 genetics projects in universities. In the sub-field of plant genetics, AEC sponsors studies with molds and other fungi, such genetically interesting plants as trillium and spiderwort, and, among crop plants, corn and peanuts. This work is designed primarily to determine how radiation causes genetic changes, how the amount and rate of radiation affects the number and kind of mutations, and how genetic changes in a plant affect both its own development and its offspring.

It is not within the scope of this report to discuss AEC research in fundamental plant genetics nor its application in the AEC program. Rather, this report mentions only that work where genetics work has been specifically applied to crop research.

In addition to work directly sponsored by AEC, numerous genetic experiments in the country use radioisotopes. Germ cells and tissues of many plants, animals, and micro-organisms are exposed in research to X-rays, neutrons, and other radiation.

Hybrid Corn Experiments

In a fundamental study of radiation genetics, Brookhaven National Laboratory is growing genetic stocks of corn in various radiation intensities in its gamma ray field (see p. 78). Exact calculations of exposures were made during the 2-week period when male sex cells in the pollen grains were maturing—that is, when radiation was likely to have the greatest genetic effects.

As a general rule, mutations increase with radiation dosage, but microscopic examination of kernels from mature ears produced in this experiment disclosed these variations:

a) Plants receiving less than 5 roentgens a day during their entire life produced kernels that showed no more detectable mutations in this year than those which occurred spontaneously in corn receiving no radiation. Genetic studies with animals have indicated, however, that a radiation dose below this level may increase the mutation rate. With corn it has not been possible so far to designate exactly the level below which there is no mutation because there is considerable fluctuation in the controls. Pollen was affected at around 2.5 *r* per day.

b) Mutations increased approximately in direct proportion to amounts of radiation between 5 and about 55 roentgen a day. From 55 roentgen upward, this increase was accelerated. Plotted on graph paper, the data resulted in approximately straight lines that sloped gently from 5 to 55 roentgen, then suddenly became steeper straight lines. The project leader concluded that the heavier radiation exposures had pyramiding effects—that a given amount of ionization at the higher dosages caused a larger amount of genetic change.

c) Not all the genes responded equally to the radiation. The *r* gene, for example, which controls the production of red pigment in kernels of corn spontaneously mutates at a relatively high rate; but it showed less percentage increase with increasing radiation than did three other genes whose spontaneous mutation rates are lower. This indicated that radiation may affect some particular genes more than others, and that this pattern of radiation effects differs from the patterns caused by heat, chemicals, and other mutation-inducing agents. There is some suggestion, moreover, that radiation-induced mutations are not only more numerous but also may be qualitatively different from spontaneous mutations.

Size of sample. Some 300,000 kernels of corn were studied in the 1950 Brookhaven genetics work. Large numbers are required to yield enough mutations to have statistical significance without excessive margins of error. For example, only about 1.5 percent of kernels receiving 100 roentgens a day—a heavy exposure—showed mutations in the *r* gene.

A practical objective. In addition to producing fundamental knowledge about the effects of radiation, the Brookhaven investigators hoped to speed the incorporation into hybrid corn of a genetic mutation which results in a hybrid shorter plant with a higher proportion of grain to stalk. This desirable mutation appeared spontaneously once in a sweet corn line and has been incorporated into several inbred strains of field corn. To test the possibility that radiation can accelerate the breeding of this trait, a type of tall inbred corn is being grown in the Brookhaven gamma field and its pollen used to fertilize short corn plants grown without radiation exposure.

The chance that such cross-breeding will succeed increases with the amount of radiation and the number of kernels involved in the experiment. Both factors serve to improve the odds—which are naturally very low—that at least a few of the mature seeds will carry the desired array of characteristics. Selective breeding of the Brookhaven stock for several generations of corn plants will be required to determine whether the objective is achieved.

Other plant species. Apart from its principal work with corn, Brookhaven grew tobacco and other plants in its radiation field and sent the harvested seed to cooperating scientists for studies of genetic effects. They have also tried to grow millet and cotton for plant breeders in the South, but these crops were not adaptable to northern conditions.

Study With Irradiated Peanuts

A large-scale study of mutations in irradiated peanuts is under way at North Carolina State College with financial assistance from AEC. In addition to its fundamental significance, this project is designed to determine whether radiation can produce a new strain which will resist leaf spot disease that causes substantial losses in peanut crops.

First year's results. In 1949, seeds from a pure strain of peanuts were exposed to 10,000 to 18,500 roentgen of X-rays in the Biology Laboratory at Oak Ridge. The original planting of these seeds in North Carolina produced 60,000 seedlings, many of which showed direct radiation injury and abnormalities. Many plants showed partial variations from type, and three seedlings—all of them sterile—bore all the marks of another recognized variety of peanut.

The original seed was a "Virginia" type that produces its leaves in an upright bunch, but the irradiated seeds produced some prostrate Virginias, some upright "Valencias," and a number of forms never seen before. One Valencia-type plant bore a single pod; all the rest of this type were sterile.

One clearly defined class had thick and short stems; another had slender stems and short leaves. In an occasional plant, some stems were overgrown and others were stunted. One of the most frequent radiation-induced conditions was stunted development of roots.

Second year. A second planting, in 1950, included seed from all interesting mutants observed in 1949, together with a representative sample of the entire 1949 seed crop. The 1950 work produced a half-million seedlings which were searched for blight-resistant mutants. "The occurrence of this mutation," said the director of the research at North Carolina, "while possible, may be extremely rare. Thus every plant in the large area planted must be closely observed several times during the year."

Third year. In 1951, mutants isolated as individual plants in 1950 were tested by planting their seed in rows in a twenty-five acre field. Accumulation of data from this large-scale project is currently being completed, and analysis and publication of the results will require another year or more. Drawing scientific judgments from such a study involves statistical analysis of many thousands of individual observations.

While the North Carolina project will yield additional knowledge on radiation and genetics, it may or may not achieve the immediate practical goal. It is not certain, for example, that peanuts are inherently capable of resisting leaf spot. Radiation can accelerate the occurrence of mutants but it cannot produce traits for which there is not already a genetic potential in the species.

Mutations in Fungi

Ohio Agricultural Experiment Station, under contract with AEC, cultured a parasitic leaf blight fungus in a nutrient containing radioactive phosphorus, removed the spores, and used them to infect corn plants. The parasite multiplied at about the normal rate; apparently the radiation had not succeeded in introducing any trait into the genes of the fungus that would diminish its virulence.

When corn plants—instead of the fungus—were grown in a radioactive nutrient, those subjected to the highest concentrations of radioactivity became the most heavily infested with corn smut. It appeared that the smut was more resistant than the corn plants to radiation. Spores from fungi grown on these corn plants, however, showed a marked decline in ability to germinate, and continued studies are under way to see whether this is a means of developing smut-resistant plants.

Work at Minnesota. An AEC-supported group at University of Minnesota cultured the fungus that causes corn smut on a nutrient containing uranium nitrate. Though the level of radiation used from this chemical was little above the "background" rate that exists everywhere from cosmic rays and other natural causes, the frequency of mutations increased. Traits emerging in the progeny after such treatment were unfavorable to survival of this fungus, and the new strains showed less than normal virulence in their action against corn plants.

No immediate application of the less virulent corn smut is in sight, but the ability to induce mutations in fungi by weakly radioactive nutrients opened up other promising possibilities. Commercially valuable mutations were produced at Minnesota by culturing edible brown mushrooms in uranium nitrate. Some of the radiation-induced mutants had white caps, which are more marketable, and other strains grew more rapidly and fruited earlier.

The Minnesota group also is exploring the possibility of inducing useful mutations in micro-organisms that produce antibiotics and other valuable products. Enhanced penicillin production, for example, was obtained some years ago at the Carnegie Institution of Washington by isolating a more productive strain of *Penicillium* obtained by radiation.

Bikini Corn

Several generations of corn have been grown by California Institute of Technology and Cornell University from seed exposed to neutrons and gamma rays in the Bikini atomic bomb tests of 1946. A check lot of seed was given a heavy dose of X-rays. Genetic disturbances were noticeable in the first crop of plants from both the X-rayed and bomb-exposed seed. Some seed failed to sprout. Most of the seed produced living plants but many of them were stunted and had yellow-streaked leaves caused by lack of chlorophyll, the green substance that enables plants to carry on photosynthesis.

Microscopic examinations of seed produced by these plants disclosed a high frequency of broken chromosomes. Genetic damage was evident in both the X-rayed and bomb-exposed stock, but chromosome breaks at the particular spot where the gene controlling the development of chlorophyll is located were nearly twice as frequent in the bombed stock.

When a second generation of 12,000 plants was grown from the Bikini stock, however, only three plants had the yellow stripes. The chlorophyll deficiency plants, common in the first generation, were not able to reproduce. Thus, the irradiated stock had largely eliminated the damaged genes by selective breeding. For the most part, the damaged plants had either failed to produce fertile seed or to grow at all.

Other Genetic Studies

Oak Ridge and Brookhaven National Laboratories and many universities are studying the spiderwort *Tradescantia*, a plant with large chromosomes that make it a favored subject for studies of chromosome breakage. In one series of experiments, spiderwort tissue was subjected to various concentrations of oxygen and then irradiated. The amount of chromosome damage was proportional to the oxygen content.

This finding confirmed similar results obtained from experiments with mice. It suggests, first, that the gene-chromosome system in living cells is especially sensitive to radiation, and, second, that the presence of oxygen somehow favors ionization, which results in chemical changes within the cell.

Genetics of bacteria. AEC-sponsored work in the genetics of bacteria is under way in several laboratories such as Brookhaven and Oak Ridge National Laboratories, Amherst College, Cornell University, California Institute of Technology, and the University of Wisconsin.

Genetics in life chemistry. Studies are being made at California Institute of Technology on the tropical bread mold, *Neurospora*, which reproduces rapidly and otherwise lends itself to genetic study. One reason for studying this mold is that it yields rich information on the interaction between genes and enzymes. In the past few years a working hypothesis has been used that the genes in living cells control the enzymes which in turn regulate all processes necessary to the development and welfare of the organism. In this light, the growth-inhibiting effects of radiation traced in the earlier discussions here may be attributed in substantial measure to underlying genetic disturbances.

Plant Research With Isotopes

While the changes that radiation causes in living matter are of great scientific interest, atomic energy plays another more important role in biological research. In this role, atomic energy is used not to cause changes but to probe into the nature of more or less normally functioning life processes. The tools for this probing are isotopes or "tagged atoms," which are a major AEC product.

Several isotopes of an element, varying from each other in atomic weight but not in chemical properties, may exist in nature or can be produced in a nuclear reactor. Many isotopes are radioactive but some are not, varying only by a difference in weight. For instance, of the element hydrogen there are three isotopes—hydrogen 1, which composes nearly all the hydrogen found in nature; hydrogen 2, deuterium;

and hydrogen 3, tritium. Deuterium is a naturally occurring nonradioactive isotope which when combined with oxygen forms what is known as heavy water. The tritium isotope is even heavier than deuterium and in addition it is radioactive. It also occurs in nature but in minute traces. When tritium combines with oxygen, a radioactive and even heavier water than deuterium water is formed.

Plants use radioactive isotopes in substantially the same way that they use normal forms of these elements, but the radioactive isotopes throw off radiations that can be traced wherever they go in the plant and through all chemical combinations.

Radioactive isotopes of some elements lose their radiation so rapidly that they cannot be used in biological experiments. Stable (nonradioactive) isotopes often serve as tracers in these cases. An example is nitrogen for which no usable radioactive isotope exists. A mixture of nitrates in which a small amount of a heavy stable isotope of nitrogen has been included is used by plants in the normal manner, and the life processes into which the nitrates enter can be traced by measuring the heavy-nitrogen content of the various tissues.

Research with radioisotopes is making it possible to understand many hitherto obscure things about life processes—to trace the movement of fertilizers through soil and into plants, for example, and to delineate the steps in the complex process of photosynthesis by which plants use the sun's energy to build up the plant tissues that animals and men depend upon for food. Because of the special ability to chart their course through living organisms and intact objects, isotopes have been called the most important scientific tool developed since the microscope.

The existence of isotopes was known and they had been isolated in minute amounts years before the AEC existed. Radioisotopes became available in quantity and some new ones produced with the building of an atomic energy industry with its nuclear reactors and electromagnetic isotope separators. General distribution of radioisotopes was inaugurated by the Manhattan Engineer District in August 1946 and has steadily increased under AEC. Low prices and extensive and rapidly expanding use of radioisotopes in research is a development of the last 5 years.

More than 700 research institutions in the United States, and 250 in 31 other countries, are using AEC radioisotopes. Since August 1946, more than 22,000 lots have been shipped in the U. S., of which 957 shipments went for research in plant life by 81 institutions in 41 states, Hawaii, and Puerto Rico. Virtually all the 49 plant-life studies performed under AEC research contracts depend on isotopes for their accomplishment.

Efficient Use of Fertilizers

Although fertilizers that depended on radioactivity for their action proved useless (see page 82), radioactive tracers are showing how conventional fertilizers can be used more efficiently and economically. American farmers spend 750 million dollars a year for commercial fertilizers. Isotopes research already has found ways to get greater returns in crop yields from this money. It has been suggested by a leading agricultural scientist that research with radioactive phosphorus has yielded more new knowledge of phosphate fertilizers in the last four years than had been gained in many years of other studies.

Until recent years, the effects of fertilizers could be determined only by comparative measurements of growth, bulk, and yield of fertilized crops. With isotopes, it became possible for the first time to glean other highly meaningful data—whether, for example, the phosphorus content in mature plants actually came from fertilizer or was drawn from phosphates naturally present in the soil. Isotopes enable scientists to trace nutrients through soil, into roots, and thence through plants, to measure the extent and speed of their movement; to determine at what stage in its growing cycle the plant needs fertilizer most; to know where and how fertilizer should be placed to give the plants the maximum benefit; to establish what kinds of fertilizers work best in the country's varied soils; and to answer other practical questions about the techniques of fertilizer use.

USDA-AEC Project

In 1946, when radioisotopes first became available in quantity, the Agriculture Department's Bureau of Plant Industry, Soils, and Agricultural Engineering, the country's center of fertilizer research, began working with phosphate fertilizer in which tracer amounts of radiophosphorus were mixed. In 1947 and 1948 the work was extended to include investigations at four cooperating State agricultural experimental stations. These limited tests showed the value of radioisotopes in fertilizer research. They also revealed a strong need for more fundamental work to evaluate the uses of radioisotopes in agricultural research, and for improved methods and facilities to prepare isotope-tagged fertilizers of standard strength, mix, and quality.

In January 1949, AEC entered into a contract with the Department of Agriculture to support research and development necessary for the safe and extensive use of radioisotopes in agricultural science. This is a cooperative agreement under which AEC supports basic phases of the program, including facilities for producing different tagged fertilizers. USDA cooperates with State agricultural experimental stations in conducting actual field experiments. Under the arrangement, any general applications of procedures developed in research on solving national and regional agricultural problems will be supported by USDA's own funds.

Since the experiment stations in the individual States lacked facilities for incorporating tracer isotopes in ordinary fertilizers, a small central mixing plant was built at the USDA experiment station at Beltsville, Md. This USDA-operated plant and the associated laboratories at Beltsville serve as an isotopes training center for fertilizer scientists from the participating states.

The Beltsville plant represents a capital investment of $275,000 in AEC funds. AEC pays only a part of the project's operating costs; all other expenses are borne by USDA and the cooperating State experiment stations. Through this joint sponsorship, AEC fulfills its responsibility for fostering the application of atomic energy in one of the country's most important industries, and USDA was able to apply isotope techniques to agricultural research sooner than would otherwise have been possible.

In 1950, test lots of isotope-tagged phosphate materials for research on soils, fertilizers, and plant nutrition were shipped from Beltsville to 22 State experiment stations for 67 different studies. In the 1951 growing season, 29 experiment stations conducted 114 such studies. (See Appendix 12 for list.) The 1951 tests covered the whole range of commercial phosphate fertilizers—normal phosphates, concentrated and ammoniated superphosphates, and various combinations of calcium and phosphates.

Results With Particular Crops

The experiments have shown that crops differ widely in their abilities to use natural phosphorus from the soil and phosphorus from commercial fertilizers. Tests have been made with some 25 crop plants. For any crop, the beneficial effect depends greatly on what form of phosphate is used, when it is applied, and where in relation to the seeds (see diagram, p. 103).

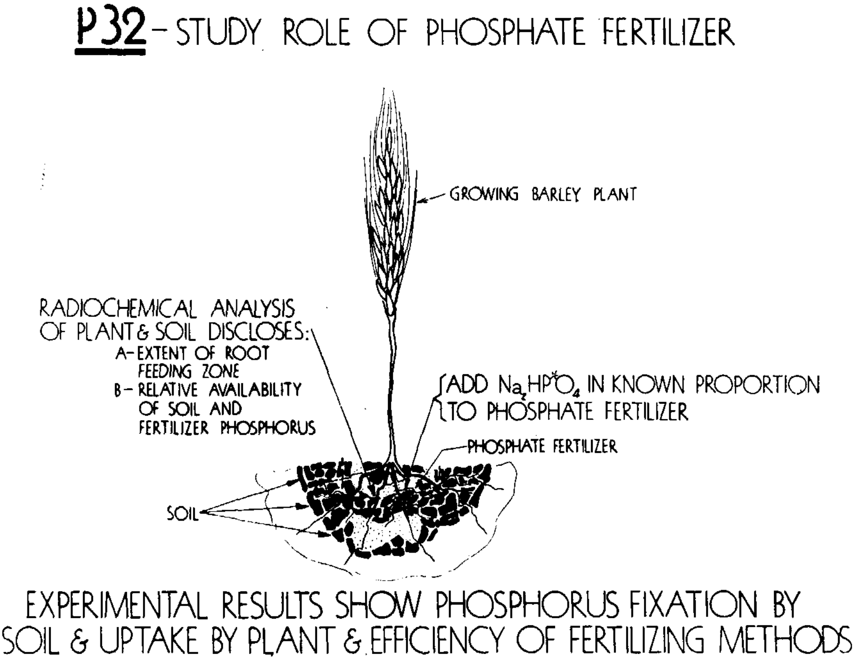
Corn. Corn plants take up phosphorus from the applied phosphate fertilizer during their first stages of growth. As the plants grow older, the roots reach deeper and draw most of their phosphorus from deposits already in the soil. In normal crop rotation, it may prove beneficial to apply phosphate to the crop planted before the corn, thus benefiting the earlier crop and the corn crop as well.

Fertilizer placement also affects the rate of phosphorus uptake. Placing the fertilizer at seed depth in bands on either side of the corn seed row gave the best results.

Potatoes. With potatoes, the results show that the applied fertilizer is the main source of phosphorus throughout the growing season. Potatoes should therefore be heavily fertilized each season.

Some Specific Tests

Some tests with the USDA-AEC fertilizers produced findings of more or less local usefulness; others resulted in more general applications.



Utilization of radioactive phosphorus 32 in fertilizer research.

Northeast. New England farmers apply 3.5 times as much phosphorus to their truck crops as harvested crops take out, leaving a build-up in phosphorus fertility. Experiments with radiation-tagged fertilizers in the region's State experiment stations showed that the build-up is particularly large in fields producing truck crops and potatoes. Similar experiments were run by broadcasting radioactive superphosphate on the surface of pastures. It was found that the phosphate fertilizer was adequately taken up through the leaves and roots. Thus, the old pastures in this area can be rejuvenated by broadcasting phosphate without plowing them up. As a result, the Northeastern Soil Research Committee recommended that if limited by fertilizer supply one could cut the fertilization of truck crop fields 30 percent and apply the savings to improvement of pastures and hay fields.

North Carolina. Experiments in the South with radioactive fertilizers have developed procedures for studying the distribution of roots in the soil without digging up the plant. For cotton, corn, tobacco, peanut, and grape plants these studies are giving important information as to the best place to apply phosphate fertilizers. The North Carolina State Experiment Station found that *cotton* began using phosphorus out of a band 3 inches from the seed row 15 days after planting, from a 9-inch band at 60 days, and from an 18-inch band at 75 days. *Corn* also drew from a 3-inch band after 15 days but reached the more distant bands much earlier than cotton because of its more extensive lateral roots.

An experimenter at North Carolina State College demonstrated that phosphate applied to the surface of bare ground does not penetrate deeply enough to be worth much during the current season, especially to a crop with a short growing season like *tobacco.* Tobacco, unlike pasture grasses previously cited, cannot use phosphate fertilizers put on the surface during the growing season. As a result, the fertilizer industry eliminated the phosphorus content from the nitrogen-potassium-phosphorus mixture previously used for top dressing the soil. This saved North Carolina farmers an estimated 4,300 tons of superphosphate a year and saved the Nation an equal amount of sulfur, a critical commodity used in manufacturing superphosphate.

Michigan. In well-drained Brookston clay loam manured and planted to *oats*, the Michigan station tested growing plants by radioactive assay and found that ammonium phosphate and ammoniated superphosphate were the best phosphorus carriers. Next came ordinary superphosphate and dicalcium phosphate, and finally calcium metaphosphate and alpha tricalcium phosphate.

Ohio. In tests on Wooster silt loam, the Ohio Experiment Station compared the ability of superphosphate and calcium metaphosphate to provide phosphorus to *corn* plants when the calcium was supplied by lime and the nitrogen by manure. Superphosphate supplied more phosphorus to young plants but by the end of the season corn fertilized with metaphosphate caught up. Radioactive analysis of the plants showed that manuring did not influence the plants' uptake of phosphorus, but limed and manured plots averaged 6 to 25 bushels an acre higher than plots given only phosphate treatment.

Colorado. Using sugar beets, alfalfa, wheat, barley, and potatoes, experimenters with radioactive fertilizers have found that nonwater soluble forms of phosphate fertilizers such as dicalcium phosphate and fused tricalciumphosphate were not satisfactory phosphate fertilizers in calcareous soils of this area. These experiments have an immense bearing on the type of phosphate fertilizers that are produced in the western U. S.

Colorado investigators have also studied the ability of the crops to use water soluble liquid phosphoric acid (labeled with radioactive phosphorus) when placed in the irrigation water as compared to the normal practice of adding dry material such as superphosphates. The results indicate that both methods of applying phosphate to the soil are equally satisfactory and thus we have a new method of applying phosphate fertilizer.

Wisconsin. In a test to determine the most efficient placement of fertilizer, *corn* was planted in Miami silt loam and superphosphate was drilled into the soil at depths of 2, 3.5, and 5 inches, in bands on one side of some rows and both sides of others. Leaves from the plants were assayed for radioactive phosphorus at five different stages of growth. The Wisconsin Experiment Station found that double banding was more efficient than use of the same amount of phosphate in a single band, particularly when it was drilled to the greater depths.

Iowa. With supplemental financing by the fertilizer industry, the Iowa station tested four types of phosphatic materials on *oats* planted on four different soils native to the State. Phosphorus uptakes and harvests varied among the four fertilizers from soil to soil, yielding data useful in specific localities but showing no over-all superiority in any one of the four materials.

Indiana. Growing tests at Purdue University showed that large applications of nitrogen and potassium doubled the uptake of phosphorus by *corn* plants.

Texas. In tests with *beans* planted in Houston black clay, the Texas Research Foundation reported that dicalcium and tricalcium phosphates, which have given good results in eastern soils, were "virtually useless" in the naturally alkaline Houston type.

Kentucky. Isotope investigators have been studying the problems of winter killing of alfalfa and leguminous plants. By applying radioactive fertilizer during the winter season they have found that there is considerable uptake of phosphate fertilizer during this time. It is possible that winter killing can be substantially reduced by winter fertilizing.

Other Major Plant Nutrients

Because of the key importance of phosphorus in the Nation's agricultural economy and the ready availability of usable radioactive phosphorus, the USDA-AEC project and its cooperating institutions concentrated on phosphate fertilizers in the first 2 years of work. Future work will include other major plant nutrients, such as calcium, nitrogen, and potassium.

Tracer research with these elements has been retarded for lack of isotope materials. Previously available radioactive isotopes of calcium have lost their radiation so rapidly that they could not be traced throughout a growing season, but AEC now produces a calcium isotope that maintains half its radioactivity after 152 days. The shorter-lived material has been used for some time in USDA studies of calcium movement in soil, and the new isotope was used by North Carolina State College and other institutions in 1951 to study calcium utilization by tobacco.

Calcium is also of an immediate value to the crops when calcium phosphate fertilizers are applied, though the phosphorus is generally the more limiting mineral for growth. Calcium is especially valuable for the acid tobacco soils of the East which have depleted calcium supplies. Therefore, labeled calcium fertilizers have recently been used to determine the value of the calcium in commercial fertilizers. In addition, because of waste disposal, the AEC is interested in the movement of calcium in soils. This is followed when the radioactive calcium fertilizers are applied.

Independent Fertilizer Studies

In addition to the foregoing fertilizer tests which receive assistance through the USDA-AEC project, AEC has sold isotopes for fertilizer research to universities, State experiment stations, scientific foundations, and an oil company.

The University of Tennessee Agricultural Experiment Station, using the facilities provided by the UT-AEC agricultural research program, has employed long-lived radioactive calcium to study the behavior, fate, and availability of this element in calcium carbonate and re-fused Wilson Dam slag when added to soil. Preliminary results with two types of soil suggest that the calcium from even the more soluble sources may not be completely exchanged with the available soil calcium after a year's time. The crops themselves determined to a large extent the rate at which calcium in the fertilizer became available for use. It was possible to distinguish between the amount of native soil calcium and that of added fertilizer calcium which was being removed by the rainwater and the crops.

Biological Sources of Plant Nutrients

Aside from minerals applied in chemical fertilizers, plants receive nourishment from organic matter in the soil. AEC contributes to two studies of such biological fertilizers. The University of Arizona is studying the supply of phosphorus from the residues of previous crops and from algae carried to the soil in irrigation water. The University of Wisconsin is applying isotope tracer techniques to nitrogen fixation by soil bacteria.

Three other university research groups have purchased isotopes from AEC for studies of biological plant foods. In this field of research Cornell University has done a great deal toward an understanding of the efficiency of barnyard manure fertilizers.

Phosphorus from Crop Residues

One Arizona study is designed to determine the conditions under which plants obtain maximum phosphorus contribution from the roots, plowed-under plants, or other residues of previous crops. The decomposition of these residues into forms that new plants can use depends on the activity of microbes, which are sensitive to chemical conditions in the soil.

The investigators tagged barley plants with radioactive tracers by growing them in pots containing radioactive phosphorus. The plants were harvested and separated into their principal parts, such as hay, straw, grain, and hulls, which were used as manures in pots of several Arizona soils. Rye grass was grown in these pots under variable concentrations of carbon and nitrogen. The efficiency of the various soils and treatments in making phosphorus from residues available to new plants was determined by measuring the yields, phosphorus content, and radioactivity of the rye grass, and by comparing them with control results obtained by fertilizing with phosphoric acid.

Results. Some of the findings were:

a) Rye grass obtained maximum phosphorus from the straw of barley harvested at a stage of medium maturity. It might have been expected that grain or flour, the part of the barley richest in phosphorus, would have provided the most efficient fertilizer, but these materials ranked below medium-mature straw, young hay, mature chaff and awns, and mature straw. The phosphorus in the grain was evidently in a form that was not readily released as a plant nutrient. The cause is being sought.

b) In medium-mature barley plants, the concentration of phosphorus was higher in the tops than in the roots, but in mature plants the tops and roots equalized.

c) Doubling the amount of applied phosphorus, either as barley residues or as inorganic fertilizer in the control tests, greatly increased the phosphorus content of the rye grass but rarely doubled it.

d) The uptake of phosphorus from barley residues was less in virgin and comparatively rich soils than in over-cropped and phosphorus-poor soils.

e) For optimum activity of the microbes that break down the residues and best delivery of phosphorus to the next crop, there is a critical ratio of carbon and phosphorus in the soil, which in turn is influenced by the nitrogen content—all of which can be regulated by supplemental treatments of the soil.

This study is directly aimed to yield fundamental knowledge but it has foreseeable applications. It points, for example, toward an answer to the question of how long to let "green manure" crops grow before plowing them under, and what supplements should then be added to the soil.

Algae as a Fertilizer

Arizona investigators are also studying the fact that algae growing on irrigated land in that area may add as much as 6 tons of organic matter to an acre of soil in a year, and that these low-order plants are rich in phosphorus. The problem was to measure the availability of this potential nutrient source to crops.

To prepare tracer material, green algae were incubated in a solution containing radioactive phosphorus. The algae were introduced into samples of three Arizona soils, and parallel control samples were prepared by treating them with phosphoric acid tagged with radioactive phosphorus. Barley seedlings then were grown for 16 days in each soil specimen under various controlled concentrations of phosphorus, carbon, and nitrogen. The phosphorus content of the dead algae appeared to be as available to barley seedlings as the phosphorus from water-soluble phosphoric acid. Measured by weight of the harvested seedlings, there was no significant difference between plants fed from the organic and the inorganic phosphorus source.

Current work on this study is aimed to determine what ratio of carbon to phosphorus in the soil most favors the decomposition of algae into an available plant nutrient and how the nitrogen content of the soil influences plants' consumption of phosphorus from algae.

Nitrogen-Fixing Bacteria

A group at the University of Wisconsin is exploring the long-known but imperfectly understood processes by which certain micro-organisms convert free gaseous nitrogen into "fixed" nitrogen. This process of nitrogen fixation is performed by bacteria dwelling in nodules on the roots of peas, beans, alfalfa, and other legumes, and also by certain free living species of bacteria in arable soils.

Bacteria on leguminous roots build up the nitrate content of the soil to nourish future generations of growing plants—sometimes adding 400 pounds of nitrogen per acre from a single alfalfa crop. The nitrogen fixed by the free-living bacteria in the soil is not immediately available to plants. The practical objective of the Wisconsin work is to find means of increasing the amount of nitrogen in the soil available to nonleguminous plants—especially wheat, which needs large amounts of this element.

Soil scientists believe the chances of accomplishing this feat would be improved if they knew more about the relationships between the bacteria and the plant in the root nodule process. Studies of nitrogen fixation have been handicapped by the fact that it ceases as soon as the nodules are removed from legume roots for any type of investigation. In a search for the factor that stops these life processes, the Wisconsin group tried to maintain life by applying various remedies to cut-off nodules.

Heavy nitrogen isotope. To determine the efficacy of these treatments, the Wisconsin investigators exposed excised nodules to nitrogen gas containing a measured fraction of isotopic nitrogen. Since no radioactive isotope of nitrogen maintains its radioactivity long enough for such work, a stable isotope, about 7 percent heavier than ordinary nitrogen, was used. If analysis of the nodule material in a mass spectrometer showed a more-than-normal proportion of heavy atoms, this would be evidence that the experimenters had succeeded in maintaining fixation of nitrogen in the cut-off nodules.[13]

Results. Very recently these investigators have achieved the long-sought goal—fixation of nitrogen by cut-off root nodules. Nodules separated from soybean plants have been handled so as to consistently fix heavy nitrogen sufficiently to be detected in the soluble portion of the nodules. Preliminary studies with the separated nodules have indicated that the rate of nitrogen fixation drops off very rapidly, which in the past has made it difficult to detect.

Only two species of free-living nitrogen-fixing bacteria had been found in 65 years of previous work: *Azotobacter* and *Clostridum*. The Wisconsin group has worked on four new ones: *Rhodospirillum*,

[13] The material used was nitrogen 15. AEC manufactures many different isotopes but N 15 was supplied for this experiment by Eastman Kodak Co. The mass spectrometer, used in determining the abundance of various isotopes in a material under test, is an instrument in which heavier and lighter materials are separated by the differential action of an electromagnetic field on them.

Rhodopseudomonas, *Chlorobacterium*, and *Rhodomicrobium* and is seeking others which may exist in nature.

Key role of ammonia. In tests on these independently existing micro-organisms with heavy-nitrogen tracers, the experimenters deduced that the first chemical products formed in a short time during nitrogen fixation would be the richest in isotopic nitrogen. When *Azotobacter* was allowed to fix nitrogen for a short period, the highest concentration of heavy nitrogen appeared in glutamic acid, one of the amino acids from which proteins are formed. Since ammonia is an intermediate product in the formation of glutamic acid, the theory is that nitrogen gas is first incorporated with hydrogen into ammonia. These observations and facts supported a hypothesis that ammonia is the key intermediate product in nitrogen fixation by synthetic means. Parallel studies with legumes indicated that nitrogen fixation follows the same pathway in root nodules.

Movements of Minerals in Plants

Movements of mineral nutrients in plants, the chemical reactions that readily dissolve some and cause others to bind up in insoluble compounds, and the remedies for resultant nutritional disorders are studied in seven AEC-supported tracer research projects. Because of their ability to signal the actions and motions of substances within living plant systems, tagged atoms have exceptional value in this area of research. AEC has a direct interest in determining how plants handle fission products and other atomic energy industrial wastes.

One institution is investigating the mobility of the common soil minerals as affected by their chemical relations with one another and with the so-called trace minerals, small quantities of which are essential to plant growth. Plant physiologists know that the freedom of movement of the nutrients depends in large degree on the proportions in which they are taken up by plants, but tracing identified elements through living plant systems was impossible before radioisotopes were available for this type of research.

Two groups are studying the sources of internal energy on which plants draw to bring about the complex exchanges of nutrients between roots and leaves and between mature and growing tissue. Other investigators are seeking causes and applying remedies for the widespread nutritional diseases which result when the excess or lack of a particular mineral causes nutrients to become bound up in forms that plants cannot assimilate properly. A western regional problem, the concentration by grain and fodder crops of a mineral, selenium, in quantities poisonous to animals and man, engages the efforts of two groups working with AEC financial assistance.

Apart from the 11 studies that receive AEC financial assistance, AEC has sold isotopes to a number of other institutions for use in research studies on movements of minerals in plants (see Appendix 12).

Mechanisms of Mineral Movements

Studies of the mechanics of the movement of nutrients involve the metabolic processes of plants as well as their anatomy. When a plant lifts dissolved minerals against gravity from roots to leaves, it expends energy. Plant physiologists have concluded that this is not wholly accomplished by osmotic pressure, the force which diffuses nutrients through membranes. The University of Missouri is investigating the role in mineral movements of more obscure sources of energy, such as transpiration pressure.

Transpiration, the process by which plants lose water by evaporation into the atmosphere, makes it necessary that the plant lift large amounts of water from the soil to the leaves. This process is regarded by plant physiologists as a partial explanation of the means by which minerals from the roots are lifted up to the leaves. To test this hypothesis, investigators at the University of Missouri developed an apparatus consisting of glass hemispheres, in which squash plants were fed tagged phosphorus through the roots. Since the rate of transpiration varies inversely with the concentration of water vapor in the surrounding air, the experimenters controlled the rate by varying the humidity in the hemispheres.

Repeated tests showed that radiophosphorus accumulated in the leaves at roughly the same rate that transpiration went on so long as plenty of phosphorus remained in the nutrient medium. As the phosphorus supply neared exhaustion, phosphorus accumulation declined but transpiration continued. Some phosphorus continued to accumulate in the leaves despite exhaustion of the root medium. This demonstrated that the leaves were drawing on some other phosphorus source in the plant, a movement to which transpiration contributed little or no action.

Mobile and Immobile Nutrients

The chemical relationships of nutrient elements and the effect of these relations on mobility of minerals inside plants are being investigated at State College of Washington. Many plant pathologists believe that this field of chemical interactions holds the key to plant nutritional diseases, such as the widespread, anemia-like chlorosis.

The Washington State workers grew soybeans and other plants in solutions containing tagged phosphorus, calcium, potassium, and nitrogen, in various combinations with iron, manganese, and other trace elements.

Phosphorus. Bean plants were grown in solutions in which the phosphorus concentration was varied and the plants later radioautographed—that is, laid over sheets of X-ray film (see photo). The resulting pictures showed that the phosphorus uptake increased within

Autoradiogram film of radioactive phosphorus 32 showing the characteristic distribution of this element in a bean plant. The younger tissues have acquired the highest concentration of the radioactivity. Washington State College.

but not beyond a very low concentration range of phosphorus in the soil. When a plant was fed radiophosphorus, then deprived of all phosphorus, radioautographs showed that the new growing leaves drew on mature leaves for the element until the old leaves were depleted and died. The phosphorus distribution in plants fed through the leaves rather than the roots followed much the same pattern.

Calcium and sulfur. The Washington State experimenters studied the uptake of calcium by bean plants from soils whose alkalinity had been reduced by adding acid fertilizers. Radioautographs showed that when the nutrient solution was low in calcium ions, low in phosphorus, and slightly acid or, in other words, low in pH, the element calcium was freely mobile in the plant. However, when the reverse of any of the above took place the element became immobile.

In contrast the element phosphorus is freely mobile within the plant regardless of any change in the nutrient solution or soil. This suggests the possibility of obtaining good results from spray application of phosphorus compounds rather than by adding them to the soil where they would not be utilized as effectively.

Plant Nutritional Diseases

The immobility of trace elements is accounted for by their compounding in forms that make them insoluble, and the accumulation of data on these phenomena presents a line of attack on nutritional disorders. A major purpose in studying mineral movements and metabolism in plants is to gain understanding of the plant nutritional disease called chlorosis, which the USDA has called the "primary limitation" on current fruit production. The disease is symptomized by yellow leaves, stunted growth, and dwarfed fruit. Though chlorosis is found in all parts of the country, it is particularly prevalent in large areas of the West, where the meagerness of rainfall allows calcium and other alkaline components to build up in the soil. This situation apparently inhibits plants' utilization of trace minerals, particularly iron. Chlorosis also occurs when other trace minerals, such as zinc, copper, and manganese, are naturally deficient or imperfectly assimilated.

Utah State College has studied lime-induced chlorosis under an AEC research contract, and Washington State is studying chlorosis caused by lack of zinc. The USDA-AEC Beltsville laboratory is also comparing lime-induced chlorosis of western soils with chlorosis occurring in organic Michigan soils deficient in copper. The University of Tennessee is studying the effect on iron movement of excessive manganese in the soil.

Iron injections. The Utah workers injected iron mixed with a radioactive isotope of this metal into the trunks of chlorotic peach trees growing in an alkaline Utah soil. The leaves, which were yellowish when the iron was applied, turned black and dropped from the trees within a few days. Radioactive assay disclosed a heavy concentration of iron in the dead leaves. Within 11 days of the application, new leaves appeared containing iron. They were green at first but soon turned chlorotic. Measurement of the iron content of new leaves showed that they contained smaller quantities of the radioactive iron. The workers ascribed the failure of the treatment to produce permanent green leaves to some unassimilable characteristic in the iron retained in the plant.

Iron and other elements. In further tests at Utah State and Washington State, radioactive iron was introduced into chlorotic beans and other vegetable plants in solutions containing potassium, calcium, and phosphorus in various concentrations. These experiments produced the following conclusions: (*a*) A high lime concentration in the soil does not inhibit the plant's uptake of iron—but, once within the plant, iron taken from such soils does not move freely; (*b*) leaves of chlorotic plants show a high content of potassium but this appears to be a result, not a cause, of chlorosis; (*c*) a high phosphorus level in the soil causes plant roots to precipitate iron but there is no conclusive evidence that the precipitation causes the chlorosis. In a separate experiment, the workers have found evidence that manganese deficiency is also a contributing cause of trace mineral-induced chlorosis.

Copper and iron. Although iron moves sluggishly when taken up from alkaline soils and although the incidence of chlorosis in plants grown in such soils is high, the absence or inaccessibility of other essential trace elements will also cause chlorosis. Biochemically, the seat of chlorotic disturbance is believed to lie in the metabolism of the plant. These trace elements are components of plant enzymes—such as manganese in chlorophyll. During 1951, USDA's Beltsville laboratory, in an effort to trace chlorosis to a failure in an enzyme system, compared reactions of chlorotic plants in a Utah calcareous soil deficient in iron and a Michigan organic muck soil deficient in copper.

Several plant species were grown on the Michigan soil, the Utah soil, and mixtures of the two in the presence of radioactive copper or iron. Preliminary findings related the chlorosis to an enzyme, though not conclusively. Spring wheat grown on the iron-deficient Utah soil to which radiocopper was added developed only slight chlorotic symptoms. Analysis of radioactive content showed only slight activity in the iron enzyme but the copper enzyme was highly active, suggesting that it abated the chlorosis. On the other hand, wheat grown in a copper-deficient organic soil supplied with radioiron became severely chlorotic, showing that iron apparently cannot substitute for copper.

Zinc deficiency. USDA and Washington State are jointly investigating chlorosis and other nutritional disorders induced by zinc deficiency. Designed to study the lack of this trace mineral in the Columbia basin's irrigated soils, this research holds interest for seven other states and the Territory of Hawaii, where zinc scarcity limits corn and fruit production. AEC aids with the supply and utilization of radioactive zinc in the Washington State and Utah State experiments. USDA-AEC Beltsville program is also studying zinc deficiency in work similar to their phosphoric fertilizer experiments.

Biochemical research has shown that zinc is essential in the production by plants of the growth stimulator, auxin. Zinc sulfate applied to the leaf has proved an effective remedy for the pigmy leaves, dwarfed blossoms, and withering fruit symptomatic of zinc starvation in corn and fruit trees. When this project began, however, virtually nothing was known of the factors which inhibit the uptake of zinc from the soil, of its effect on other minerals, or of the levels of zinc required for nourishing various plant tissues.

Using conventional methods of microscopic study and chemical assay, the research force is studying the role of zinc in nutrition of a number of plants and its effect on uptake of other elements, including calcium, potassium, iron, and copper. None of the chemical methods of discriminating between mobile and immobile zinc in soils has won general acceptance.

Tracer research is employed to determine zinc distribution in corn, its effect on uptake of calcium and nitrogen, and its availability in soils. Corn is grown in calcareous soils which supply zinc to plants and in other soils which do not. By adding radiolabeled zinc in varying amounts to the zinc-withholding soils, the workers hope to come upon a formula which will induce the movement of the mineral. The results of these tests are studied by making radioautographs which chart the course of the tracer zinc in the plants.

Iron and manganese. Plants are known to become chlorotic when grown on soils containing excess manganese. Nutrient culture studies with peanuts at the University of Tennessee-AEC agricultural project at Oak Ridge showed that large amounts of manganese in the nutrient solution almost completely prevented the movement of radioactive iron from the solution to the young leaves. The amount of iron which did move to the leaves was closely correlated with the severity of the chlorosis.

"Alkali Disease"

A problem in which plants take up too much rather than too little of an element is "alkali disease," in which grain and fodder crops in some western areas pick up selenium in amounts unharmful to themselves but poisonous to animals eating the plants. Autopsies on selenium-poisoned animals have disclosed erosion of the bones, suggesting an interference by selenium in the metabolic process by which calcium and phosphorus are converted into bone tissue.

South Dakota State College is growing "selenium indicator" plants on soils treated with radioactive tagged selenium. These plants, all vetches such as *Astragalus*, a wild native leguminous plant, have a particular power to concentrate selenium from the soil. By following the course of the radioactive selenium in these plants and in feed plants such as wheat and alfalfa, the workers hope to uncover the reason for the "indicator" plants' ability to concentrate larger amounts of selenium. The study also seeks to discover the relationship in the indicator plants' metabolism between selenium and sulfur, a chemically related element which the plant needs in quantities. The University of Wyoming with AEC support is also studying the toxicity and metabolism of selenium by mice and other small animals

Tracer Research on Trees

Tree nutrition and tree diseases are being explored by five universities in tracer research supported by AEC. Nutrition problems are approached from three directions: Duke University studies absorption of nutrients by roots; the University of Michigan, absorption by leaves; North Carolina State College, the movement of elements in various species of trees. Tree diseases are investigated by the University of Idaho, which is seeking the cause of pole blight, and by the University of Wisconsin, which is studying the fungus that causes oak wilt.

Root Absorption of Nutrients

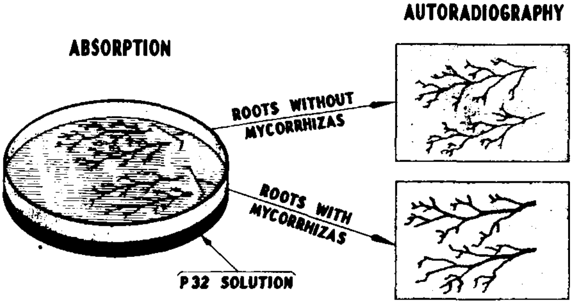
The Duke project is studying radioactive phosphorous assimilation by two kinds of pine tree roots: mycorrhizal roots, which are normally found in nature and are contaminated with a soil fungi, and non-mycorrhizal roots, which are not infected with the fungi. One Duke experiment was designed to establish whether there is a mutually beneficial relationship between the fungi and the host pine tree. Short pieces of pine root were sterilized of fungi, submerged for three hours in a solution of radiophosphorus, then rinsed of surface phosphorus and placed over photographic plates. The resultant image on the plates measured the quantity of the radiophosphorus nutrient absorbed within the roots. The same procedure was repeated with fungi growing on the root. A brighter picture showed up on the radioautogram. This demonstrated that the presence of the fungi had increased the root's absorption of phosphorus (see diagram, p. 117).

Current experiments are directed at resolving conflicting theories as to how the fungus-root relationship benefits the trees. One theory holds that the fungi predigest nutrients for the trees, and the other that the fungi increase the roots' absorptive surfaces by enlarging the mature portion of root where the fungi dwell.

To test the predigestion theory, pine seedlings are inoculated with fungi and planted in sterile sand. To this the workers apply radioactive carbon in an inorganic form which only the fungi can assimilate. The presence or absence of radioactivity in the pine seedlings, as disclosed by radioautograms, should determine whether the fungi, by digesting the carbon into an organic compound, make it available to the seedlings.

RADIOACTIVE PHOSPHORUS – P32

FOR STUDYING ABSORPTION BY PINE ROOTS HAVING MYCORRHIZAS



ADVANTAGES:

1- AUTORADIOGRAPH SHOWS AMOUNT AND LOCATION OF ABSORBED PHOSPHATE

2- SHOWS GREATER ACCUMULATION OF PHOSPHATE IN ROOTS WITH MYCORRHIZAS BECAUSE OF:
A - INCREASED SURFACE
B - HIGHER METABOLIC ACTIVITY

Illustrating how radioactive phosphorus 32 is utilized in studying the value of mold filaments (mycorrhizas) on pine roots.

Other Factors in Nutrient Movements

Botanists have long known that trees raise simple inorganic compounds from roots to leaves and lower complex organic carbohydrates formed by leaves to nourish root cells. In a project commenced in 1951, workers at North Carolina State College are attempting to determine how the composition of the soil affects upward movement, and how seasonally changing temperatures and variations in the structural anatomy of trees affect both upward and downward movements.

Specimens ranging in variety from conifers to hardwoods, and in age from greenhouse seedlings to mature field trees, are being studied. On seedlings, upward movement is traced by applying radiophosphorus, radiocalcium, and radiosulfur in water solution at the roots, then radioautographing the stems. In tracing downward movement, radiolabeled carbon is applied as carbon dioxide gas to the leaves and the plant is then radioautographed.

In field experiments with mature trees, the roots of various types with trunks up to 6 inches in diameter are excavated and vials of radiophosphorus, radiocalcium, or radiosulfur applied to the root tips. At intervals, the trees are felled, trunks and branches sectioned, leaves stripped, and all material reduced to ash. By analyzing the ash from each portion of the tree for radioactivity, the experimenters determine how high and how fast the minerals have moved.

Such knowledge finds applications both in solving basic problems of tree nutrition and in developing techniques of protecting desirable trees from fungi, insects, and the competition of undesirable tree species. Elements used in tree nutrition—sulfur, for example—are also compounded into the poisons used against the enemies of trees.

Leaf Spray Fertilizers

Feeding sickly trees through the leaves is not a new idea, but claims that fruit trees absorb fertilizers applied as sprays more readily than they do fertilizers from the soil have not been subjected to thorough scientific investigation. Reports that leaf applications of dissolved iron, copper, and zinc cured malnutrition in fruit trees prompted Michigan State College to undertake tracer studies of comparative utilization by trees of soil fertilizers and leaf sprays.

The Michigan workers apply tagged potassium, calcium, and phosphorus by root to some trees and by leaf to others, then analyze the radioactivity in leaves and fruit.[14] A painting of radioactive potassium on a lateral branch of a dormant plum tree during February 1951 brought surprising results. Despite subzero temperatures and presumed immobility of the tree sap at this season, the tracer material moved 18 inches on each side of the point of application in 48 hours. Tagged potassium applied to the branches of other dormant trees, kept in the greenhouse at summer temperatures, moved to the roots in 26 hours.

Pole Blight in Pine

Intensive research by the University of Idaho and the United States Forest Service on pole blight preceded negotiation in early 1951 of an AEC contract for study of the problem. The symptomatic scanty foliage on the crowns of trees, yellowing foliage lower down, and lesions on the bark, had become common among mature white pines over 100,000 acres of Northern Rocky Mountain timberlands while the earlier search for cause and cures went forward. Chemical

[14] Leaf sprays of strontium, an atomic energy fission product, also are being tested at Michigan State College; see page 87.

analyses of dead and dying trees disclosed heavy concentrations of phosphorus and deficiencies of calcium, nitrogen, manganese, and boron, but the soil itself showed no such deficiencies. The same soils, moreover, supported diseased and healthy trees in close proximity.

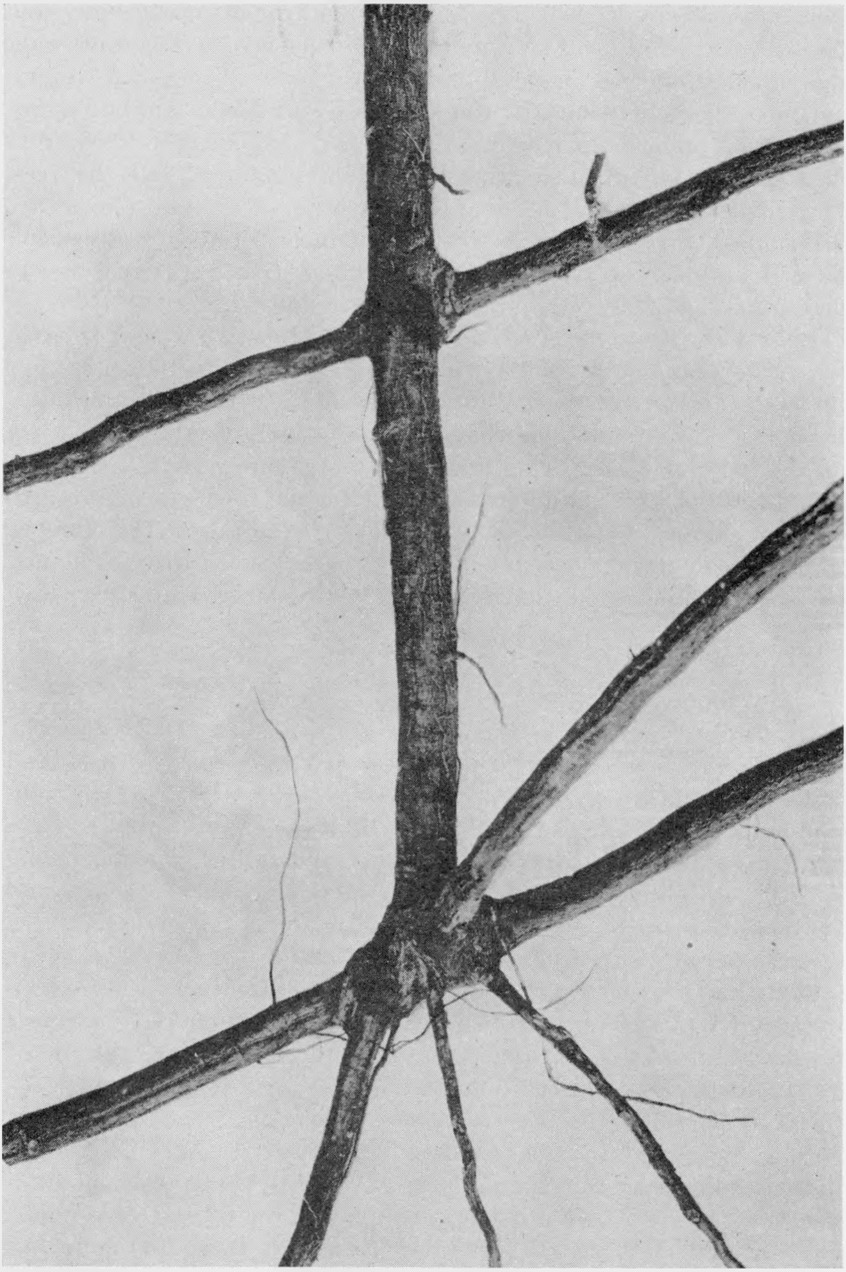
Under the AEC contract, the University of Idaho applies radioactive phosphorus and calcium to diseased and healthy trees from flasks fastened to intact root tips, then, after an interval, fells the trees. Distribution of the calcium and concentration of the phosphorus are determined by radiation detectors. The trunks are cut in sections and burned, and the ash from healthy and diseased tissues is analyzed to determine the calcium and phosphorus distribution.

Besides these searches for a nutritional malfunction within diseased trees, the Idaho workers are studying the possibility that a fungus interferes in the distribution of nutrients. Pine seedlings are inoculated with the fungus *Armillaria mellea*, an organism known to live on the roots of pines. The infected seedlings are immersed in solutions of radioactive phosphorus and calcium and their rates of absorption are compared with those of uninfected seedlings. This fungus, so far as is known, has not been harmful to pine, but the research may possibly disclose a mutation that made one or more strains parasitic.

Oak Wilt

As deadly as pole blight and more widespread, oak wilt is caused by *Chalara quercina*, a fungus that grows in the sapwood of oaks and stops the exchange of nutrients between roots and leaves. The wilt, symptomized by dull and curling leaves in the crown, followed by a downward spread until all leaves blacken and fall, is endemic among red oaks in Minnesota, Indiana, Iowa, Missouri, and Wisconsin, and has attacked bur and pin oaks. The spread of this wilt has been recently surveyed from low-flying aircraft, and it is now reported to extend into Northern Arkansas and Western Kentucky. The University of Wisconsin determined one means of its spread by nontracer research and is now plotting patterns of the spread with the use of radioactive iodine and rubidium.

By transposing dyes between trees, excavating roots, and transferring spores between infected and healthy trees, the Wisconsin workers established that spontaneous grafts between the roots of adjacent trees are one transmission pathway for the disease (see photo, p. 120). This did not explain, however, why red oaks are more susceptible than pin and bur oaks, or why the infection occasionally passed over trees close by but appeared in healthy stands a few hundred yards to a mile away.



Root grafting between roots of oak trees which is the pathway for the spread of the oak wilt disease. Radioactive tracers have been used to study these pathways underground. University of Wisconsin.

Radioactive iodine, applied by cones fastened to the trunks of selected trees in test plots, has cleared up some of this obscurity. The penetrating radiation emitted by the radioisotope, moving within root systems and mapping their intricacies in the plots of oaks, showed numerous root grafts among the red oaks, almost none among the bur and pin oaks. When traced in isolated trees, the isotope followed pathways corresponding to the pattern of wilt symptoms. Its movement in bur and pin oaks was slower and less extensive than in red oaks.

These findings, which partially account for the higher resistance of bur and pin oaks to the disease, may also help explain the occasional erratic "over-jumps." Work in progress bears upon various possible causes, including density of stands, the characteristics of infected and bypassed sites, and effect of temperature. In cold seasons, when movement within trees is slower, radioiodine is replaced by the radioactive rubidium, which has a longer half life though it emits a radiation that is less penetrating.

Studies of Crop Pests

In fulfilling its obligation to broaden peaceful applications of atomic energy, AEC contributes to tracer research on crop pests. Fungi and insects inflict 6 billion dollars of damage a year, and weeds are a further source of loss. Dusts and sprays hold down losses but constant improvements are required to maintain control. Rusts, smuts, molds, mildews, and insects develop resistance to poisons, and the lethal range of the new weed-killing chemicals is restricted.

By building radioactive isotopes into the chemical structures of pest-killing preparations, researchers gain clearer knowledge of their basic action, their advantages and limitations. Radioisotopes are peculiarly useful in this field because insecticides and weed-killers are ordinarily used at such low concentration that detecting them by other means is difficult or impossible. As tags on food given air-borne fungi and insects, isotopes are used to "label" these species and map their patterns of dispersion.

AEC lends support to five projects on control of crop pests. The Boyce Thompson Institute of Plant Research at Yonkers, N. Y., tests the action of fungicides on crop leaves and their poisonous effect on fungi; the Battelle Memorial Institute at Columbus, Ohio, studies their complex lethal mechanisms. The two laboratories report the tracer tools are indispensable in comparing fungus-killing properties of inorganic Bordeaux mixtures (which appear merely to coat the surface of crop leaves) with the effects of the complex postwar organic compounds (which apparently are absorbed by leaf tissue).

The Connecticut Agricultural Experiment Station is attempting to find means of radiation attack on the fungus that causes Dutch elm disease. The University of California's Citrus Experiment Station at Riverside is studying insecticides; Oregon State College is studying insect migration and weed killers.

Fungi and Fungicides

The Boyce Thompson project seeks to determine (*a*) whether the cilia, the thread-like organs through which fungi feed, penetrate the host plant mechanically or by secreting a dissolving fluid; (*b*) the effectiveness of wetting agents which are added to Bordeaux mixtures to facilitate their spread on leaves; (*c*) the action upon the fungi of sulfur, the lethal element in the Bordeaux mixtures; and (*d*) whether, as external evidence indicates, plants sprayed with the postwar organic fungicides absorb the material, making fewer sprayings necessary. E. I. du Pont de Nemours & Co., producer of dimethyldithiocarbamate, and Union Carbide & Carbon Corp., producer of glyoxaldine, contributed toward the cost of preparing isotope-tagged lots of organic fungicides used in these tests.

In non-tracer tests of the du Pont compound, not financed by AEC, fungus spores set out on the upper sides of apple leaves failed to germinate when the lower sides were sprayed with the chemical. A similar property in the Union Carbide preparation was deduced from the fact that scab fungus was killed when it was set out on leaves that budded after mature leaves had been sprayed. The Boyce Thompson workers, using the istope-labeled fungicides, confirmed that both compounds are absorbed by leaves and distributed widely through the tissue. They also discovered that the leaves converted part of each compound into carbon disulfide.

Boyce Thompson also developed new data on the reaction of sprayed plants and fungi to sulfur. In one experiment, tomato plants were exposed for several days to radiotagged sulfur in a vaporized form. Subsequent analysis showed radioactivity in every part of the plants, diminishing from six times the background count in stems nearest the exposed leaves to only twice the background count at the roots.[15]

Research at Battelle. The study at Battelle is aimed at determining whether Bordeaux mixtures and organic compounds merely adhere to the walls of the spore cells or are absorbed into the cell protoplasm. The first problem was to separate protoplasm from the cell walls which enclose it, a delicate task. The Battelle workers worked out a

[15] Background count: Response of a counter to the very low radiation from cosmic rays and trace amounts of radioactive elements naturally present in and about the counter.

successful technique for this separation method and are currently applying tracers to the larger problem.

Insecticides and Insect Migrations

Radioisotopes play a part in testing complex organic insecticides which are being developed to cope with pests that develop resistance to older insecticides. One problem in making compounds useful in orchards has been the development of solvents which, while coating leaves evenly, will not interfere with the absorption of the compound by the insect that eats it.

In tests of a number of compounds, California's Citrus Experiment Station at Riverside first used the cockroach, which can be bred easily and which reacts, as many crop-destroying insects do, to insecticides. The workers labeled with P 32 four phosphorus-containing organic insecticides and prepared each in different solvents. Measured doses of the compounds were injected in roaches by micrometric needle. After definite time intervals, the roaches were frozen to death in crushed dry ice, dissected, and tested for radioactivity.

Though the insecticides were known to be of different toxicities, all four materials were found in the roach bodies in about the same amounts. This led to the conclusion that the differences in toxicity were not caused by differences of permeability among the four compounds. In addition, when used in a glycol solution, the insecticides tended to concentrate in the abdomen, though all of them owe their lethality to their effect on the insect's brain.

Further experiments were made to test the possibility that a low excretion rate would account for the higher toxicity, but the most toxic of the four also showed the highest excretion rate. The workers found, however, that the more water-soluble the compound, the more it was concentrated in the abdomen. This correlation indicated that the compounds may be transported in the roach's blood stream, which has a high percentage of water. Whether this explains the higher toxicity of certain compounds remains to be determined.

California crop pests. Other problems of California insect control are citrus thrips, against which tartar emetic insecticides are no longer effective; red scale, which has become resistant to fumigation by hydrocyanic acid; and soft brown scale, which seems impervious to the organic compound parathion. The Riverside station currently is seeking, with isotopes, to clarify the failures of insecticides in the hope that this knowledge will lead to effective substitutes.

One study concerns the action of pyrophosphoramide, a compound which is relatively nontoxic when applied directly to insects but be-

980705—52——9

comes highly toxic to thrips, red aphids, red mites, and other sucking insects when they take it from the sap of plants. The Riverside workers applied measured amounts of radiolabeled pyrophosphoramide to lemon trees, potatoes, squash, tomatoes, beans, and other plants as a soil nutrient, then fed the plant sap to insects. The insects were dissected and radio-assayed for absorbed poison. With most plants, only trace amounts of the insecticide were found in the insects.

Tagged flies. Using radiophosphorus, Oregon State College has carried out studies on insect migrations. Experiments on the blowfly have increased knowledge of the flight powers and migratory habits of this barnyard pest.

A colony of 15,000 flies, bred in captivity, was deprived of water for several days, then allowed to drink from a radiophosphorus solution. The flies then were released outdoors in the center of an area in which traps baited with decomposed liver had been set in concentric circles to a maximum distance of 4 miles. Twenty-four hours later, many radioactive flies were found in the 4-mile circle, well beyond their anticipated 24-hour flight range. Traps were then moved out to 8 and 12 miles. Blowflies recovered from the 8-mile circle after the second day suggested a stronger migratory tendency in the species than earlier nontracer experiments had indicated.

Older methods for tracing insect migrations involve shaking the insects in sacks containing special pigment. The Oregon workers credited the tracer technique with producing data more reliable than pigment marking, with a saving in labor. The isotope tags could not rub off in flight as pigments sometimes do, and when the total catch in the traps was sorted for tracer flies, radiotagged insects were more quickly and surely detected than those marked with pigment.

Action of Weed-killers

Under an AEC research contract, Oregon State College is studying chemical compounds which poison plants selectively and have therefore come into wide use in weed control. Of more than 100 such weed killers on the market, the Oregon workers are currently investigating two with opposing toxic properties. One is the widely used 2,4-D, which kills wild onion, Canada thistle, and other broad-leafed weeds at concentration levels that do not injure grains and pasture grass. The other is I. P. C. which shows promise as a killer of quack grass and other noxious grasses at low concentrations that do not harm flax, clover, and alfalfa.

Seeking an explanation of the lethal action of 2,4-D on broad-leafed plants, the Oregon workers studied its absorption and distribution in the soybean. This valuable plant reacts to 2,4-D in much the same way as broad-leafed weeds, and its physiology has been more thoroughly studied than that of many weeds. A solution of 2,4-D labeled with radioactive carbon was applied to the first, or primary, leaf on 30 bean plants grown in the greenhouse, at a time when those leaves were fully expanded and buds of other leaves were still small. Plants were harvested in groups at intervals of 2, 8, 48, 96, and 144 hours after application. The plants were dried and sectioned and the treated and untreated leaves, terminal buds, stems, and roots were separately assayed for radioactivity.

Among plants harvested after 2 hours, radioactivity in all parts was equal, indicating rapid migration of the herbicide. At 8 hours and above, specific activity in the stem exceeded that in all parts except the treated leaf. This demonstrated a concentration of the weed-killer in the stem. Concentration in the roots increased progressively from 8 hours upward.

Chemical analysis of weeds treated with 2,4-D has indicated that the compound inhibits their uptake of soil phosphorus. Confirmation was sought through a tracer experiment. Bean plants were grown in a solution of radiophosphorus, and half of them were treated with 2,4-D. After 5 days, the plants were harvested and the parts assayed for radiophosphorus. Radioactivity in the plants treated with 2,4-D was less than half that in untreated plants. This test confirmed the phosphorus-inhibiting action of the weed killer.

A third experiment, in which radiotagged 2,4-D was applied to the primary leaves of oat plants, explained the resistance of this narrow-leafed grain to the compound. When harvested after 96 hours and radioassayed, the various sections of the plants showed only small amounts of the compound absorbed by the primary leaf and still less translocated to other parts.

Additional experiments of this nature are in progress at the University of Oklahoma, where investigators are examining the extent to which 2,4-D and other materials which influence plant growth, are absorbed in darkness and light, and with reference to the amount of starch distributed in the plant.

I. P. C. studies. Since the grass killer, I. P. C., is generally applied to the soil surface, Oregon State is seeking to determine its penetration of soil under varying amounts of rainfall. Samples of soil are packed in long plastic tubes whose open tops are covered with filter paper on which I. P. C. labeled with radioiodine is placed. Water equivalent to the rainfall condition being studied is dripped on the filter paper for varying intervals and the tubes allowed to stand for 1, 2, and 3 days. They are then sectioned and assayed for radioactivity. These tests have not yet produced conclusive findings.

Photosynthesis and Biosynthesis

Because isotopes were available in quantity, biochemists in the past 5 years have gleaned new knowledge of photosynthesis, the chain of processes in which algae and land plants (*a*) take in water and carbon-dioxide gas, (*b*) use the sun's energy to build up energy-rich carbohydrates, proteins, and fats from these inert raw materials, and (*c*) release oxygen into the air.

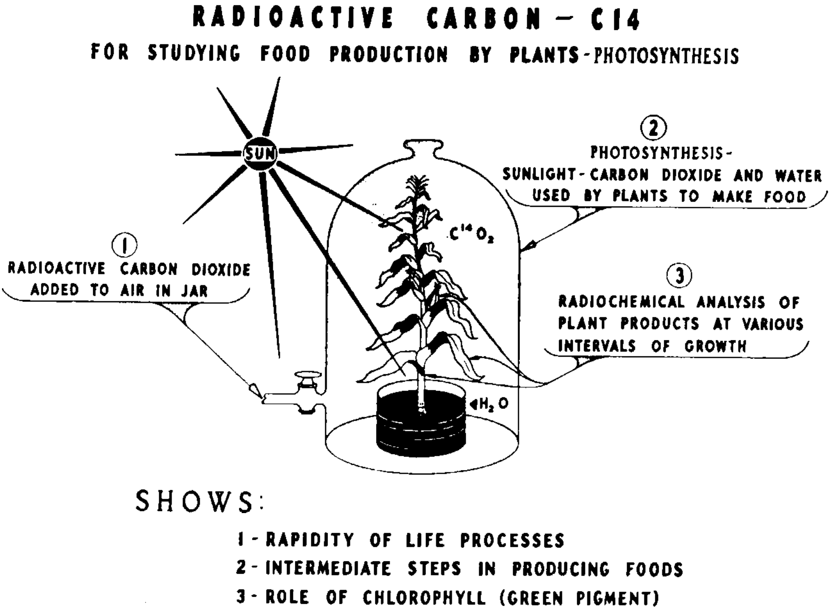
In photosynthesis, as in studies of other life processes, the special value of isotopes is that, by following their radioactivity, scientists can trace out the things that happen in normally functioning organisms. Older and still useful research tools lack this ability. Experimenters learned some years ago, for example, how to insert fine needles in the cells of green algae without apparently killing them, but the probing put an immediate end to photosynthesis. Any experimental procedure which disrupts the cell stops photosynthesis. This drawback is overcome when tagged atoms are used to study the photosynthetic process.

Photosynthesis is one of the most important phenomena in nature. Without it no life could survive, for plant tissue, produced by photosynthesis, is the ultimate source of food for plants, marine life, and animals. The world's coal and petroleum came from plant tissues produced ages ago by photosynthesis, and the same phenomenon produces the world's forests today. Photosynthesis not only provides food and fuel; it helps to replenish the earth's supply of fresh oxygen, and keeps animals and men from asphyxiating themselves on the carbon dioxide that is given off with every living breath and every burning of fuel (see diagram, p. 127).

Photosynthesis has fascinated generations of investigators whose only motive was to understand its mysteries, but it is also a study with potentially revolutionary applications. If man can learn to make photosynthesis take place more efficiently or to guide it into producing the more valuable kinds of nutrients, the world's food supply can be greatly expanded and improved. If it becomes possible to synthesize carbohydrates economically enough—either in living plants or in chemical reactions that imitate the processes in plants—these products can be converted into hydrocarbons, with the effect of alleviating demands on the limited supply of petroleum and coal.

Apart from such very long-range possibilities, photosynthesis research with radioactive isotopes already finds a more limited application in the biosynthesis of tagged plant materials. Food and medicinal plants are grown in an atmosphere containing radioactive carbon dioxide, causing them to photosynthesize radioactive carbon into their characteristic tissues and chemical products. These compounds are extracted, purified, and used in tracer research studies of practical problems in medicine and animal nutrition.

To explore the use of atomic energy techniques in fundamental photosynthesis research, AEC finances a project at the University of California Radiation Laboratory, at Oak Ridge and Brookhaven National Laboratories, and contributes to cost-sharing studies at the Universities of Utah, Arkansas, and Wisconsin, and the Smithsonian



Radioactive carbon 14 research in photosynthesis.

Institution. Tagged plant materials are produced by photosynthesis at Argonne National Laboratory and, on a smaller scale, at Brookhaven and Oak Ridge.

In addition to this work that receives direct cash support, AEC, in the last 5 years, sold radioisotopes to a number of other investigators for photosynthesis study (see Appendix 12).

Photosynthesis Research at California

The history of photosynthesis study with atomic tracers began in 1939–40, when the University of California Radiation Laboratory first succeeded in producing radioactive carbon 11 and carbon 14 in the cyclotron. Carbon enters into every process of life chemistry; plants utilize radioactive carbon in the same way as they do ordinary carbon; and carbon 14 maintains its radioactivity for very long periods at a virtually undiminished level.[16] For these reasons, carbon 14 is an ideal tool for photosynthesis research. It was scarce and expensive when it was produced in the cyclotron, but this handicap was overcome when, at the end of the war, the nuclear reactor at Oak Ridge started the quantity production of radioisotopes.

The photosynthesis studies with carbon 14 begin by growing plants in an atmosphere containing radioactive carbon dioxide. The green leaves immediately begin to take in the radioactive gas and to photosynthesize it into compounds, which are tagged with the radiocarbon.

It had long been known that photosynthesis produced sugars containing six carbon atoms, but the intermediate products the plant created in arriving at sugar were unknown. The initial objective of the Berkeley project was to determine the first organic compound formed during photosynthesis, and then to determine the nature and order of appearance of subsequent intermediates.

Experimental technique. Since plants require time to complete each intermediate step, the Berkeley experimenters attacked their problem by giving plants a limited time to assimilate the radioactive carbon dioxide. When the time was made very short, the tagged atoms could then appear only in the earliest intermediate compounds.

To identify these compounds, the experimenters first used the regular isolation methods of organic chemistry and some of the special techniques of ion exchange which had been successfully developed by the Manhattan Engineering District for other separation problems. Later they used paper chromatography, a technique developed by British scientists in 1944. After exposing the plants to the radioactive carbon dioxide for a measured period, they stopped photosynthesis by freezing the leaves in liquid nitrogen followed by extraction in boiling alcohol. This produced a green extract containing the products of photosynthesis. A small amount of the concentrated extract was placed near the corner of a large filter paper and allowed to dry. An adjacent edge of the paper then was placed in a trough filled with organic solvents mixed with water, which slowly flowed as in a wick across the paper. As this liquid passed the spot of dried leaf extract, the extract dissolved and moved with the solvent. Each compound has a characteristic speed of movement, depending on its solubility. Sugars—early products in the photosynthesis chain—move slowly, whereas fats move more rapidly. This manipulation segregated the various products of photosynthesis into separate locations on the filter paper.

[16] A quantity of carbon 14 loses half its radioactivity in 5,900 years. In contrast, the half-life of carbon 11 is only 20 minutes.

Since the plants had been given only a short time to assimilate radioactive carbon dioxide, the spots of compounds formed during the first stages in photosynthesis were radioactive and those formed at later stages were not. The distribution of radioactive material was determined by laying a sheet of X-ray film over the filter paper. The result was a radioautogram—a map on which the location and relative radioactive intensity of each radioactive compound appeared as an exposed spot on the film. The radioautogram from a plant that had photosynthesized 1 minute in radioactive carbon dioxide showed at least 50 tagged compounds.

Phosphorus map. Collateral evidence indicated that the products first produced in photosynthesis contained phosphorus as well as carbon. Following this lead, the experimenters next used the filter paper and radioautograph technique on extracts from plants that had been fed radiophosphorus while they were growing in carbon dioxide. Thus, the radioactive tag was now on phosphorus atoms. The phosphorus map had some black spots that corresponded exactly with those on the carbon map—showing that the compounds they represented contained both elements.

The first product. The experimenters made the exposures to radioactive carbon dioxide shorter and shorter, causing fewer and fewer radioactive compounds to appear in the radioautographs. In 2 seconds, the plants had time to produce only two or three tagged compounds. By this method, the Berkeley group determined that the first stable organic chemical a plant produces in photosynthesis is phosphoglyceric acid, which contains three carbon and one phosphorus atoms, oxygen, and hydrogen. Slightly longer exposures disclosed that other early products are derived by biochemical reactions from phosphoglyceric acid. This chain of reaction leads to the formation of sugars and other compounds essential to plant life.

Other products. Next after phosphoglyceric acid, the plants produced triose phosphates, also containing three carbon atoms. This material then changed, in several steps, into fructose phosphates, with six carbon atoms. The way in which this merger or condensation was accomplished in the plants was determined by breaking down the compounds and locating the radioactive carbon atoms at each structural position in the molecules. It was found that the six-carbon sugars were formed by a head-to-head combination of two three-carbon pieces—perhaps the reverse of the sequence by which six-carbon sugars are broken down in animals and yeasts.

When plants were allowed to photosynthesize 2 minutes, the radioactive carbon tag appeared in most of the numerous amino acids which go into the building of protein molecules, and even in proteins and fats. This showed that carbon fixed by photosynthesis goes very rapidly into all constituents of the plant.

One basic process. Tests with radioactive carbon at California showed that photosynthesizing bacteria, various green algae, and barley, soybeans, sugar beets, geraniums and all other higher plants tested make the same compounds during the first stages of photosynthesis. Only later in the chain does each plant begin to produce its specialized products.

Some implications. Once the mechanism of photosynthesis is largely determined, it may be possible that certain chemical pathways may be blocked and others opened wider. The Berkeley experimenters found, for example, that the algae, *Scenedesmus* given radioactive carbon dioxide one minute under acidic conditions produced 10 times as much sucrose sugar as plants grown under alkaline conditions, but malic acid was formed more rapidly in the alkaline environment. Proceeding along independent lines, the laboratory of the Carnegie Institution of Washington at Stanford, Calif., succeeded in growing the green algae *Chlorella*, the cells of which are normally largely protein, under conditions favoring the formation of abnormally high proportion of fats.

Photosynthesis Research at Oak Ridge

Since 1947, work on photosynthesis at the Oak Ridge National Laboratory has been mainly concerned with the effect of damaging radiations on photosynthetic processes and with the method by which light energy is transformed into chemical energy. It was shown that one of the steps in photosynthesis—a step related to the light absorption process—is damaged by radiation. It was shown also that cytochrome c, a compound closely related to hemoglobin, the red coloring matter of blood, can receive the chemical energy which the green particles in plants create from light energy.

Within the last year work has been centered on a new phenomenon—the fact that green plants not only can absorb light energy, but that they also can produce light in much the same way that fireflies create light, that is, by chemical reactions. The experiments suggest that this light production actually represents the reverse of early steps in photosynthesis. For this reason, this luminescence may be used to study the early chemical steps in photosynthesis and untangle some of the puzzling questions about the storage of light energy as chemical energy (sugars, etc.).

Such instruments as photomultipliers, whose use has been extensively studied at Oak Ridge in connection with instruments for counting radioactivity have greatly aided in the discovery and study of this light production by green plants, especially since this light is of low intensity. The combination of excellent instrumentation and this biochemical work promise to increase our knowledge about the photosynthetic process.

Photosynthesis Research Contracts

AEC contributes to the cost of four other research projects in or related to photosynthesis:

Organic acid metabolism. A group at the University of Wisconsin is investigating the metabolism of organic acids by plants and microorganisms. It submerged tobacco leaves in solutions of radiocarbon-tagged organic acids, applied a vacuum to draw the contained gas out of the leaf pores, then released the vacuum. This technique of vacuum infiltration caused the leaves to take in the organic acids. After allowing them a few hours in darkness to metabolize these materials, the investigators separated and analyzed the organic acids they contained. These experiments establish the interrelationships among the various organic acids involved in photosynthesis and plant respiration.

Photosynthetic bacteria. A University of Arkansas biochemist is exploring the ability of certain bacteria (*Athiorhodaceae*) to release hydrogen gas. His investigation covers four major problems of photosynthesis: (*a*) the mechanism of hydrogen transfer, (*b*) the mechanism by which the bacteria fix carbon dioxide into organic materials, (*c*) the nature of the substances they assimilate directly, and (*d*) the relation of these processes to nitrogen metabolism.

Influence of light on structure. Under an AEC research contract signed in 1951, Smithsonian Institution will study the relations of plant growth and development under the influence of light. There are several known photochemical processes in plants: photosynthesis, chlorophyll synthesis, phototropism (bending toward the light), and photoperiodism (response of growth to the length of days and nights). By exposing plants to long-wave length red light, certain biochemical processes have been activated with a corresponding change in the growth pattern without causing other light-catalyzed processes such as photosynthesis or chlorophyll formation to occur. Thus the Smithsonian investigator hopes to gain a clearer understanding of the interdependent effects of light on plants.

"Cell-free" photosynthesis. A group at the University of Utah is trying to make photosynthesis take place outside living cells. They

are using plant extracts containing chlorophyll obtained from the cell by applying high pressure. It was already known that such "cell-free" extracts could split water into hydrogen ions and release oxygen, but all attempts to make them convert carbon dioxide into carbohydrates—the other half of the photosynthetic process—had failed. Numerous investigators are at work in efforts to accomplish this.

The immediate purpose of such studies is to gain fundamental knowledge of nature, but practical applications suggest themselves. If, for example, man strives to "train" plant materials to produce foods in large quantities, it may well be that the end can be achieved only after scientists have learned to make photosynthesis take place outside living cells.

Biosynthesis of Tagged Compounds

How some vegetable nutrients and drugs do their work in animal and human bodies has never been clear, but radioactive tracer research is beginning to illuminate some of the obscurities. To prepare tracer forms of these plant compounds, AEC laboratories grow a variety of food and medicinal plants in an atmosphere containing radioactive carbon dioxide.

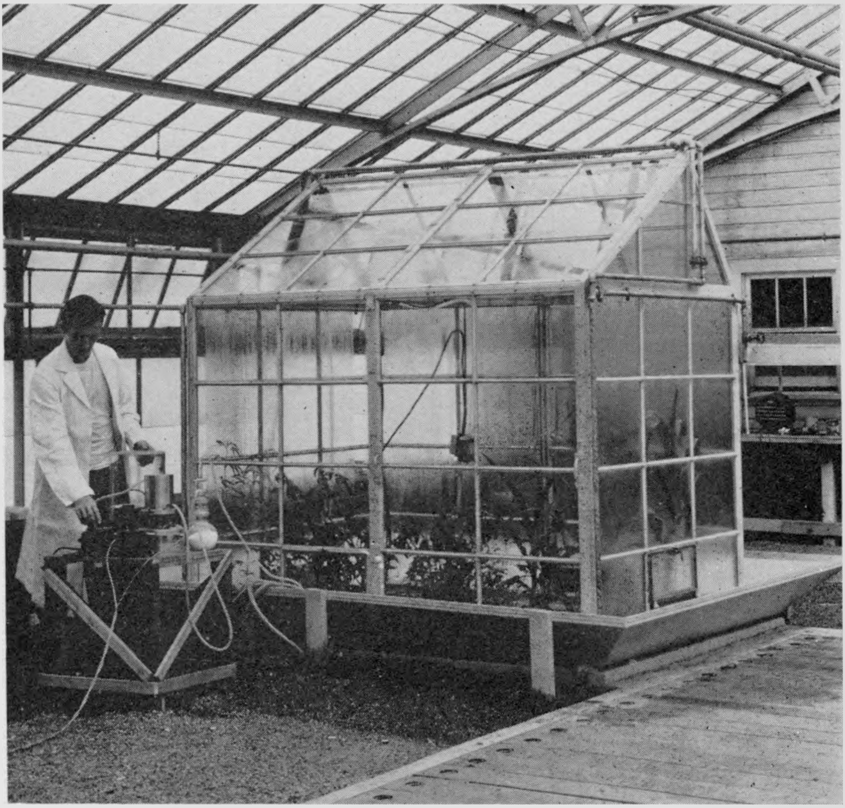
Argonne National Laboratory has grown soybeans, alfalfa, sugar beets, opium poppies, digitalis, tobacco, onions, and other plants under conditions that make them take up and fix radioactive carbon. The plant tissues are dried, assayed for radioactivity, and various tagged substances are extracted, including sugars, organic acids, starch, amino acids, proteins, pigments, and alkaloids (see photo p. 133).

In cooperation with the Office of the Surgeon General and with the Commercial Solvents Corp. of Terre Haute, Ind., Argonne has biosynthesized tagged dextran. Basic work on photosynthesis and fermentation mechanisms at Brookhaven has aided in this study. Dextran is of special interest as a substitute for blood plasma, particularly in the event of a large-scale catastrophe that could exhaust the supply of natural blood plasma. Dextran's fate in the body is not sufficiently clear, however, and its secretion, utilization, and deposition in the body are being investigated with this carbon-tagged material.

In the first step of producing a standardized form of tagged dextran, Argonne exposed canna leaves to radioactive carbon dioxide in the presence of light, then extracted the sucrose they had photosynthesized. Dextran was prepared from the tagged sucrose by the fermentation action of *Leuconostoc mesenteroides*, a species of bacteria.

Using similar methods, Oak Ridge and Brookhaven National Laboratories have produced radioactivity-tagged carbohydrates, such as starch and raffinose, and four sugars—sucrose, fructose, galactose, and glucose. At Brookhaven it has been found possible to tag particular carbon atoms in the molecule. Many of the Argonne, Oak Ridge, and Brookhaven biosynthesized compounds have been used by biological and medical researchers outside the AEC program.[17]

Apart from the biosynthesis programs sponsored by AEC, AEC sells isotopes to eight institutions that synthesize and distribute tagged



One of Argonne National Laboratory's plant growth chambers is shown. Large quantities of plants grown in this chamber are supplied with water, nutrient materials, and radioactive carbon dioxide. By the process of photosynthesis, plants combine these materials into many important radioactive tagged plant products.

compounds: Tracerlab, Inc., Boston; Abbott Laboratories, Chicago; U. S. Testing Co., Hoboken, N. J.; Radioactive Products, Inc., Detroit; Texas Research Foundation, Renner, Tex.; Nuclear Instrument and Chemical Corp., Chicago; Technical Associates, Glendale, Calif.; and Bureau of Standards, Washington. Five university groups also have purchased isotopes for special biosynthesis projects.

[17] Distribution of these compounds is handled by the AEC Isotopes Division, Oak Ridge, Tenn.

APPENDIX 1

U. S. Atomic Energy Commission, Principal Staff, and Managers of Operations and Area Offices

Atomic Energy Commission	Gordon Dean, *Chairman.*
	T. Keith Glennan.
	Thomas E. Murray.
	H. D. Symth.
	(*Vacancy.*)
General Manager	M. W. Boyer.
Deputy General Manager	Walter J. Williams.
Assistant General Manager for Manufacturing.	Thomas F. Farrell.
Controller	Lindsley H. Noble.
General Counsel	Everett L. Hollis.
Secretary to Commission	Roy B. Snapp.
Director of Intelligence	Walter F. Colby.
Director of Classification	James G. Beckerley.
Chief, Office of Special Projects	John A. Hall.
Director, Division of Research	Thomas H. Johnson.
Director, Division of Engineering	Lawrence R. Hafstad (*Acting*).
Director, Division of Production	R. W. Cook.
Director, Division of Military Application.	Col. K. E. Fields.
Director, Division of Reactor Development.	Lawrence R. Hafstad.
Director, Division of Biology and Medicine.	Dr. Shields Warren.
Director, Division of Raw Materials	Jesse C. Johnson.
Director, Division of Construction and Supply.	E. J. Bloch.
Director, Division of Security	John A. Waters, Jr.
Director, Division of Organization and Personnel.	Fletcher C. Waller.
Director, Division of Information Services.	Morse Salisbury.

Managers of Operations and Area Offices:	
Chicago (Ill.) Operations Office	A. TAMMARO.
Ames (Iowa) Area Office	W. W. LORD.
Berkeley (Calif.) Area Office	H. A. FIDLER.
Lockland (Ohio) Area Office	E. M. VELTEN.
Pittsburgh (Pa.) Area Office	LAWTON D. GEIGER.
Colorado (Grand Junction) Raw Materials Office.	FRANK H. MACPHERSON.
Hanford (Wash.) Operations Office	DAVID F. SHAW.
Idaho (Idaho Falls) Operations Office	L. E. JOHNSTON.
New York (N. Y.) Operations Office	WILBUR E. KELLEY.
Brookhaven (Long Island, N. Y.) Area Office.	E. L. VAN HORN.
Cleveland (Ohio) Area Office	EDWARD C. SARGENT.
Fernald (Cincinnati, Ohio) Area Office.	JAMES F. CHANDLER.
St. Louis (Mo.) Area Office	C. L. KARL.
Oak Ridge (Tenn.) Operations Office	S. R. SAPIRIE.
Dayton (Miamisburg, Ohio) Area Office.	FRED H. BELCHER.
Kentucky (Paducah) Area Office	KENNETH A. DUNBAR.
San Francisco (Calif.) Area Office	JOHN A. DERRY.
Santa Fe (Albuquerque, N. Mex.) Operations Office.	CARROLL L. TYLER.
Eniwetok Proving Ground Field Office (Albuquerque, N. Mex.).	PAUL W. SPAIN.
Los Alamos (N. Mex.) Field Office	RALPH P. JOHNSON.
Nevada Test Site (Las Vegas) Field Office.	SETH R. WOODRUFF, JR.
Pantex (Amarillo, Tex.) Field Office	WALTER W. STAGG.
Sandia (N. Mex.) Field Office	DANIEL F. WORTH, JR.
Savannah River (Augusta, Ga.) Operations Office.	CURTIS A. NELSON.
Dana (Terre Haute, Ind.) Area Office.	CHARLES W. REILLY.
Wilmington (Del.) Area Office	GEORGE H. CHRISTENSEN.
Schenectady (N. Y.) Operations Office	JON D. ANDERSON.

APPENDIX 2

Membership of Committees

STATUTORY COMMITTEES

Joint Committee on Atomic Energy—Eighty-second Congress

This committee was established by the Atomic Energy Act of 1946 (sec. 15) to make "continuing studies of the activities of the Atomic Energy Commission and of problems relating to the development, use, and control of atomic energy." The committee is kept fully and currently informed with respect to the Commission's activities. Legislation relating primarily to the Commission or to atomic energy matters are referred to the committee. The committee's membership is composed of nine members of the Senate and nine members of the House of Representatives.

Senator Brien McMahon (Connecticut), chairman.
Representative Carl T. Durham (North Carolina), vice chairman.
Senator Richard B. Russell (Georgia).
Senator Edwin C. Johnson (Colorado).
Senator Tom Connally (Texas).
Senator Clinton P. Anderson (New Mexico).
Senator Bourke B. Hickenlooper (Iowa).
Senator Eugene D. Millikin (Colorado).
Senator William F. Knowland (California).
Senator John W. Bricker (Ohio).
Representative Chet Holifield (California).
Representative Melvin Price (Illinois).
Representative Paul J. Kilday (Texas).
Representative Henry M. Jackson (Washington).
Representative W. Sterling Cole (New York).
Representative Charles H. Elston (Ohio).
Representative Carl Hinshaw (California).
Representative James E. Van Zandt (Pennsylvania).
William L. Borden, executive director.
Harold Bergman, deputy director.

Military Liaison Committee

Under sec. 2 (c) of the Atomic Energy Act of 1946, as amended, "there shall be a Military Liaison Committee consisting of a Chairman, who shall be the head thereof, and of a representative or representatives of the Departments of the Army, Navy, and Air Force, detailed or assigned thereto, without additional compensation, in such number as the Secretary of Defense may determine. Representatives from each of the three Departments shall be designated by the respective Secretaries of the Army, Navy, and Air Force. The committee Chairman shall be appointed by the President, by and with the advice and consent of the Senate, and shall receive compensation at a rate prescribed by law for the Chairman of the Munitions Board. The Commission shall advise and consult with the committee on all atomic energy matters which the committee deems to relate to military applications, including the development, manufacture, use and storage of bombs, the allocation of fissionable material for military research, and the control of information relating to the manufacture or utilization of atomic weapons. The Commission shall keep the committee fully informed of all such matters before it and the committee shall keep the Commission fully informed of all atomic energy activities of the Department of Defense. The committee shall have authority to make written recommendations to the Commission on matters relating to military applications from time to time as it may deem appropriate. If the committee at any time concludes that any action, proposed action, or failure to act of the Commission on such matters is adverse to the responsibilities of the Department of Defense, derived from the Constitution, laws, and treaties, the committee may refer such action, proposed action, or failure to act to the Secretary of Defense. If the Secretary concurs, he may refer the matter to the President, whose decision shall be final."

Hon. ROBERT LEBARON, chairman.
Brig. Gen. HERBERT B. LOPER, United States Army.
Brig. Gen. STANLEY R. MICKELSEN, United States Army.
Rear Adm. CHARLES F. COE, United States Navy.
Rear Adm. FREDERIC S. WITHINGTON, United States Navy.
Maj. Gen. ROGER M. RAMEY, United States Air Force.
Brig. Gen. HOWARD G. BUNKER, United States Air Force.
Capt. R. P. HUNTER, executive secretary, United States Navy.

General Advisory Committee

This committee was established by the Atomic Energy Act of 1946 (sec. 2 (b)). The nine civilian members are appointed by the President to advise the Commission on scientific and technical matters relating to materials, production, and research and development. Under the Atomic Energy Act, the committee shall meet at least four times in every calendar year; the committee held its first meeting in January 1947, and to date has averaged six meetings a year.

Dr. J. ROBERT OPPENHEIMER, chairman; director, Institute for Advanced Study, Princeton, N. J.
Dr. OLIVER E. BUCKLEY, chairman, Bell Telephone Laboratories, New York, N. Y.
Dr. JAMES B. CONANT, president, Harvard University, Cambridge, Mass.
Dr. LEE A. DUBRIDGE, president, California Institute of Technology, Pasadena, Calif.
Dr. W. F. LIBBY, professor of chemistry, University of Chicago, Chicago, Ill.
EGER V. MURPHREE, president, Standard Oil Development Co., New York, N. Y.
Dr. I. I. RABI, professor of physics, Columbia University, New York, N. Y.
Dr. CYRIL S. SMITH, director, Institute for the Study of Metals, University of Chicago, Chicago, Ill.
WALTER G. WHITMAN, chairman, Research and Development Board, Department of Defense, Washington, D. C., on leave from his position as head, department of chemical engineering, Massachusetts Institute of Technology, Cambridge, Mass.
Dr. RICHARD W. DODSON, secretary; chairman, department of chemistry, Brookhaven National Laboratory, Upton, Long Island, N. Y.

PATENT COMPENSATION BOARD

This board was established in April 1949 pursuant to section 11 of the Atomic Energy Act of 1946, which provides that upon application for just compensation or awards or for the determination of a reasonable royalty fee certain proceedings shall be held before such a board. To date the board has held 8 sessions; 10 cases have been filed, of which 6 have been finally determined by the board; 1 claim has been awarded and 1 claim has been withdrawn.

CASPER W. OOMS, chairman; of Dawson & Ooms, Chicago, Ill.
ISAAC HARTER, chairman, Babcock & Wilcox Tube Co., Beaver Falls, Pa.
JOHN V. L. HOGAN, consulting engineer, Hogan Laboratories, Inc., New York, N. Y.

PERMANENT PANEL APPOINTED BY THE PRESIDENT—ATOMIC ENERGY LABOR RELATIONS PANEL

The members of this panel were appointed by the President in 1949 and in 1950 to take jurisdiction and mediate labor-management disputes which threaten to interfere with essential operations of the Atomic Energy Commission. The panel operates under procedures designed to safeguard continuity of operations while not inhibiting free collective bargaining between AEC contractors and unions. To date it has acted upon 33 labor-management disputes in AEC installations, and has reported semiannually to the President on its activities (see Appendix 7).

WILLIAM H. DAVIS, chairman; of Davis, Hoxie & Faithfull, New York, N. Y.; chairman, Patent Survey Committee, U. S. Department of Commerce.
FRANK P. DOUGLASS; of Douglass & Douglass, Oklahoma City, Okla.
JOHN T. DUNLOP, professor of economics, Harvard University, Cambridge, Mass.; public member, Wage Stabilization Board.
AARON HORVITZ, lawyer and arbitrator, New York and New Jersey.
GODFREY P. SCHMIDT, lawyer, New York, N. Y.
EDWIN E. WITTE, chairman, department of economics, University of Wisconsin, Madison, Wis.

SENIOR RESPONSIBLE REVIEWERS

The Manhattan District appointed and the Atomic Energy Commission reaffirmed the need for the committee of Senior Responsible Reviewers. The committee reviews the major phases of the AEC program and is the principal advisor to the AEC on declassification matters, making recommendations for formulating and modifying the rules and guides for classifying scientific and technical information.

Dr. W. C. JOHNSON, chairman, department of chemistry, University of Chicago, Chicago, Ill.
Dr. J. M. B. KELLOGG, division leader, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
Dr. W. F. LIBBY, professor of chemistry, University of Chicago, Chicago, Ill.
Dr. R. L. THORNTON, professor of physics, University of California, Berkeley, Calif.
Dr. FREDERIC DE HOFFMANN, secretary; Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

ADVISORY BODIES TO THE ATOMIC ENERGY COMMISSION

Advisory Committee on Biology and Medicine

The Advisory Committee on Biology and Medicine was created in September 1947, on the recommendation of the Commission's Medical Board of Review.

980705—52——10

The committee reviews the AEC programs in medical and biological research and health and recommends to the Commission general policies in these fields. The committee has held 29 meetings and reports to the Commission on each meeting.

Dr. ALAN GREGG, chairman; director for medical sciences, Rockefeller Foundation, New York, N. Y.

Dr. ERNEST W. GOODPASTURE, vice chairman; dean, school of medicine and professor of pathology, Vanderbilt University, Nashville, Tenn.

Dr. EDWARD A. DOISY, director, department of physiology and biochemistry, St. Louis University School of Medicine, St. Louis, Mo.

Dr. GIOACCHINO FAILLA, head, department of radiology, Columbia University Medical School, New York, N. Y.

Dr. E. C. STAKMAN, chief, division of plant pathology and botany, University of Minnesota, Minneapolis, Minn.

Dr. CURT STERN, professor of zoology, University of California, Berkeley, Calif.

Dr. JOSEPH T. WEARN, dean, school of medicine, Western Reserve University, Cleveland, Ohio.

Advisory Committee on Chemistry

This committee was appointed in June 1949 to advise on policy concerning the AEC program of supporting basic unclassified chemistry research in universities, and the relationship of this program to the AEC's own chemistry research program. Most of the work of the committee is accomplished by individual consultation as specific problems arise.

Dr. FARRINGTON DANIELS, professor of chemistry, University of Wisconsin, Madison, Wis.

Dr. G. B. KISTIAKOWSKY, professor of chemistry, Harvard University, Cambridge, Mass.

Dr. JOSEPH E. MAYER, professor of chemistry, University of Chicago, Chicago, Ill.

Dr. GLENN T. SEABORG, professor of chemistry, University of California, Berkeley, Calif.

Dr. DON M. YOST, professor of chemistry, California Institute of Technology, Pasadena, Calif.

Community Operations Panel

This committee was appointed in July 1950 to study the problems of introducing private ownership of real property and self-government in the AEC communities at Los Alamos, N. Mex.; Richland, Wash.; and Oak Ridge, Tenn. The committee has visited the three communities and made detailed reports to the Commission relating to these problems.

RICHARDSON G. SCURRY, chairman; of Scurry, Scurry & Pace, Dallas, Tex.

FREDERICK M. BABCOCK, private consultant in construction finance and housing, Washington, D. C.

GEORGE E. BEAN, city manager, Grand Rapids, Mich.

GEORGE GOVE, vice president for housing projects, Metropolitan Life Insurance Co., New York, N. Y.

Advisory Board of Contract Appeals

This board was established in February 1950. One or more of its members hears contract appeals arising under the "disputes articles" of AEC contracts and subcontracts and makes recommendations to the General Manager concerning their disposition.

SHELDON ELLIOTT, dean of the law school, University of Southern California, Los Angeles, Calif.

HERBERT F. TAGGART, assistant dean, school of business administration, University of Michigan, Ann Arbor, Mich.

(One Vacancy)

Advisory Committee on Isotope Distribution

This committee was originally appointed by the Manhattan District to advise on the off-project distribution of isotopes. The Commission approved its continuation in December 1947 to aid in establishing new policies on distributing radioactive materials and to review existing policies. The committee reviews all initial applications for use of radioisotopes in human beings, and all other requests for their use in research, education, and industry which are referred to it by the Commission.

Dr. FARRINGTON DANIELS, chairman; professor of chemistry, University of Wisconsin, Madison, Wis.

Dr. AUSTIN M. BRUES, director, biology division, Argonne National Laboratory, Chicago, Ill.

Dr. SIMEON T. CANTRIL, Tumor Institute of the Swedish Hospital, Seattle, Wash.

Dr. RICHARD CHAMBERLAIN, University of Pennsylvania Medical School, Philadelphia, Pa.

Dr. SAMUEL E. EATON, A. D. Little, Inc., Cambridge, Mass.

Dr. ROBLEY D. EVANS, professor of physics, Massachusetts Institute of Technology, Cambridge, Mass.

Dr. STERLING B. HENDRICKS, head chemist, Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture, Beltsville, Md.

Dr. A. H. HOLLAND, Jr., medical director, Armour Research Laboratory, Chicago, Ill.

Dr. DONALD E. HULL, research chemist, process division, California Research Corp., Richmond, Calif.

Dr. EDITH H. QUIMBY, associate professor of radiology, College of Physicians and Surgeons, Columbia University, New York, N. Y.

Dr. HOWARD E. SKIPPER, associate director, Southern Research Institute, Birmingham, Ala.

Dr. PAUL C. AEBERSOLD, secretary; chief, isotopes division, AEC, Oak Ridge, Tenn.

Patent Advisory Panel

This panel was appointed in January 1947 to make a general review and appraisal of the problems raised by the patent provisions of the Atomic Energy Act of 1946. It makes informal reports and recommendations to the Commission and its staff on various questions of policy and procedure relating to patents and inventions.

H. THOMAS AUSTERN; of Covington & Burling, Washington, D. C.

WILLIAM H. DAVIS; of Davis, Hoxie & Faithfull, New York, N. Y.; chairman, Patent Survey Committee, U. S. Department of Commerce.

JOHN A. DIENNER; of Brown, Jackson, Boettcher & Dienner, Chicago, Ill.

HECTOR M. HOLMES; of Fish, Richardson & Neave, Boston, Mass.

CASPER W. OOMS; of Dawson & Ooms, Chicago, Ill.

Advisory Committee on Personnel Management

This committee of leading authorities from government, industry, and education was named in September 1948 to provide the Atomic Energy Commission with a continuous review of its personnel management practices and to evaluate the best personnel methods of government and industry in determining over-all AEC policies. The committee usually meets once a month.

ARTHUR S. FLEMMING, chairman; assistant to the director of manpower, Office of Defense Mobilization, Washington, D. C.; president, Ohio Wesleyan University, Delaware, Ohio.

LAWRENCE A. APPLEY, president, American Management Association, New York, N. Y.

L. CLAYTON HILL, professor of industrial relations, University of Michigan, Ann Arbor, Mich.

ROBERT RAMSPECK, chairman, U. S. Civil Service Commission, Washington, D. C.

WALLACE SAYRE, professor of public administration, school of business and civic administration, City College of New York, N. Y.

THOMAS G. SPATES, professor of industrial administration, Yale University, New Haven, Conn.; former vice president, General Foods Corp.

Personnel Security Review Board

This board was appointed in March 1949 primarily to review specific personnel security cases which arise under the Commission's administrative review procedure and make recommendations concerning them to the General Manager. The board, in its monthly meetings, also advises the Commission on the broader considerations regarding personnel security, such as criteria for determining eligibility for security clearance and personnel security procedures.

GANSON PURCELL, chairman; of Root, Ballantine, Harlan, Bushby & Palmer, Washington, D. C.

ARTHUR S. FLEMMING, assistant to the director of manpower, Office of Defense Mobilization, Washington, D. C.; president, Ohio Wesleyan University, Delaware, Ohio.

BRUCE D. SMITH, director, United Corp., New York, N. Y., and Lehigh Coal & Navigation Co., Philadelphia, Pa.

Committee on Raw Materials

This committee was appointed in October 1947 to review the Atomic Energy Commission's raw materials program and to advise on questions of exploration, development, and procurement. The committee has met nine times since its formation.

Dr. DONALD H. MCLAUGHLIN, chairman; president, Homestake Mining Co., San Francisco, Calif.

EVERETTE L. DEGOLYER, petroleum geologist, DeGolyer & McNaughton, Dallas, Tex.

THOROLD F. FIELD, consulting mining engineer, Duluth, Minn.

J. K. GUSTAFSON, consulting geologist, M. A. Hanna Co., Cleveland, Ohio.

IRA B. JORALEMON, geologist, San Francisco, Calif.

WALTER L. MAXSON, vice president, Oliver Iron Mining Co., Duluth, Minn.

ERNEST H. ROSE, chemical engineer, Tennessee Coal, Iron & Railroad Co., Birmingham, Ala.

WALTER O. SNELLING, director of research and consulting chemist, Trojan Powder Co., Allentown, Pa.

ORVIL R. WHITAKER, consulting mining engineer, Denver, Colo.

CLYDE E. WILLIAMS, director, Battelle Memorial Institute, Columbus, Ohio.

Industrial Committee on Reactor Location Problems

The committee will assist and advise the Commission in determining the criteria to be used in the location of atomic energy plants with regard to populated areas and in evaluating the adequacy and necessity for the isolation of such plants. It will balance carefully the technical and scientific aspects of reactor hazards, which have been thoroughly developed by the Reactor Safeguard Committee, against the nontechnical aspects of reactor locations. Consideration will be given to such matters as public relations and the impact on adjacent communities of large scale Government acquisition of land.

C. ROGERS MCCULLOUGH, chairman; General Development Department, Monsanto Chemical Co., St. Louis, Mo.

W. P. CONNER, Jr., manager, physics div., Research Department, Hercules Powder Co., Wilmington, Del.

R. L. DOAN, manager, Atomic Energy Division, Phillips Petroleum Co., Idaho Falls, Idaho.

K. R. OSBORN, manager of industrial development, General Chemical Division, Allied Chemical and Dye Corp., New York, N. Y.

D. A. ROGERS, manager, central engineering, Allied Chemical & Dye Corp., Morristown, Pa.

REUEL C. STRATTON, supervising chemical engineer, Engineering & Loss Control Division, The Travelers Insurance Co., Hartford, Conn.

Reactor Safeguard Committee

This committee was established in the fall of 1947 to advise the Commission on the hazards of the operation of reactors. The committee reviews safety studies made by the contractors on proposed reactors for completeness and accuracy and may make recommendations for modifications or further study. This committee of experts in the fields of physics, chemistry, sanitary engineering, meteorology and medicine meets whenever problems arise which require its consideration. In the past this has been about four times a year.

Dr. EDWARD TELLER, chairman; assistant director for weapons development, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. MANSON BENEDICT, technical assistant to general manager, AEC, Washington, D. C.; on leave from his position as professor of chemical engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Dr. HYMER L. FRIEDELL, director, department of radiology, Lakeside Hospital, Western Reserve University, Cleveland, Ohio.

Col. BENJAMIN HOLZMAN, meteorologist, office of director of research and development, United States Air Force, Washington, D. C.

Dr. FREDERICK SEITZ, professor of physics, University of Illinois, Urbana, Ill.

Dr. JOHN A. WHEELER, James Forrestal Research Center, Princeton University, Princeton, N. J.

Dr. ABEL WOLMAN, head, department of sanitary engineering, Johns Hopkins University, Baltimore, Md.

Dr. I. B. JOHN, central research department, Monsanto Chemical Co., Dayton, Ohio.

Stack Gas Problem Working Group

The appointment of this group was authorized in May 1948 to advise the Commission on the development of methods and equipment for keeping the atmosphere at and near AEC installations free of toxic or radioactive contamination. The group has held five meetings. Individual members also give consulting advice on specific proposals and problems.

Dr. ABEL WOLMAN, chairman; head, 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, New York, N. Y.

Dr. H. FRASER JOHNSTONE, professor of chemical engineering, University of Illinois, Urbana, Ill.

Dr. MOYER D. THOMAS, department of agricultural research, American Smelting & Refining Co., Salt Lake City, Utah.

Dr. WILLIAM P. YANT, director of research, Mine Safety Appliances Co., Pittsburgh, Pa.

Technical Information Panel

This panel, representing the major AEC research contractors, was appointed in June 1948 to advise the Commission on all aspects of its technical information services. Meetings are held three times a year to consider technical information services.

Dr. ALBERTO F. THOMPSON, chairman; chief, technical information service, division of information services, AEC, Washington, D. C.

Dr. HENRY A. BLAIR, director, Atomic Energy Project, University of Rochester, Rochester, N. Y.

BREWER F. BOARDMAN, technical advisor, technical information service, division of information services, AEC, Oak Ridge, Tenn.

W. E. DREEZEN, administrative aide to director, Ames Laboratory, Ames, Iowa.

WILLIAM H. HAMILTON, staff assistant to assistant manager, Westinghouse Atomic Power Division, Pittsburgh, Pa.

SYLVAN HARRIS, manager, documents department, Sandia Corp., Albuquerque, N. Mex.

W. L. HARWELL, head, patents and declassification department, Carbide & Carbon Chemicals Co., div. of Union Carbide & Carbon Corp. (K–25), Oak Ridge, Tenn.

JOHN F. HOGERTON, technical reports director, Vitro Corp. of America, New York, N. Y.

Dr. E. J. MURPHY, assistant to research director, Carbide & Carbon Chemicals Co., div. of Union Carbide & Carbon Corp. (ORNL), Oak Ridge, Tenn.

Dr. G. M. MURPHY, professor of chemistry, New York University, New York.

Dr. DANIEL J. PFLAUM, chief, materials and information branch, division of research, AEC, Washington, D. C.

DENNIS PULESTON, head, technical information division, Brookhaven National Laboratory, Upton, Long Island, N. Y.

Dr. RICHARD F. RILEY, chief, radiation chemistry section, Atomic Energy Project, University of California, Los Angeles, Calif.

Dr. CHARLES SLESSER, director, division of technical information and declassification, AEC, New York, N. Y.

Dr. RALPH CARLISLE SMITH, assistant director for classification and security, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. J. R. STEHN, physicist, theoretical physics division, Knolls Atomic Power Laboratory, Schenectady, N. Y.

C. G. STEVENSON, chief librarian, General Electric Co., Richland, Wash.

Dr. R. K. WAKERLING, chief, information division, Radiation Laboratory, University of California, Berkeley, Calif.

Dr. JOHN C. WOODHOUSE, director, technical division, atomic energy division, E. I. du Pont de Nemours & Co., Wilmington, Del.

Dr. H. D. YOUNG, director, information division, Argonne National Laboratory, Chicago, Ill.

Ad Hoc Committee on Technological Information for Industry

This committee was appointed in July 1949 to advise the Commission on ways to improve the dissemination of its technological information to industry. A working committee examined the Commission's technological files and processes, and reported in January 1951 that "The declassification of information by the AEC has, in our opinion, been found to be satisfactory. In no case have we uncovered any huge amounts of secret information of value to industry, although some specific cases of valuable information are noted in our reports." In November the committee met with representatives of the AEC and its major contractors to consider further methods of disseminating AEC technological information for industrial use.

SIDNEY D. KIRKPATRICK, chairman; member of working committee; vice president and director of editorial development, McGraw-Hill Book Co., Inc., New York, N. Y.

H. E. BLANK, editor, Modern Industry, New York, N. Y.

GENE HARDY, National Association of Manufacturers, Washington, D. C.

KEITH HENNEY, member of working committee; editor, Nucleonics; consulting editor, Electronics, McGraw-Hill Publishing Co., Inc., New York, N. Y.

EDWARD KREUTZBERG, editor, Penton Publishing Co., Washington, D. C.

Dr. WALTER J. MURPHY, editor, Chemical and Engineering News, American Chemical Society, Washington, D. C.

D. O. MYATT, managing editor, Industrial and Engineering Chemistry, Washington, D. C.

CHARLES S. RICH, editor, Electrical Engineering, American Institute of Electrical Engineers, New York, N. Y.

GEORGE STETSON, editor, Mechanical Engineering, American Society of Mechanical Engineers, New York, N. Y.

George F. Sullivan, managing editor, The Iron Age, Chilton Publications, Inc., New York, N. Y.

E. E. Thum, chairman of working committee; editor, Metal Progress, American Society for Metals, Cleveland, Ohio.

S. A. Tucker, member of working committee; standards manager, The American Society of Mechanical Engineers, New York, N. Y.

F. J. Van Antwerpen, member of working committee; editor, Chemical Engineering Progress, American Institute of Chemical Engineers, New York, N. Y.

Dr. Alberto F. Thompson, secretary; chief, technical information service, division of information services, AEC, Washington, D. C.

APPENDIX 3

Major Research Centers of the U. S. Atomic Energy Commission

Ames Laboratory (Iowa State College, contractor), Ames, Iowa

Director — Dr. Frank 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
- Ohio State University
- Oklahoma Agricultural and Mechanical College
- Purdue University
- St. Louis University
- State University of Iowa
- Washington University (St. Louis, Mo.)
- Western Reserve University
- University of Chicago
- University of Cincinnati
- University of Illinois
- University of Kansas
- University of Michigan
- University of Minnesota
- University of Missouri
- University of Nebraska
- University of Notre Dame
- University of Pittsburgh
- University of Wisconsin

Director — Dr. Walter H. Zinn
Deputy Director — Dr. Norman Hilberry
Business Manager — John H. McKinley
Associate Director for University Relationships — Dr. Joseph C. Boyce
Assistant Director — John T. Bobbitt

Brookhaven National Laboratory (Associated Universities, Inc., contractor), Upton, Long Island, N. Y.

The participating institutions are:

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

Chairman, Board of Directors — George A. Brakeley
President, AUI — Dr. Lloyd V. Berkner
Vice President, AUI and Laboratory Director — Dr. Leland J. Haworth
Deputy Laboratory Director — Dr. Gerald F. Tape
Assistant Director, University Liaison — Dr. Robert A. Patterson

Knolls Atomic Power Laboratory (General Electric Co., contractor), Schenectady, N. Y.

General Manager, Operating Department — William H. Milton, Jr.
Manager, Technical Department — Dr. K. H. Kingdon

Los Alamos Scientific Laboratory (University of California, contractor) Los Alamos, N. Mex.

Director — Dr. Norris E. Bradbury
Technical Associate Director — Dr. Darol K. Froman

Mound Laboratory (Monsanto Chemical Co., contractor), Miamisburg, Ohio

Project Director — Dr. C. A. Hochwalt
Executive Director, AEC Projects — Dr. Joseph J. Burbage

Oak Ridge National Laboratory (Carbide & Carbon Chemicals Co., div. of Union Carbide & Carbon Corp., contractor), Oak Ridge, Tenn.

Director — Dr. C. E. Larson
Executive Director — L. B. Emlet
Research Director — Dr. A. M. Weinberg
Acting Assistant Research Director — Dr. E. H. Taylor
Assistant Research Director (Y–12) — Dr. E. D. Shipley
Acting Project Director (Homogeneous Research Project) — Dr. J. A. Swartout

Oak Ridge Institute of Nuclear Studies (contractor), Oak Ridge, Tenn.

The sponsoring universities of the Institute are:

Agricultural and Mechanical College of Texas
Alabama Polytechnic Institute
Catholic University of America
Duke University
Emory University
Florida State University
Georgia Institute of Technology
Louisiana State University
Mississippi State College
North Carolina State College
Rice Institute
Tulane University of Louisiana
Vanderbilt University
Virginia Polytechnic Institute
University of Alabama
University of Arkansas
University of Florida
University of Georgia
University of Kentucky
University of Louisville
University of Maryland
University of Mississippi
University of North Carolina
University of South Carolina
University of Oklahoma
University of Puerto Rico
University of Tennessee
University of Texas
University of Virginia

Chairman of Council — Dr. Louis A. Pardue
Vice Chairman of Council — Dr. Pete Kyle McCarter
President of Institute — Dr. Paul M. Gross
Vice President of Institute — Dr. J. W. Beams
Scientific and Educational Consultant — Dr. George B. Pegram
Executive Director of Institute — Dr. William G. Pollard

Radiation Laboratory (University of California, contractor) Berkeley, Calif.

Director — Dr. Ernest O. Lawrence
Associate Director — Dr. Donald Cooksey
Business Manager and Managing Engineer — Wallace B. Reynolds
Assistant Director — William M. Brobeck
Director, Crocker Laboratory—Medical Physics — Dr. Joseph G. Hamilton
Director, Donner Laboratory of Medical Physics — Dr. J. H. Lawrence
Assistant Director, Donner Laboratory — Dr. Hardin Jones

Rochester Atomic Energy Project (University of Rochester, contractor) Rochester, N. Y.

Director — Dr. Henry A. Blair
Assistant Director for Education — Dr. J. Newell Stannard
Business Manager — C. M. Jarvis

Sandia Laboratory (Sandia Corp., contractor) Sandia Base, Albuquerque, N. Mex.

President — George A. Landry
Vice President — F. Schmidt

University of California, Los Angeles, Atomic Energy Project (University of California, contractor) Los Angeles, Calif.

Director — Dr. Stafford Warren
Business Manager — Robert J. Buettner

APPENDIX 4

Distribution of Isotopes, Oak Ridge, Tenn.

	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 June 30, 1950	July 1, 1950, to June 30, 1951	July 1, 1951, to Nov. 30, 1951	Total to Nov. 30, 1951
Shipments classified by broad field of utilization:							
Radioactive isotopes:							
Medical therapy	407	884	1,564	2,594	3,532	1,634	10,615
Animal physiology	280	712	890	1,150	1,296	501	4,829
Physics	82	175	271	376	413	102	1,419
Chemistry	74	188	254	223	250	109	1,106
Plant physiology	49	107	195	282	244	80	957
Industrial research	42	68	135	217	322	166	950
Bacteriology	11	53	79	64	114	59	380
General research and development						466	466
Other		4	187	392	717	325	1,625
Total	945	2,191	3,575	5,298	6,896	3,442	22,347
Stable isotopes:							
Physics	27	175	245	298	214	88	1,047
Chemistry	12	69	68	92	121	43	405
Animal physiology	16	35	33	34	45	15	178
Industrial research		21	4	6	2	1	34
Plant physiology		5	9	2	1	0	17
Bacteriology		2	4		2	2	10
Other			6	2	3	1	12
Total	55	307	369	434	388	150	1,703
Shipments classified by kind of isotope:							
Radioactive isotopes:							
Iodine 131	276	741	1,213	1,994	2,758	1,377	8,359
Phosphorus 32	260	747	1,221	1,582	1,864	908	6,582
Carbon 14	88	134	148	216	318	143	1,047
Sodium 24	32	113	152	303	213	55	868
Sulfur 35	31	35	89	115	122	86	478
Gold 198, 199	63	23	39	79	217	118	539
Calcium 45	22	40	55	75	98	53	343
Iron 55, 59	26	34	48	57	72	25	262
Cobalt 60	24	22	55	82	165	93	441
Potassium 42	23	24	53	95	138	49	382
Strontium 89, 90	7	15	17	36	41	41	157
Other (61)	93	263	485	664	890	494	2,889
Total	945	2,191	3,575	5,298	6,896	3,442	22,347
Stable isotopes:							
Deuterium oxide (heavy water)	31	115	116	96	122	47	527
Deuterium (hydrogen 2)	22	97	79	103	105	38	444
Boron 10 and 11	2	35	32	37	13	7	126
Helium				7	1	5	13
Oxygen 18		23	17	17	23	8	88
Electromagnetic concentrated		37	125	174	124	44	504
Argon 38						1	1
Total	55	307	369	434	388	150	1,703

Distribution of Isotopes—Continued

DOMESTIC	TOTAL NUMBER OF SHIPMENTS TO NOVEMBER 30, 1951	
	Radio-active	Stable
Shipments classified by State and Territory:		
Alabama	56	1
Arizona	5	
Arkansas	97	
California	2,207	111
Colorado	141	2
Connecticut	369	68
Delaware	38	7
District of Columbia	494	91
Florida	107	4
Georgia	248	1
Hawaii	22	
Idaho	4	
Illinois	1,840	224
Indiana	346	58
Iowa	237	9
Kansas	102	8
Kentucky	113	1
Louisiana	334	10
Maine	4	
Maryland	1,548	54
Massachusetts	2,137	192
Michigan	788	48
Minnesota	615	41
Mississippi	11	
Missouri	621	28
Montana	6	7
Nebraska	123	
New Hampshire	6	
New Jersey	384	57
New Mexico	35	
New York	2,897	203
North Carolina	438	18
North Dakota	2	
Ohio	1,449	147
Oklahoma	114	8
Oregon	222	8
Pennsylvania	1,357	129
Rhode Island	19	1
South Carolina	72	
South Dakota	4	
Tennessee	603	24
Texas	978	49
Utah	198	3
Virginia	157	7
Washington	224	14
West Virginia	3	1
Wisconsin	558	69
Wyoming	14	
Total	22,347	1,703

FOREIGN	TOTAL NUMBER OF SHIPMENTS TO NOVEMBER 30, 1951	
	Radio-active	Stable
Shipments classified by country:		
Argentina	63	
Australia	99	
Belgium	107	
Brazil	74	
Canada	64	
Chile	41	
Colombia	5	
Cuba	9	
Denmark	162	
Dominican Republic	1	
Egypt	1	
Finland	5	
France	44	
Iceland	3	
India	1	
Israel	2	
Italy	14	
Japan	44	
Lebanon	5	
Mexico	4	
Netherlands	44	
New Zealand	10	
Norway	37	
Pakistan	3	
Peru	9	
Spain	4	
Sweden	154	
Switzerland	42	
Trieste	2	
Turkey	5	
Union of South Africa	28	
United Kingdom:		
Bermuda	15	
British West Africa	1	
England	103	
Uruguay	8	
Total	1,213	
Shipments classified by kind of isotope:		
Phosphorus 32	524	
Iodine 131	272	
Carbon 14	140	
Sulfur 35	60	
Iron 55, 59	53	
Cobalt 60	71	
Calcium 45	30	
Strontium 89, 90	12	
Other	51	
Total	1,213	

APPENDIX 5

Current AEC Unclassified Research Contracts in Physical and Biological Sciences and in Reactor Development[1]

PHYSICAL RESEARCH CONTRACTS

Chemistry

Arkansas, University of. R. Arndt and P. E. Damon, Investigation of the Radioactivity of Thermal Waters and Its Relationship to the Geology and Geochemistry of Uranium.

California Institute of Technology. H. Brown, Study of Fundamental Geochemistry of Critical Materials & Development of Economic Processes for their Isolation.

Canisius College. R. H. Schuler, Use of Iodine as a Radical Detector in Radiation Processes.

Columbia University. J. L. Kulp, Uranium-Lead Method of Age Determination.

Columbia University. V. K. LaMer, Fundamental Investigations of Phosphate Slimes.

Columbia University. J. M. Miller, Radiochemical Program at Nevis.

Florida State College. R. E. Johnson, Exchange Between Labeled Halogens and Certain Inorganic Halides.

Illinois Institute of Technology. G. Gibson, The Fundamental Chemistry of Uranium.

Illinois Institute of Technology. H. E. Gunning, The Fundamental Mechanisms for the Decomposition of Organic Molecules by Metal Photosensitization and other Collisions of the Second Kind.

Illinois Institute of Technology. M. E. Runner, Acids of the Hydrogen Fluoride System.

Indiana University. F. T. Gucker, Jr., Equipping of Laboratory for Work with Radioactive Tracers.

Iowa, State University of. R. E. Buckles, The Mechanisms of Addition of Halogen and of Halogenation Arising from the Action of Polyhalogen Complexes on Organic Molecules.

Massachusetts Institute of Technology. A. M. Gaudin, Techniques in Mineral Engineering.

New Hampshire, University of. H. M. Haendler, Infra-red Spectroscopy of Fluorides.

North Carolina State College. F. P. Pike, Performance of Contractors for Liquid-Liquid Extractors.

Oklahoma Agricultural and Mechanical College. T. E. Moore, A Study of the Liquid-Liquid Extraction and Separation of Salts.

---

[1] Contracts listed as of Nov. 30, 1951.

Oregon, University of. D. F. Swinehart, Construction and Use of Mass Spectrometer for Studying Chemical Reaction Kinetics in the Gas Phase.

Pennsylvania State College. T. F. Bates, An Investigation of the Mineralogy and Petrography of Uranium-Bearing Shales.

Princeton University. J. Turkevich, (A) Study of Nucleation Processes, (B) Temporary and Permanent Effects Produced by Radiation on Solids.

Southern California, University of. H. L. Friedman, Solutions of Inorganic Electrolytes in Solvents of Low Dielectric Constant.

Syracuse University. B. P. Burtt, Mechanisms of Gaseous Radiation Chemical Reactions and the Chemical Reactions of Electrons.

Syracuse University. L. Gordon, (A) Coprecipitation from Homogeneous Solution; (B) Analytical Chemistry of Thorium.

Tennessee, University of. G. K. Schweitzer, Study of Radiocolloids.

Tennessee, University of. P. B. Stockdale, Investigation of the Chattanooga Black Shale as a Source of Uranium.

Vanderbilt University. M. D. Peterson, Radiation Stability and Inorganic Radiochemistry.

Virginia, University of. W. R. Winsbro, The Development and Study of Continuously Operated Ion Exchange Separation Equipment.

Wisconsin, University of. F. Daniels, Uranium Exploration and Recovery from Low Grade Ores.

Yale University. J. N. Sturtevant, (A) Accurate Measurement of Rapidly Changing Voltages and Currents; (B) The Synthesis and Study of Organic Complexing Agents.

Metallurgy

California, University of. R. C. Grassie and H. A. Johnson, (A) Metallurgical Investigation of Materials Subjected to Liquid Lead-Bismuth Environments; (B) Heat Transfer Characteristics of Liquid Lead-Bismuth.

Carnegie Institute of Technology. R. Smoluchowski, Radiation Effects.

Columbia University. C. Bonilla, Heat Transfer to Molten Metals.

Horizons, Inc., E. Wainer, Investigation of New Methods for the Production of Zirconium Metal.

Illinois Institute of Technology. T. Neubert, Imperfections in Solids.

Illinois, University of. F. Seitz, Experimental and Theoretical Investigation of Radiation Damage in Solid Materials.

Massachusetts Institute of Technology. A. J. Chipman and M. Cohen, (A) Metal Thermodynamics; (B) Solid Solutions and Grain Boundaries; (C) Fundamentals of Cold-working and Recrystallization.

Massachusetts Institute of Technology. F. H. Norton, Metal-ceramic Interactions.

North Carolina State College. K. O. Beatty, Measurement of Thermal Properties of Non-metallic Materials at High Temperatures.

Ohio State University. C. H. Shaw, Soft X-ray Absorption and Emission Spectra of Certain Metals and Alloys.

Stanford University. O. C. Shepard, Resistance of Materials to Environment of Molten Lead and Bismuth.

Physics

Florida, University of. D. O. Swanson, Air and Rainfall Measurements.

Johns Hopkins University. S. S. Hanna, Fast Neutron Cross-Section Measurements.

Johns Hopkins University. L. Madansky, Gamma-ray Spectra and Meson Detection.

Kansas State College. C. M. Fowler, Precision Beta-ray Spectrometry.

Massachusetts Institute of Technology. C. R. Harrison, Echelle Spectroscopy.

Michigan, University of. H. R. Crane, 300 Mev Racetrack Synchrotron.

Nuclear Development Associates. H. Goldstein, Fast Neutron Data Project.

Ohio State University. J. N. Cooper, Nuclear Spectroscopy.

Ohio State University. M. L. Pool, H^3 and He^3 Bombardments of Various Nuclides in a Cyclotron.

Purdue University. R. O. Haxby, Basic Research Using High Energy Electrons and X-rays Produced by a 300 Mev Synchrotron.

Rice Institute. T. W. Bonner, Nuclear Physics of the Light Elements.

Vanderbilt University. S. K. Haynes, Beta-ray Spectroscopy.

Vanderbilt University. D. Hill, Neutron Spectroscopy with Specific Ionization Techniques.

Washington, University of. C. L. Utterback, 60-inch Cyclotron Project.

Wisconsin, University of. J. Dillinger and C. K. Lane, Studies in Low Temperature Phenomena.

REACTOR DEVELOPMENT RESEARCH CONTRACTS

Brookhaven National Laboratory. L. P. Hatch, Waste Disposal. Ultimate disposal of radioactive materials by permanent fixation on natural clays.

California, University of. N. B. Gotans, Research and Development on the Use of Sewage Treatment Processes on Radioactive Wastes. Investigating use of sanitary engineering methods for disposal of high-volume, low-level radioactive wastes.

California, University of. R. Bromberg and W. L. Martin, Liquid Systems Engineering Research. Studies of bubble and gas formation in liquid systems and transient behavior of high-temperature, high-pressure water systems.

Columbia University. E. L. Caden and C. G. King, Utilization of Fission Products. To study possibilities of a commercial process of food preservation, utilizing the bactericidal properties of penetrating X- and gamma radiation, including mixed fission products.

Columbia University. W. A. Selke, Utilization of Fission Products. Research and development on the effect of radiations from fission products, particularly the effect of gamma radiation on chemical reactions.

Harvard University. H. A. Thomas, Waste Disposal. Determination of distribution and disposition of radioactive material introduced into fresh water reservoirs and streams.

Harvard University. Philip Drinker, Air Cleaning. Research and development on air cleaning, including equipment, sampling methods, compilation of air-cleaning handbook, and training of personnel.

Illinois, University of. H. F. Johnstone, Aerosol Research and Development. Investigation of fundamental properties of aerosols as related to air cleaning.

Johns Hopkins University. Abel Wolman, Disposal of Liquid and Solid Radioactive Wastes. Concentration of radioactivity in plumbing systems; adsorption of radioactive material on natural waterborne silts; circulation of estuarial waters, and distribution of activity in institutional incinerators.

Johns-Manville Co. H. T. Coss, Thermal Insulation Matter. To develop insulations with better insulating properties than those now available and with characteristics suitable for reactor use.

Arthur D. Little, Inc. E. Stafford and W. J. Smith, Filter Research and Development. Development of high-efficiency, high-temperature, acid-resistant filters for removal of aerosols from gaseous effluents.

Massachusetts Institute of Technology. Rolf Eliassen, Water Decontamination. Removal of radioactivity from water supplies by conventional water-treatment methods.

Massachusetts Institute of Technology. B. E. Proctor, Utilization of Fission Products. An investigation of uses for fission products in the sterilization of foods, pharmaceuticals, and tissues.

Michigan, University of. C. W. Good, Industrial Utilization of Fission Products. Investigate possible use of fission products and identify areas within which (a) industrial uses of such products are technically and economically feasible; and (b) further research and development would be useful.

Minnesota, University of. H. S. Isbin and N. R. Amundson. Reactor cooling investigations to study pressure drop and transient flow characteristics in two phase, water-steam, systems.

National Bureau of Standards and Office of Naval Research. L. S. Taylor, Penetration and Diffusion of High-Energy Gamma Rays. Analytical and experimental studies to provide data for design of gamma ray shields.

National Bureau of Standards. U. Fano, Shielding Calculations. Detailed calculations of gamma ray attenutation in various media, covering a wide range of gamma energies.

New Mexico, University of. C. W. Beck, Waste Disposal. Petrographic and mineralogic studies related to disposal of radioactive wastes.

New York University. C. Edwards and W. E. Dobbins, Waste Disposal. Feasibility of trickling filter and activated sludge process for treatment of dilute radioactive wastes.

New York University. Gordon Strom, Atmospheric Disposal. Investigation of feasibility of using wind tunnels in evaluating disposal of gaseous effluents.

Powder Weld Process Co. R. A. Wiese, Protective Coatings. To provide for development of methods of applying special metals on odd shapes.

Rensselaer Polytechnic Institute. J. O. Hougen, Liquid-Liquid Extraction Studies. Research in liquid-liquid extraction; experimentation with pilot-plant size extraction column.

980705—52——11

Stanford Research Institute. P. W. Cook, Feasibility Study of Solar Evaporation. To evaluate feasibility of using energy content in sun's rays to evaporate, reduce volume, and decontaminate liquid radioactive wastes.

Stanford Research Institute. P. J. Lovewell, Industrial Survey. To stimulate industry in investigating uses of fission products and to determine areas of desirable research and development.

U. S. Bureau of Mines. R. C. Corey, Incineration of Radioactive Wastes. To develop a practical incinerator for disposal of solid combustible radioactive wastes at non-AEC locations.

Yale University. R. H. Bretton, Utilization of Fission Products. Research on effect of radiations from fission products, particularly gamma radiation on chemical reactions.

BIOLOGY, MEDICINE, AND BIOPHYSICS RESEARCH CONTRACTS

Biology

Amherst College. G. W. Kidder, Research in Radiobiology and Biochemical Genetics using Radioactive Isotopes.

Arizona, University of. W. H. Fuller and W. T. McGeorge, Utilization of Phosphorus from Biological Materials and Uptake of Strontium by Various Type Crops.[2]

Arkansas, University of. P. L. Day, J. R. Totter, J. S. Dinning, and I. Mescham, Studies on the Biochemical and Nutritional Aspects of X-radiation Injury.

Arkansas, University of. I. Mescham and E. Kerekes, Basic Studies in the Utilization of Cobalt 60 as a Radium Substitute.

Arkansas, University of. J. M. Siegel, Investigation of Intermediary Metabolism of the Photosynthetic bacteria.[2]

Battelle Memorial Institute. K. S. Chester, The Nutrition of Obligate Parasites in Plants.[2]

Battelle Memorial Institute. K. S. Chester, Study of Mode of Action of Fungicides.[2]

Boyce Thompson Institute. G. L. McNew, Use of Tracer Fungicides in Determining the Mechanics of Protecting Plants from Fungus Diseases.[2]

Brooklyn, Polytechnic Institute of. C. Neuberg, Factors Influencing the Solubility of Heavy Metal Complexes and Their Metabolism.

Brooklyn, Polytechnic Institute of. G. Oster, Effect of Ultra-violet Radiation on Enzymes and Viruses.

Brown University. J. W. Wilson, The Role of the Intestinal Flora in Radiation Injury.

California Institute of Technology. G. W. Beadle, The Genetic and Cytological Effects of High Energy Radiation.[2, 3]

California Institute of Technology. H. Borsook, Biological Synthesis of Proteins Labeled with Isotopes.[3]

---

[2] Plant science project.

[3] Contract administered through Office of Naval Research, Washington, D. C.

California, University of. H. A. Barker, W. Z. Hassid, and C. C. Delwich, Chemical Activities of Plants and Bacteria.[2]

California, University of. A. S. Crafts, The Translocation of Herbicides in Plants. The use of radioactive isotopes and other indicators to study absorption and distribution of herbicidal chemicals.[2]

California, University of. G. H. Hart, The Effect of Radiation on Work Capacity and Longevity of the Dog.

California, University of. L. Jacobson and R. Overstreet, Study of the Internal or Metabolic Factors and the External or Environmental Factors Influencing Ion Absorption by Plants.[2]

California, University of. M. Kleiber, Intermediary Metabolism of Organic Compounds and Biological Synthesis in Farm Animals.

California, University of. F. M. Turrell, F. S. Gunther, R. L. Metcalf, and R. B. March; Use of Radioactive Tracers in Studies of the Mode of Action of Organic Insecticides.[2]

California, University of, at Los Angeles. T. A. Geissman, The Sites and Mechanisms of Action of Physiologically-active Substances, with Particular Application to Drugs Acting Upon the Autonomic Nervous System.

California, University of, at Los Angeles. S. G. Wildman, The Study of Plant Viruses as Approached by the Study of the Normal Plant Proteins.[2]

Chicago, University of. E. M. K. Geiling, Biosynthesis of Radioactive Drug Compounds.

Columbia University. T. Dobzhansky, The Population Genetics of Species of Drosophila.

Columbia University. C. G. King and H. B. Burch, The Metabolism of Ascorbic Acid, Glucuronic Acid and Glucose Labeled with C 14 in Known Positions.

Connecticut Agricultural Experiment Station. A. E. Dimond and J. G. Horsfall, Therapy of Plant Disease by Nuclear Radiations.[2]

Cornell University. M. R. Zelle, Cytological and Genetic Studies of Bacteria as Related to Effects of Radiation.

Delaware, University of. A. M. Clark, Radiation Effects upon Haploids and Diploids of Habrobracon.

Duke University. P. J. Kramer, Study of the Factors Affecting the Absorption of Radioactive Phosphorus by Mycorrhizal and Non-mycorrhizal Roots of Pine.[2]

Duke University. K. M. Wilbur, Isolation and Properties of Rat Liver Nuclei; Shell Formation in Mollusks and Barnacles as Studied by Radioisotopes.

Emory W. Thurston Laboratories, Los Angeles, Calif. B. H. Ershoff, Comparative Effects of the Known B Vitamins and an Unidentified Antitoxic Factor in Liver on Radiation Injury in the Rat.

Florida, University of. G. K. Davis, R. L. Shirley, and A. M. Pearson, Concentration of Mineral Elements in the Fetus and the Relationship to Placental Transfer of These Elements.

Fordham University. E. V. Brown, Fate of Thiamine Analogs in the Animal Body; Mechanism of Thiamine Inhibition by Thiamine Analogs.

---

[2] Plant science project.

Fordham University. F. F. Nord, Investigation on Enzymatic Degradation of Native and Chemically Modified Proteins.

Georgia, University of. E. P. Odum and J. J. Paul, An Ecological Study of Land-use, Succession, and Indicator Invertebrate and Warm-blooded Vertebrate Populations of the Savannah River Operations Areas.[2]

Georgia, University of. H. Shoenborn, The Production of Mutant Strains of Euglenoid Flagellates and Their Use in the Study of Carbon Dioxide Fixation Processes.[2]

Harris Research Laboratories, Washington, D. C. M. Harris, The Chemistry of Biosynthesized Isotopically Labeled Cellulose and Allied Polysacharides.[2]

Harvard University. K. Sax, Dosage Curves under Varying Conditions of Time and Intensity of Radiation.[3]

Howard University. L. A. Hansborough, The Effect of Labeling the Germ Cells on Fertilization and Development.

Idaho, University of. W. K. Ferrell, T. S. Buchanan, and E. E. Hubert, A Study of Absorption and Translocation of Mineral Elements in Diseased and Healthy Western White Pine by the Use of Radioactive Materials.[2]

Illinois, University of. I. C. Gunsalus, Intermediary Metabolism of Carbohydrates.

Illinois, University of. R. C. Johnson and H. E. Carter, Nutritional Biochemistry on the Metabolism of Amino Acids and Vitamins.

Illinois, University of. H. H. Mitchell, Content in Human Tissues of Trace Elements.

Indiana University. F. Haurowitz, The Mechanism of the Combination of Antigen and Antibody.

Indiana University. H. J. Muller, The Influence of Radiation in Altering the Incidence of Mutations in Drosophila.

Indiana University. T. M. Sonneborn, Specific Immobilization Substances (Antigens) of *Paramecium aurelia.*

Indiana University. W. J. van Wagtendonk, Immunochemistry of *Paramecium aurelia.*

Iowa State College. S. Aronoff, Metabolism and Physiology of Roots.[2]

Iowa State College. J. W. Gowen and J. Stadler, Quantitative Study of Life-time Sickness and Mortality and Progeny Effects Resulting from Exposure of Animals to Penetrating Irradiation.

Iowa State College. F. Schlenk, Nucleic Acid Metabolism.

Iowa State College. F. H. Spedding, Combined Biochemical and Physiological Action of Tyrosine and Vitamin B 12.

Iowa State College. C. H. Werkman, Synthesis and Dissimilation of Bacterial Nucleic Acids.

Johns Hopkins University. R. Ballentine and W. D. McElroy, Metabolism and Functional Significance of Cobalto-protein.[2]

---

[2] Plant science project.
[3] Contract administered through Office of Naval Research, Washington, D. C.

Johns Hopkins University. B. F. Crow, Purification of Intrinsic Factor in Gastric Juice.

Johns Hopkins University. W. D. McElroy and C. P. Swanson, Modification Through the Use of Supplemental Environmental Factors of the Frequency of Gene and Chromosome Changes Induced by X-rays, Radioactive Isotopes, Ultraviolet Light and Nitrogen Mustard.

Johns Hopkins University. C. P. Richter, Part Played by the Adrenals in the Ability of Rats to Withstand Radiation Effects.

Kansas State College of Agriculture and Applied Science. P. A. Dahm, An Autoradiographic Study of the Distribution of Radioisotope Labeled Synthetic Organic Insecticides in Relation to Insecticidal Resistance to These Compounds by the House Fly.[2]

Kansas, University of. C. A. Leone and A. B. Leonard, Radium Chloride and Hemopoietic Physiology of Rodents.

Long Island Biological Association, Inc. B. Wallace, Adaptive Value of Experimental Populations Exposed to Radiations.

Louisiana State University and Agricultural and Mechanical College. J. F. Christman and V. Williams, The Effect of Biotin on Acetate. Utilization and lipide synthesis by micro-organisms.

Louisiana State University. H. E. Wheeler, Investigations of the Physiology, Genetics, and Host-parasite Relationships of Plant Pathogenic Fungi by the Use of Radioisotopes.[2]

Maryland, University of. J. C. Shaw, The Metabolism of Acetate, B-hydro-oxybutric Acid, Glucose, and Other Carbon Compounds in Lactating Ruminants.

Michigan State College. R. U. Byerrum and C. D. Ball, Transmethylation in Plants.[2]

Michigan State College. H. B. Tukey, The Absorption and Utilization of Radionuclides Applied to the Leaves of Plants; the Absorption and Utilization of Strontium by Plants.[2]

Michigan State College. L. F. Wolterink and E. P. Reineke, Hormonal and Nutritional Factors which Alter Half-lives and Differential Absorption Ratios of Calcium Manganese, and Cobalt in the Animal Body.

Michigan, University of. C. L. Markert, Mutagenic Effects of Different Types of Radiation.

Michigan, University of. J. V. Neel, The Estimation of the Rate of Mutation of Certain Human Genes.

Minnesota, University of. W. E. Peterson, A. Hemingway, and L. Mix, Study of Milk Formation by the Use of Radioactive Compounds.

Minnesota, University of. E. C. Stakman, Effects of Radioactive Substances on Plant Pathogens and Other Micro-organisms.[2]

Missouri, University of. S. Brody, Determination of Thyroid Activity in Farm Animals by the Use of Radioactive Tracers.

Missouri, University of. J. Levitt, Translocation of Mineral Substances in Plants.

---

[2] Plant science project.

Missouri, University of. L. J. Stadler, The Genetic Nature of Induced Mutatons.

Nebraska, University of. E. F. Frolik and R. Morris, The Genetic Effects of Thermal Neutron Irradiation of Crop Seeds.[2]

North Carolina State College. D. B. Anderson, Investigation of the Rate of Movement of Organic and Inorganic Compounds in the Tissues of Intact Tree Species.[2]

North Carolina State College. W. C. Gregory, Effects of Nuclear Reactor Radiation upon Genetics and Physiological Characteristics of Peanuts.[2]

North Carolina State College. D. S. Grosch, The Genetic and Developmental Effects of Ingested Radioactives.

North Carolina State College. N. S. Hall, Study of the Movement of Ions Through Soil Systems.[2]

North Carolina State College. S. B. Tove, Effect of the Composition of the Diet on Lipide Metabolism.

North Carolina, University of. D. P. Costello, The Effects of Radiations of Specific Energies on Mitosis.

North Carolina, University of. M. Whittinghill, The Partial Elimination of Lethal Genes Before Reproduction in Drosophila by the Use of Environmental Agents.

Notre Dame, University of. C. S. Bachofer, Study of Protection of Virus Systems against Irradiation.

Oberlin College. G. T. Scott, Studies on the Physiology of Ion Accumulation and Electrolyte Balance in Living Cells.

Ohio Agricultural Experiment Station. T. Kommendahl, The Physiology and Genetics of Plant Pathogenic Micro-organisms when Grown in the Presence of Various Radioisotopes.[2]

Oklahoma Agricultural and Mechanical College. R. M. Chatters, Effects of Radiation on Plant Growth.[2]

Oklahoma Agricultural and Mechanical College. A. Eisenstark, Study of Azotobacter Mutants Produced by Beta Irradiation.[2]

Oklahoma Agricultural and Mechanical College. R. MacVicar, Isotope Investigation of the Mechanism of Nitrate Reduction in Bacteria.[2]

Oklahoma Research Institute, University of. R. W. Goff, Study of the Effects of Isotopic Irradiation on Embryonic Capillaries.

Oklahoma Research Institute, University of. L. Rohrbaugh and E. L. Rice, Study of the Translocation of Tagged 2,4-D and Other Growth Regulators in Plants in Light and Darkness.[2]

Oregon State College. J. N. Butts, The Mode of Action of 2,4-Dichlorophenoxyacetic Acid and Isopropyl n-phenyl Carbamate.[2]

Oregon State College. V. H. Cheldelin and B. E. Christensen, Vitamin-amino Acid and Carbohydrate-amino Acid Interrelationships Using Isotopic Tracers.

Oregon, University of. P. L. Risley and A. L. Soderwall, Localization of Radioactive Isotopes in Germ Cells and Reproductive Tissues During Quiescence and Activation.

---

[2] Plant science project.

Pennsylvania, University of. D. W. Wilson, Synthesis of Isotopic Carbon Compounds Used in Biochemistry.

Pittsburgh, University of. R. Buchsbaum, The Study of Normal and Virus-infected Living Cells in Tissue Culture in Perfusion Chambers Before, During, and After Radiation.

Pittsburgh, University of. M. A. Lauffer, Study of the Correlation of Radiation Effects with Physical and Chemical Changes in Viruses.

Purdue University Research Foundation. H. Koffler and D. M. Powelson, The Physiology of Hydrogen Bacteria.[2]

Purdue University Research Foundation. H. Koffler and P. A. Tetrault, Use of Radioactive Isotopes in Studying Mold Metabolism with Emphasis on the Assimilatory Mechanisms of Penicillium Chrysogenum and Other Representative Molds.[2]

Rice Institute. A. C. Chandler and R. V. Talmage, Action of Relaxin and Related Studies on Cellular Metabolism.

Roscoe B. Jackson Memorial Laboratory, Bar Harbor, Maine. E. S. Russell and W. S. Murray, The Maintenance of a Genetically Controlled Colony of Mice to Insure the Availability of Strains of Known Constitution to AEC Installations and Contractors.

Rutgers College. J. E. Gunckel, Histological and Physiological Effects of Irradiation on *Tradescantia paludosa.*

Rutgers College. H. H. Haskin, Distribution and Accumulation of Radioisotopes of Physiological Importance in Shellfish.

Smithsonian Institution, Washington, D. C. R. B. Withrow, A Biochemical Investigation of Photomorphogenesis in Green Plants.[2]

South Carolina, University of. W. E. Hoy, An Ecological Study of the Land Plants and Cold-blooded Vertebrates of the Savannah River Project Area Before and After Installations have been Completed.

South Dakota, University of. E. I. Whitehead and O. E. Olson, Metabolism of Selenium and Sulfur in Plants.[2]

Southern California, University of. H. J. Deuel and A. L. S. Cheng, Effect of Radiation on Intestinal Absorption and Metabolism of Fats and Carbohydrates.

Southern Illinois University. C. C. Lindegren, The Effect of X-irradiation on a Polyploid Series of Yeast Cultures Containing Determined Amounts of DNA.

Southern Research Institute. H. E. Skipper, Study of Dosages of C 14 Labeled Sodium Formate Required to Produce Radiation Effects.

Stanford Research Institute. R. Pencharz and D. Singman, Experimental Study of the Direct and Indirect Effects Produced by X-irradiation of the Spleen.

Syracuse University. J. Lein, The Study of Intermediate Carbohydrate Metabolism in Neurospora Using Radioactive Carbon and Biochemical Mutants.

Tennessee Agricultural and Industrial State College. H. B. Crouch, Radiation and Tracer Element Studies on Certain Pathogenic Protozoa and Nematodes of Rodents.

---

[2] Plant science project.

Tennessee, University of. W. K. Baker, Investigation of the Influence of Oxygen Tension on the Frequency of X-ray Induced Mutations and Chromosome Aberrations in Drosophila.

Texas Agricultural Experiment Station. R. Reiser, Metabolism of Glycerides.

Texas Agricultural and Mechanical College. J. H. Quisenberry, Effects of X-ray Irradiation on Reproduction of the Domestic Fowl.

Texas, University of. J. W. Foster, Metabolic Processes in Molds and Fungi.

Texas, University of. J. Myers, Study of the Relationships of Algae to the Disposal of Radioactive Wastes.[2]

Texas, University of. W. S. Stone, Research on Direct and Indirect Effects of Radiations on the Genetic Systems of Organisms.

U. S. Department of Agriculture—Bureau of Animal Industry. H. R. Bird, Embryonic Metabolism and Internal Radiations.

U. S. Department of Agriculture. F. W. Parker, Production and Use of Radioactive Labeled Fertilizers and the Effects of Internal Radiation on Plant Growth.[2]

U. S. Department of Agriculture—Bureau of Animal Industry. B. Winton, The Effects of Radiation on Chickens, with Special Reference to Egg Production, Fertility and Other Physiological Factors.

U. S. Department of Interior—Fish and Wildlife Service. W. A. Chipman, Survey of Accumulation of Radioactivity in Salt Water Fish.

U. S. Department of the Interior—Fish and Wildlife Service. A. M. Phillips, Physiology of Cold Water Fish.

U. S. Department of the Navy—Radiological Defense Laboratory, Physiological Studies Related to the Recovery of Dogs from Fractionated Doses of X-rays.

Union College. L. B. Clark, Biological Effects of High Voltage Radiation.[3]

Utah State Agriculture College. C. Biddulph, Use of Radioisotopes in the Study of Reproduction.

Utah State Agriculture College. D. W. Thorne, Use of Radioiron in Studying Lime-induced Chlorosis.[2]

Utah, University of. L. P. Gebhardt and L. T. Samuels, Use of Labeled Phosphorus in the Study of Nerve Tissue Metabolism During Invasion of Neurotropic Tissues.

Utah, University of. J. D. Spikes and R. W. Lumry, Studies of Photosynthetic Processes in Cell-free Preparations.[2]

Virginia Polytechnic Institute. E. P. Johnson, Radioactive Isotopes to Trace Leucosis and Newcastle Disease in Fowls.

Washington, State College of. O. Biddulph, The Zinc Nutrition of Plants in Calcareous Soils.[2]

Washington, State College of. O. Biddulph, Absorption, Translocation and Disposition of Various Elements in Plants.[2]

Washington, State College of. N. Higinbotham, The Rate of Movement of Ions Into and Through Parenchyma Tissue as Affected by Rate of Water Uptake.[2]

---

[2] Plant science project.
[3] Contract administered through Office of Naval Research, Washington, D. C.

Washington, State College of. H. B. Milne, The Effect of X-rays Upon the Optical Specificity of Papain.

Washington, State College of. L. Smith, A Study of the Factors Influencing the Biological Effects of X-rays.

Western Reserve University. H. G. Wood and L. O. Krampitz, Intermediary Metabolism of Carbohydrates by Bacteria.

Wisconsin, University of. R. H. Burris and P. W. Wilson, Biological Nitrogen Fixation with Isotope Tracers.[2]

Wisconsin, University of. R. H. Burris, M. J. Johnson, and P. W. Wilson, Metabolism of Organic Acids in Higher Plants and Micro-organisms.[2]

Wisconsin, University of. D. E. Green, Effect of Radiation on Enzymes in the Cyclophorase System.

Wisconsin, University of. J. Lederberg, Cytogenetic Effects of Radiations on Bacteria.

Wisconsin, University of. P. H. Phillips. Long Time Effects of Intermittent Radiation on Dogs.

Wisconsin, University of. A. J. Riker and J. E. Kuntz, The Use of Radioactive Isotopes in Determining the Role of Root-grafting in Forest Trees.[2]

Wyoming, University of. Investigations of the Interrelationships of Sulfur, Phosphorus and Calcium in Selenium Metabolism.[2]

Yale University. D. M. Bonner, Relationship of Genes to Biochemical Reactions in Neurospora.

Yale University. M. I. Bunting, The Genetics of Serratia.

Yale University. N. H. Giles, Jr., Investigations on the Mechanism of Radiation-induced Chromosomal Rearrangements in Tradescantia and Gene Mutations in Neurospora.

Yale University. E. C. Pollard, Irradiation of Viruses and Large Molecules.

Medicine

Beth Israel Hospital Association, Inc., Boston, Mass. H. L. Blumgart, The Use of I 131 in Treatment of Heart Diseases and Follow-up Studies on Biological Effects of Radiation.

Boston University. W. W. Jetter, The Effects of Sublethal Doses of Ionizing Radiation on Physical Performance; Related Biochemical and Pathological Studies.

Boston University. B. R. Lutz, The Effect of Irradiation on the Functions of Small Blood Vessels.

Boston University. L. C. Wyman, The Effect of Irradiation on the Growth and Functioning of Transplanted or Regenerated Adrenocortical Tissue in the Rat.

California, University of. H. Becks, Investigations of the Dietary Effects of Radioactive Strontium, Calcium, and Phosphorus (Dental).

Chicago, University of. H. S. Anker, Investigation of the Mechanism of Antibody Synthesis by the Tracer Technique.

---

[2] Plant science project.

Chicago, University of. P. P. H. DeBruyn, Radiosensitivity of the Lymphocyte.

Chicago, University of. I. Gersh, Histochemical Study of Cement Substance of the Normal and Abnormal Optic Lens.

Chicago, University of. C. P. Miller, Bacteriological Aspects of Radiation Sickness.

Chicago, University of. W. L. Palmer, A Study of the Effect on Gastric Tissues of Irradiation Therapy in Peptic Ulcer.

Chicago, University of. W. H. Taliaferro, The Effect of Localized X-irradiation on Antibody Formation and Antigen Localization. The site of antibody formation.

Chicago Medical College. P. Shubik, A Study of Latent Tumor Cells as Produced by Beta Radiation.

Children's Medical Center of Boston. S. Farber and E. S. Buckley, Jr., The Nature of Bleeding in Pancytopenia with Special Regard for Thrombocytopenia and the Vascular Defect.

Cincinnati, University of. R. C. Crafts, The Hypophysis and Iron Metabolism.[3]

Cincinnati, University of. R. A. Kehoe, F. R. Dutra, and E. J. Largent, Research on the Biological Effects of Beryllium and its Compounds.

Colorado, University of. P. M. Dean, Study of the Relationships Between Chemical Structure, Physical Characteristics, and the Biological Activity in the Intermediate Metabolism of Nucleic Acid Derivatives.

Colorado, University of. J. R. Lacher and J. D. Park, Research on the Infrared Absorption Spectra of Nucleic Acids, Amino Acids, and Related Compounds.

Colorado, University of. T. T. Puck, Bacteriophage and Radiation Mechanisms.

Columbia University. I. J. Deyrup and A. Gorbman, Biological Effects of Radiation from Excessive Amounts of Radioiodine.

Columbia University. H. Grundfest, Study of Changes in Permeability of Normal, Poisoned, and Irradiated Nerve Fibers.

Columbia University. P. B. Hudson and J. M. Reiner, The Turnover of Specific Proteins, Protein Fractions, and Nucleic Acids in Normal and Malignant Human Testes and Kidney.

Columbia University. D. Nachmansohn, Effect of Exposure to Radioactive Material and to X-ray Irradiation on Nerve Tissue.

Cornell University. H. G. Wolff, Effect of Adrenocorticotropic Hormone, Cortisone, and Other Steroid Hormones on Phospholipid Metabolism.

Creedmore State Hospital, New York. Co Tui, Investigations on the Relationship of Human Skin Types to Blood Types and Related Studies on the Mechanism of Thermal Injury.

Duke University. P. Handler, Training Program.

Duke University. P. Handler, Turnover of Organic Phosphates in the Kidney.

Duke University. J. S. Harris, Studies of Electrolyte and Fluid Balance in Health and Disease.

Duke University. R. W. Rundles, Study of the Metabolism of the Human Bone Marrow.

---

[3] Contract administered through Office of Naval Research, Washington, D. C.

Georgetown University. C. F. Geschickter, A Study of the Redistribution of Bivalent Metallic Ions in Bone Metabolism and in Bone Disease and Neoplasms Through the Use of Radioisotopes and Novel Chelating Compounds.

George Washington University, Washington, D. C. P. K. Smith and E. L. Alpen, Studies of the Effects of Radiation on the Biosynthesis and Degradation of Nucleoproteins and Its Modification by Various Agents.

Georgia, University of. S. A. Singal, The Effects of Nutritional Deficiencies on the Synthesis of Phospholipids and Nucleoproteins in the Rat.

Hahnemann Medical College and Hospital, Philadelphia, Penna. J. S. Roth and M. J. Boyd, A Study of Nutritional and Other Factors Involved in Radiation Injury and Resistance to Radiation Injury.*

Harvard University. J. C. Aub, Study of the Metabolic Activities of Living Organisms by Means of Suitable Isotopes.

Harvard University. D. G. Cogan and R. D. Evans, Production of Cataracts by Neutrons and Other Radiations.

Harvard University. D. G. Cogan and D. D. Donaldson, Stereophotography of Anterior Segment of Eye with Special Reference to Crystalline Lens.

Harvard University. D. G. Cogan and D. D. Donaldson, Assembly and Delivery of Cameras for Stereoscope Photography of the Anterior Segment.

Harvard University. A. B. Hastings, Use of Isotopes in Study of Metabolism of Organic Substances in Mammalian Tissue.

Harvard University—Pondville Hospital. S. P. Hicks, The Effects of Ionizing Radiations on the Developing Mammalian Nervous System.

Harvard University, R. F. Sognnaes and J. H. Shaw, Metabolism of the Teeth.

Harvard University. A. K. Solomon, Use of Isotopes on Medical Problems.

Harvard University. J. L. Tullis, (A) Investigation of Factors Regulating the Formation, Maturation, and Liberation of Formed Blood Elements from Bone Marrow; (B) Further Studies of the Separation and Utilization of Formed Blood Elements.

Haskins Laboratories, Inc., New York City. S. H. Hutner, The Microbiological Assay of Nucleic Acid Constituent Produced by Radiation Injury.

Henry Ford Hospital, Detroit, Mich. F. W. Hartman and G. H. Mangum, Chemical Sterilization of Blood and Plasma with Nitrogen Mustard.

Illinois, University of. A. C. Ivy, Effects of Radiation of the Gastric Mucosa.

Institute for Cancer Research—Lankanau Hospital. S. Weinhouse and G. Medes, Origin and Fate of Amino Acids in Plants and in Animals.

Iowa, State University of. T. C. Evans and P. J. Leinfelder, A Quantitative and Morphologic Study of Radiation Induced Cataracts.

Johns Hopkins University. J. S. Friedenwald, Enzymatic Histochemistry of the Ocular Lens.

Johns Hopkins University. C. L. Conley, (A) Studies of the Absorption, Utilization, and Excretion of Vitamin B 12, using B 12 Containing Radioactive Cobalt; (B) Synthesis of Compounds with Vitamin K Activity Labeled with Radioactive Carbon for Use in Tracer Studies with Vitamin C.

Johns Hopkins University. J. E. Howard, Investigation of the Mechanism of Bone Deposition and Related Physiological Studies.

Johns Hopkins University. T. G. Ward, Metabolism of Phosphorus in Virus-host Systems.

Kansas, University of. R. E. Stowell, Cytochemical, Microchemical, and Biophysical Studies of Tumors and Effects of Radiations upon Cells.

Kresge Eye Institute, Detroit, Mich. V. E. Kinsey, Effects of Neutrons and Other Radiations on the Ocular Lens.

Lovelace Foundation for Medical Education and Research, Albuquerque, N. Mex. W. R. Lovelace, II, J. Grossman, J. Hickman, C. S. White, R. Kniseley, and M. Helpern, Indirect Blast Injuries.

Maryland, University of. T. E. Woodward, Studies on Monkeys Following Exposure to Large Doses of Total Body Irradiation.

Massachusetts General Hospital. J. C. Aub, J. T. Nathanson, and P. C. Zamecnik, A Biochemical Study of the Effects of Radiation on Cells.

Massachusetts General Hospital. H. L. Hardy, Establishment of a Beryllium Case History.

Massachusetts General Hospital. O. Cope, Effects of Radioactive Iodine on Biology of Thyroid Gland.

Massachusetts General Hospital. W. H. Sweet, The Use of Thermal and Epithermal Neutrons in the Treatment of Neoplasms.

Massachusetts General Hospital. W. H. Sweet, External Localization of Brain Tumors Employing Positron Emitting Isotopes.

Massachusetts Memorial Hospitals. F. J. Inglefinger, Effects of Radiation on the Structure and Function on the Digestive System, Particularly the Gastro-intestinal Tract in Man.

Massachusetts Memorial Hospitals. J. F. Ross, Physiological and Therapeutic Investigations and Fundamental Blood Studies Using Radioactive Isotopes.

Meharry Medical College. P. F. Hahn, Use of Radioactive Gold in Treatment of Tumors.

Michigan, University of. F. H. Bethell, Biological Effect of Irradiation.

Michigan, University of. R. L. Kahn and F. T. Hodges, Universal Serologic Reaction Following Irradiation.

Minnesota, University of. W. D. Armstrong, Effect of Ionizing Radiations on Electrolyte and Water Metabolism.

Minnesota, University of. G. E. Moore, Localization of Radioactive Materials in the Nervous System.

Minnesota, University of. S. Schwartz, Synthesis of Hemoglobin in Bone Marrow and Maturation and Multiplication of Blood Cells; Studies in Chemical Hemotology.

Minnesota, University of. C. J. Watson, The Influence of Radiation and Chemically-induced Bone Marrow Injury upon Porphyrin Metabolism.

Montefiore Hospital for Chronic Diseases. D. Lazlo and K. G. Stern, The Relationship of Stable and Radioactive Lanthanum to Nucleic Acid Synthesis in Normal and Neoplastic Tissue.

Mount Sinai Hospital. H. Sobotka, The Use of Isotopes in the Study of the Etiology of Drug Eruptions.

New England Center Hospital. W. Dameshek, Physiopathology of Platelets and Development of Platelet Substitutes.

New England Deaconess Hospital. S. P. Hicks, *et al.*, Acute and Chronic Radiation Injury.

New York Medical College. A. L. Copley, Study of Vascular Factors in Radiation Hemorrhage and Other Hemorrhagic Diatheses in Patients and Experimental Animals.

New York University. J. M. Converse, (A) The Effect of Refrigeration of Human and Animal Skin Upon its Use in Skin Grafts Following Thermal Injury; (B) A Study of Antibodies Produced by Homologous Skin Grafts in Animals and in Man.

New York University. N. Nelson, Influence of Particle Size on the Retention of Mist Particles in the Human Respiratory System.

New York University. W. S. Tillett and R. Soberman, The Influence of Ionizing Radiation on Enzyme Systems.

North Carolina, University of. J. C. Andrews and M. K. Bekrut, Tracer Studies and Irradiation in Dental Metabolism.

North Carolina, University of. A. Roe, Effect of C 14 on the Course of Certain Organic Reactions.

North Carolina, University of. C. D. VanCleave and C. T. Kaylor, Radioautographic Study of Distribution and Retention of Beryllium in the Rat.

North Dakota, University of. W. E. Cornatzer, The Effects of Radiation on the Functional Capacity of Tissues and the Mechanisms Involved.

Northwestern University. J. G. Bellows, Studies on Radiation Induced Cataracts.

Northwestern University. J. A. D. Cooper and H. L. Alt, The Diagnostic and Therapeutic Use of Radiosotopes in Experimental Medicine.

Northwestern University. L. Davis, Further Development and Utilization of Radioactive Dyes in the Diagnosis and Localization of Brain Tumors.

Northwestern University. R. W. Schayer, Studies of the Metabolism and Biogenesis of Histamine.

Notre Dame University. J. A. Reyniers, Study of the Effect of X-irradiation on Germ-free Rats.[3]

Ohio State University Research Foundation. J. L. Morton, Use of Radioisotopes for Cancer Therapy.

Oklahoma Research Institute. S. H. Wender, Isolation and Identification of Flavonoid Pigments.

Oregon, University of. E. S. West, Studies in the Metabolism of Cholesterol and Ketone Bodies.

Oregon, University of—Medical School. E. E. Osgood and A. J. Seaman, The Effects of Adrenocortical Hormones Upon the Cultivation and Transplantation of Human Blood Cellular Elements, and Follow-up Studies of Radiation Therapy Patients.

Peter Bent Brigham Hospital. F. D. Moore, Intracellular Changes in Trauma, Depletion, and Repair.

---

[3] Contract administered through Office of Naval Research, Washington, D. C.

Philadelphia General Hospital. H. P. Schwartz, The Effect of X-ray Radiation on the Infra-red Spectra of Neural and Radiosensitive Visceral Tissue.

Pittsburgh, University of. A. J. Allen and C. Moses, Effects of Neutrons From a Cyclotron on Mammals with Particular Reference to the Development of Cataracts.

Pittsburgh, University of. F. S. Cheever, The Effect of Radiation on the Virus-host Cell Relationship.

Pittsburgh, University of. F. J. Dixon, The Study of the Effects of Radiation on the Immune Response with Special Reference to Factors which Increase the Radioresistance of the Immune Response.

Pittsburgh, University of. M. A. Fischer and S. E. Purvis, Mechanism of Protection Against Radiation.

Presbyterian Hospital of the City of Chicago. R. G. Gould, Studies of Cholesterol and Lipoprotein Metabolism.

Reed College. F. P. Hungate, The Application of the Radioactive Tracer Technique in the Field of Cellular Metabolism.

Reed College. A. H. Livermore, The Biochemical Synthesis of Peptide bonds.

Reed College. A. F. Scott and A. H. Livermore, The Effect of Ionizing Radiation on Biochemical Compounds.

Reed College. A. F. Scott, Training Program.

Rochester, University of. G. H. Whipple, Plasma Proteins with Labeled Amino Acids.[3]

Rochester, University of. L. E. Young and W. S. McCann, Studies on Erythrocyte-Antibody Reactions and on Mechanisms of Erythrocyte Destruction.[3]

Saranac Laboratory of the Trudeau Foundation. A. J. Vorwald, Clinical Effect of Cortisone on Chronic Pulmonary Granulomatosis (Beryllium).

Saranac Laboratory of the Trudeau Foundation. A. J. Vorwald and F. W. Klemperer, (A) Biochemical Aspects of Pulmonary Disease in Beryllium Workers; and (B) Clinical and Experimental Investigations Concerning the Biological Hazards of Beryllium.

Sloan-Kettering Institute for Cancer Research. C. P. Rhoads, *et al.*, Biological Effect of Radiation and Related Biochemical and Physical Studies.

St. Louis University. H. Pinkerton, Study of the Relation of Rickettsial and Viral Infections to Radiation Injury.

St. Louis University—School of Medicine. E. A. Doisy, Sr., Metabolism of Steroids Utilizing Radiocarbon Labeled Compounds.

Syracuse University. E. L. Lozner, Body Defenses Against Hemorrhage in Health and Disease.[3]

Temple University. R. Robbins, Investigation of the Breakdown Products of Para-aminobenzoic Acid After Radiation With X-rays.

Tennessee, University of. L. Van Middlesworth, Thyroid Metabolism and Study of the Metabolism of Radioactive Methionine in Tissues.

Tennessee, University of. R. R. Overman and D. B. Silversmit, Mechanisms of Ionic Imbalance and Pathophysiologic States.

---

[3] Contract administered through Office of Naval Research, Washington, D. C.

Tennessee, University of. D. H. Sprunt, C. E. Nurnberger, and A. H. Lipscomb, Study of the Effect of Radioactive Iodine on Patients with Carcinoma of the Thyroid and with Hyperplastic Thyroids.

Tennessee, University of. E. F. Williams, Jr., Absorption and Intermediary Metabolism of Calcium.

Tennessee, University of. J. L. Wood, The Origin and Fate of Thiocyanate Ion in Metabolism.

Tufts College. D. Rapport, Study of the Effects of Radiation on Reactions Associated with Growth.

Tulane University of Louisiana. G. E. Burch, Jr., Turnover Rates of Chlorine and Rubidium Under Controlled Dietary and Therapeutic Conditions in Patients With Chronic Congestive Heart Failure and in Control Subjects.

Tulane University of Louisiana. R. H. Turner, The Influence of Radiation Injury Upon Physiology of Serum Lipids With Particular Reference to the Function of the Liver.

Tulane University of Louisiana. W. S. Wilde, The Metabolic Exchange of Tissue Electrolyte.

Utah, University of. M. M. Wintrobe and G. E. Cartwright, Metabolism of Trace Elements in Animals and in Men With Special Reference to Their Role in Erythropoiesis.

Utah, University of—Medical School. P. B. Price and R. E. McDonald, The Effects of Ionizing Radiation Upon Electrolyte and Water Balance, Blood Volume, and Nitrogen Metabolism in Dogs. Studies of the therapy of acute radiation injury.

Vanderbilt University—School of Medicine. W. J. Darby, Study of the Absorption and Metabolism of Lipids and the Alterations Which Occur in Acute Radiation Injury.

Virginia, University of—Medical School. C. L. Gemmill, The Metabolic Exchange of Radioactive Phosphorus and Potassium in Isolated Cells.

Virginia, University of. A. Chanutin, Effects of Ionizing Irradiation on Mammals.

Wake Forest College—Bowman Gray School of Medicine. C. Artom, Formation of Tissue Phospholipides.

Wake Forest College—Bowman Gray School of Medicine. G. T. Harrell, Jr., Distribution and Turnover of Sodium and Potassium in Acute Infection.

Wake Forest College—Bowman Gray School of Medicine. G. T. Harrell, Jr., *et al.*, Toxicity of Radiation as Related to Previous Damage and the Functional Capacity of an Organ; the Effect of P 32 and X-rays on Liver and Marrow.

Washington University, St. Louis, Missouri. W. M. Allen, Use of Gamma Ray as Therapeutic Agent of Carcinoma.

Washington University, St. Louis, Missouri. G. T. Cori, Enzymatic Mechanisms of Glycogen Synthesis.

Washington University, St. Louis, Missouri. G. J. Dammin and S. C. Bukantz, Investigation of the Effects of Agents Used in the Treatment of Cancer (X-ray, and Nitrogen Mustards), on the Immunologic Response of Experimental Animals.

Washington University, St. Louis, Missouri. D. Lipkin, Synthesis of Nucleotides and Related Compounds.

Washington University, St. Louis, Missouri. I. L. Sheckmeister, Investigations of the Relationship Between Radiation Damage and the Immune State.

Washington, University of. H. J. Daubin, Synthesis of Carbon 14 Labeled Diethylstilbestrol and a Study of Its Metabolism in the Body.

Washington, University of. C. A. Finch, Studies Related to Blood Preservation.

Washington, University of. C. A. Finch, Isotope Study in Iron Metabolism.

Washington, University of. R. D. Ray, Mobilization of Radioactive Emitters From Bone.

Washington, University of. R. H. Williams, Studies on Endocrine and Other Factors Governing the Incorporation of Labeled Amino Acids into Tissue Proteins *in vivo.*

Western Reserve University—School of Medicine. B. M. Dobyns, (A) The Chromotographic Separation (starch column) of Iodinated Compounds of Normal and Abnormal Thyroid Tissue; (B) A Study of the Physiological Function and Histological Changes of Thyroids Irradiated With Radioactive Iodine.

Western Reserve University. C. E. Carter, The Effects of Ionizing Radiation on the Content and Metabolic Functions of Ergothionine in Hemotopoietic Tissue.

Western Reserve University. H. L. Friedell, Investigations of the Biological Effects of Internally Deposited Radioisotopes and Related Radiobiologic Studies.

Western Reserve University. L. O. Krampitz, Effect of Incorporated Radioactivity on the Biological Activity of Bacteriophage.

Western Reserve University. A. R. Moritz, Physiological and Pathological Aspects of Thermal and Flash Burns.

Worcester Foundation for Experimental Biology. H. Hoagland and G. Pincus, Investigation of the Effects of Radiation on the Biosynthesis and Metabolism of Adrenocortical Steroids.

Yale University—School of Medicine. J. H. Heller and E. Pollard, Factors Increasing the Radiosensitivity of Malignant Neoplasms.

Biophysics

Chicago, University of. R. E. Zirkle, Use of Microbeam of Light Atomic Nuclei for Biological Investigations.

Columbia University. G. Failla, (A) Instrumentation for Dosimetry of Ionizing Radiation; (B) Study of the Biological Effects of Ionizing Radiation.

Florida, University of. D. Pomeroy and A. A. Bless, Study of Bioelectric Potentials as a Measure of Radiation Injury to Plants and Animals.

Howard University. H. Branson, Kinetic and Spectrometric Studies of Biophysical Systems with Radioactive and Stable Isotopes.

Idaho State College. C. W. McIntosh and A. E. Taylor, Determination of Quantities of Certain Radioactive Materials in Ground Water and Soil of Areas in and Adjacent to the Reactor Testing Station.

Illinois, University of. G. A. Bennet and R. A. Harvey, Distribution and Effect of Radioactive Calcium and Strontium in Bone Development.

Kansas, University of. F. E. Hoecker, Studies of Bone Metabolism Using Radium and Plutonium.

Marquette University—School of Medicine. W. A. D. Anderson, The Pathological Effects of Radioactive Isotopes of Calcium and Strontium on Bone and Soft Tissues.

Massachusetts Institute of Technology. R. D. Evans, Radium and Mesothorium Poisoning and Dosimetry and Instrumentation Techniques in Applied Radioactivity.

Michigan, University of. H. J. Gomberg and L. J. Hodges, High Resolution Detection of Radioactive Isotopes.

Mount Sinai Hospital. S. Feitelberg, Investigation of Sewage Water Contamination by Radioactive Isotopes.

New York University. M. B. Sulzberger and V. H. Whitten, Effects of Thorium-X in Selected Vehicles Applied to the Skin of Man, and the Effects of Selected Pure Beta Emitters on the Skin of Man.

Oregon, University of—Medical School. F. B. Queen, Evaluation of Body Content of Radium in Individuals With No Known Exposure.

Pittsburgh, University of. A. J. Kammer and T. F. Hatch, Hazard from Inhaled Radioactive Particulate Matter.

Southern Research Institute. L. White, Improvement of Current Models of Photo-electric Smoke Penetrometers.

Utah, University of. J. Z. Bowers, Toxicity Studies of Plutonium and Other Radioactive Substances in Animals.

Vanderbilt University. J. I. Hopkins, Elementary Particle Scattering and Studies of Decay Schemes.

Washington, University of. P. E. Church, Changes of Wind Speed and Direction with Height in Relation to the Vertical Temperature Distribution.

Washington, University of. P. E. Church and R. G. Fleagle, Determination of Relationships Between Temperature Lapse Rate, Wind Speed and Wind Shear.

Washington University—School of Medicine—Edward Mallinckrodt Institute of Radiology. Michel Ter-Pogossian, Measurement of Clinical X-ray Dosages and Intensities by Means of the Use of Scintillation Media.

Washington University—School of Medicine—Edward Mallinckrodt Institute of Radiology. W. G. Scott, Scanning of *in vivo* Concentrations of Radioactivity in an Attempt to Locate Metastatic Tumors and Internal Malignancies in the Human Body.

Wisconsin, University of. D. M. Angevine and J. J. Lalich, Development and Application of Historadiography in Relation to the Distribution of Mass and Localization of Elements in Normal and Pathologic Tissues.

980705—52——12

APPENDIX 6

Regulations of the U. S. Atomic Energy Commission [1]

Part 6—Security Policies and Practices Relating to Labor-Management Relations

AUTHORITY: §§ 6.1 to 6.40 issued under 60 Stat. 755; 42 U. S. C. 1801 to 1819.

GENERAL

§ 6.1 *Purpose.* The purpose of this part is to set forth AEC security policies and practices in the area of labor-management relations.

§ 6.2 *Basis and scope.* The specific policies contained in this part are worked out within the framework of AEC's general objectives for labor-management relations in the atomic energy program, namely;

(a) Wholehearted acceptance by contractors and by labor and its representatives of the moral responsibility inherent in participation in the atomic energy program;

(b) Development of procedures to assure (1) that all participants in the program are loyal to the United States including those whose participation involves the exercise of negotiating and disciplinary authority over bargaining units, and (2) that determination of unit, jurisdiction, and similar questions will not breach security;

(c) Continuity of production at vital AEC installations;

(d) Consistent with the Commission's responsibility under the law, the least possible governmental interference with the efficient management expected from the AEC contractors;

(e) Minimum interference with the traditional rights and privileges of American labor.

SECURITY POLICIES AND PROCEDURES IN NATIONAL LABOR RELATIONS BOARD PROCEEDINGS

§ 6.10 *Policy.* It is the policy of the Commission that NLRB cases falling within the scope of the Labor Management Relations Act at the various atomic energy installations should be conducted in normal fashion wherever possible, on the basis of open hearings, unclassified records and published decisions. This policy does not preclude adoption of special arrangements which may be required for reasons of program security at any stage of the proceedings in particular areas.

§ 6.11 *Consent elections.* In accordance with the recommendation of the President's Commission on Labor Relations in the Atomic Energy Installations, it is the policy of the Commission to encourage every effort by management and labor at atomic energy installations to determine bargaining units

[1] Regulations of the U. S. AEC announced prior to July 1951 can be found in Appendix 4, Fifth Semiannual Report to Congress; Appendix 10, Sixth Semiannual Report to Congress; Appendix 4, Ninth Semiannual Report to Congress; Appendix 6, Tenth Semiannual Report to Congress; and in the *Federal Register.*

and representatives by agreement and consent elections in preference to contested proceedings before the National Labor Relations Board.

§ 6.12 *Trial examiners.* By agreement with the National Labor Relations Board, a panel of cleared NLRB trial examiners is maintained to facilitate resolution of questions as to the materiality of classified information in NLRB hearings, and to facilitate preparation of an unclassified record. The assignment of individual trial examiners to atomic energy cases remains a matter within the discretion of the National Labor Relations Board.

§ 6.13 *Clearance of counsel.* It is recognized that clearance of counsel for the parties is sometimes desirable for proper preparation of a case even though the record is to be unclassified. Clearance of counsel makes possible their participation in any closed discussions needed preparatory to making an unclassified record. Each party is responsible for requesting clearance of its counsel well in advance so that clearance requirements will not delay the proceeding. The clearance of temporary special counsel will be terminated on completion of the proceeding.

§ 6.14 *AEC's role in proceedings.* If controversies within the scope of the Labor Management Relations Act arise which cannot be adjusted by mutual agreement, and contested proceedings before NLRB result, each party to such proceedings will present his own position and the evidence in support thereof with due regard for existing security rules. AEC will be continuously informed of the progress of such proceedings and will act as may appear desirable (a) to assure the protection of classified information; (b) to assure that material and relevant information is not withheld from the record on grounds of security if such information can be supplied in unclassified form; and (c) to assist in determining appropriate action where a decision may turn on data which can be expressed only in classified form.

LOYALTY OF PARTICIPANTS

§ 6.20 *Policy.* Loyalty to the United States is a paramount factor applicable to all participants in the atomic energy program including those whose participation (although not requiring access to restricted data) involves the exercise of administrative, negotiating and disciplinary authority over bargaining units composed of employees engaged on classified work. Individuals involved in questions of loyalty will be given full opportunity to explore the questions with the Commission. The Commission will take such further steps as may be appropriate in the circumstances.

CONTRACT NEGOTIATION AND ADMINISTRATION

§ 6.30 *Clearance of certain local union representatives.* It is recognized that security clearance of certain union representatives may be necessary to assure opportunity for effective representation of employees in collective bargaining relationships with AEC contractors. Accordingly, AEC managers may authorize investigation for "Q" clearance of union officials whose functions as representatives of employees may reasonably be expected to require access to restricted data (1) under NLRB and other procedures according to applicable law (LMRA, 1947); (2) to effectively perform their representation functions in the resolution of grievances and in other collective bargaining relationships with contractors; (3) to effectuate the recommendation of the President's Commission on Labor Relations in the Atomic Energy Installations in respect to integration of the union into the plant organization "as a two-way channel of communication and a medium of understanding between management and workers".

(a) In the precontract stage of union-management relations, the requirements of the Labor Management Relations Act normally will be the applicable criteria for determining which bargaining representatives, if any, will need access to classified material in the exercise of their functions as employee representatives;

(b) After a bargaining relationship has been established between the contractor and the representatives of its employees, the nature of this relationship and the procedures followed in it normally will be the controlling criteria for determination of the access to be granted to particular persons in carrying out their functions as employee representatives. For example, many contract grievance procedures designate by title certain union and management officials who are to have definite roles in the resolution of grievances under the procedure. Investigation for "Q" clearance will normally be in order for such officials, both company and union, employee and nonemployee. In addition, persons not so designated may be investigated for clearance where the company and the union advise the AEC manager that their established relationships contemplate access for such persons.

§ 6.31 *Clearance of conciliators and arbitrators.* Conciliators and arbitrators who are regularly assigned to atomic energy cases may be processed for "Q" clearance at the discretion of the local AEC manager, either on the manager's initiative or at the request of a contractor.

§ 6.32 *Security indoctrination of nonemployee representatives.* All collective bargaining representatives, company and union, who are to have access to restricted data, will be given appropriate security indoctrination.

§ 6.40 *Final responsibility of the Commission in security matters.* On all matters of security at all government-owned, privately operated atomic energy installations, the Atomic Energy Commission retains absolute and final authority, and neither the security rules nor their administration are matters for collective bargaining between management and labor. Insofar as AEC security regulations affect the collective bargaining process, the security policies and regulations will be made known to both parties. To the fullest extent feasible the Commission will consult with representatives of management and labor in formulating security rules and regulations that affect the collective bargaining process.

Dated at Washington, D. C., this 17th day of September 1951.

M. W. BOYER,
General Manager.

APPENDIX 7

Report to the President by the Atomic Energy Labor Relations Panel

June 1 to December 1, 1951

During the period June 1, 1951, to December 1, 1951, the Atomic Energy Labor Relations Panel closed its files on nine cases. As of December 1 two cases are still open, bringing the total number of cases considered by the Panel during the period covered by this report to 11. Since its origin in May of 1949 the Panel has taken part in 33 cases.

Disputes in construction required for the first time a large amount of the Panel's attention. Of the 11 cases handled, five involved construction projects. In two of these, prolonged strikes preceded the Panel's intervention. The rising incidence of construction cases, punctuated as some were with strike action preceding the entrance of the Panel, calls for a review of the Panel's role in the atomic energy building program.

When the President's Commission on Labor Relations in the Atomic Energy Installations wrote its report in the winter of 1949 there was relatively little building activity. The program was largely confined to the facilities which were either fully completed or at least begun while World War II was still being fought. The construction then going on was largely for the duplication or modification of existing facilities. In the then existing climate of international affairs the building of new plants did not have the same urgency as production in the existing plants. During the first 2 years of the Panel's existence there were numerous strikes in construction that were not referred to the Panel and which, in the opinion of the Panel and the Atomic Energy Commission, did not constitute a serious enough threat to the national interest to require the Panel to assume jurisdiction on its own motion. In those instances where the national interest appeared to be in jeopardy the Panel sought, and in all instances immediately obtained, full cooperation from the top leadership of the A. F. of L. to bring the work stoppage to an end.

Since the start of the Korean war the construction of new facilities has greatly increased and the urgency of the building program has at least equalled that of the production program. The increased amount of construction, and the national interest in its speedy completion, are factors in the Panel's stepped-up activity in this phase of the program. There has also been evidence of a renewed awareness on the part of both managements and unions involved in the atomic energy building program of the serious consequences of work interruptions. The last two construction cases handled by the Panel have been referred to it by the parties. In one of these a brief interruption occurred before the Panel took jurisdiction; in the other no work stoppage took place.

The Panel has continued to be guided by Section 3 of the Report of the President's Commission which recommended that "subject to the Atomic Energy Commission's responsibility under the law and to the limitations (of the national interest), the normal and typical aspects of wages, hours, and working conditions which are the substance of collective bargaining between private employers and non-governmental employees shall in Government-owned, privately operated atomic energy installations be left to collective bargaining between management and labor free from governmental interference." For the first time in its history, the Panel was able to tell one union and employer in a production facility that a strike arising out of their dispute would be of insufficient importance to the entire program to warrant Panel interference and that, accordingly, they were released until otherwise notified from their respective no-strike, no-lockout pledges so far as that dispute was concerned. In another case the issue was referred back to the parties for further bargaining and was subsequently resolved by them without Panel assistance. In still another case the Panel sent the parties back to gather further data and assigned a Panel member to give them assistance in preparing this factual data for their further bargaining. If the dispute remains unresolved after further negotiations in the light of this new data the Panel member will help them prepare a report upon which the full Panel will prepare a recommendation.

During the 6 months covered by this report the Panel also had its first experience with the issuance of wage recommendations in the light of Wage Stabilization Board policies. The Panel has in its custody a no-strike pledge covering this uniquely important industry and it believes that this advantage should be preserved and utilized to the full. To get this result the Panel has an obligation to turn over every stone that it can to uncover equitable ideas of settlement, and to use all means of persuasion to bring the parties together. It has, therefore felt a responsibility to mediate in wage disputes and, within the limits of wage stabilization policy fixed by the Wage Stabilization Board, even to make wage recommendations where necessary. At the same time the Panel will not encroach upon the field of wage stabilization policy-making. The policy-making function and the final authority of the Wage Stabilization Board are always kept in mind. The parties are not allowed to forget their responsibility to get Wage Stabilization Board approval for whatever wage agreements they may eventually reach. With these principles in mind the Panel members have initiated a close and personal liaison with the members of the Wage Stabilization Board. This liaison will be maintained in order to preserve the essential elements of wage stabilization and the best elements of mediation.

There follows a summary of the cases handled by the Panel during the period covered by this report. Full texts of Panel recommendations are to be found in the NEWSLETTER issued by the Organization and Personnel Division of the Atomic Energy Commission.

CASE NO. 17. AEC INSTALLATION: Knolls Laboratory, Schenectady, N. Y.; PARTIES: General Electric Co.; International Union of Electrical, Radio & Machine Workers, Local 301 (CIO).

The early history of this case was related in our previous report. On June 7 and 8 the Panel held hearings in Schenectady. The most urgent unresolved issue was the union's claim for added compensation in certain areas where the workers were required to wear protective clothing. The union argued that in spite of the health precautions there was a residual health hazard. This claim the company vigorously denied, citing statistics to prove that the Laboratory was one of the safest places to work throughout the General Electric establishments. The union also argued that the discomfort of wearing the necessary protective equipment merited additional compensation of 10 percent. In one area, for example, special breathing masks must be worn in order to keep radioactive substances from being inhaled.

The Panel members thoroughly explored the union's allegations and entered the areas under discussion wearing the required equipment. Upon this first-hand experience, and upon further detailed study of the comparative safety statistics which were put into the record without challenge, the Panel issued a recommendation on June 29 which said in part:

"The Panel finds that there is no unusual health hazard in * * * the Knolls Atomic Power Laboratory; that the protective clothing required for work in the 'hot' areas is uncomfortable, but not sufficiently to produce a substantial inequity between those who must wear it for a portion of their working day and those who never need to put it on."

Other items in dispute were (1) a change in day-shift working hours; (2) automatic progression schedules for skilled workers; and (3) pay for the Labor Day holiday, Sept. 4, 1950, for 95 employees whose pay was withheld by the company due to a work stoppage. The Panel recommended that the requested schedule shift be granted, that the company-wide system of progression scheduled for skilled workers should remain unaltered at the Knolls Atomic Power Laboratory, and that all employees who reported for duty at 8 a. m. on Sept. 5, 1950 (the day after the holiday) should be paid for that holiday.

CASE NO. 23. AEC INSTALLATION: Hanford Project, Richland, Wash.; PARTIES: Guy F. Atkinson Co. and J. A. Jones Construction Co.; Pasco-Kennewick Building & Construction Trades Council Negotiating Committee.

The early history of this dispute, together with a report of Panel hearings, was contained in our last report. On June 28, the Panel issued recommendations which said, in part:

"Its (the Panel's) analysis reveals that this isolation pay agreement at the Hanford Works, both in respect to its amount and its duration, rests on no objective or measurable criteria, but is rather a unique product of collective bargaining depending upon the agreement and understanding of people who have had a long history of successful relationships. No generalizations can be applied to this agreement, and therefore no outside individual or group of individuals can with reason alter the arrangement. * * * For the above reasons the Panel concludes that it should issue no recommendation in respect to the unions' request for an increase in job isolation pay.

These recommendations preserved the status quo until the termination of the contract in August. During the ensuing negotiations the parties again became deadlocked over the issue of isolation pay. Two of the building crafts referred this matter along with other issues to the Panel in October. These cases, numbers 30 and 31, are reported below.

CASE NO. 24. AEC INSTALLATION: Paducah, Ky.; PARTIES: F. H. McGraw & Co.; Sheet Metal Workers' International Asociation, Local Union 110.

On September 20 the Atomic Energy Commission asked the Panel to intervene in a labor dispute at Paducah, Ky., between F. H. McGraw & Co. and the Sheet Metal Workers' International Association. The Atomic Energy Commission's telegram stated that the dispute involved a request for an allowance, either in terms of subsistence, travel or higher rates, to increase earnings above established area rates. The telegram ended as follows:

"We are informed that the Sheet Metal Workers' Union has interested other crafts and that similar demands for increased compensation over and above area rates and conditions will be made known by a number of other crafts today and we are further advised that a strike * * * will occur at the beginning of work this morning.

"Within a few hours the above telegram was supplemented by an announcement from the Atomic Energy Commission that the Paducah job was "100 percent closed" due to a picket line.

The Panel immediately sent telegrams to Richard J. Gray, President of the A. F. of L. Building & Construction Trades Department, to William Green, President of the American Federation of Labor, and to four international presidents, which requested these officials to "exert your authority to return the men to work immediately." Before the end of the day the Panel had received assurances from many of these officials that they would take immediate steps to call off these work stoppages.

Nevertheless it took several days to return the men to full production and on September 25 Gordon Dean, Chairman of the Atomic Energy Commission, made a personal appeal to William Green of the American Federation of Labor, and to the prime contractors at both Paducah, Ky., and at the Dana Project, Newport, Ind. (where another work stoppage was in progress—see case No. 29 below). In this appeal he drew attention to some 29 work stoppages which had occurred since July 14 and which had cost the atomic energy program substantially over half a million lost man-hours. To all parties concerned Chairman Dean said: "the solution of this problem is imperative and the cooperation of all concerned is required."

By September 27 full production had been resumed and the Panel announced that it would hold a meeting with the parties to discuss the issues in dispute on October 10 in Washington.

The principal issue in dispute was over subsistence pay. When the job opened in April 1951 both parties agreed that the Louisville contract should apply to the work at Paducah. The Sheet Metal Workers claimed that the clause in this contract stipulating $5 per day subsistence for work performed beyond the normal commuting distance of a "shop" was applicable to the McGraw job, contending that the location of the McGraw "shop" was Louisville where much of the recruiting was done. The company claimed that its "shop" was right at Paducah and that there should therefore be no subsistence pay. After lengthy discussions and one work stoppage an agreement between the company and the union was reached which established a compromised journeyman's rate of $2.62½ per hour. The agreed upon rate was 27½ cents above the Louisville rate and eliminated any past and future claim for travel, transportation and subsistence by the union. This rate was then submitted to the Construction Industry Stabilization Commission of the Wage Stabilization Board where the rate of $2.62½ was disapproved on the grounds that it exceeded the area practice. The union then reverted to its original demand of $5 per day for travel and subsistence allowance.

After the Panel had listened to the arguments of both sides, the union asked for an opportunity to negotiate again with the company without Panel assistance. Thereupon the Panel withdrew from the conference room and after an hour conference the parties again reached agreement, this time on the Louisville rate plus $2.20 per day subsistence (an arrangement equal in amount to an hourly rate of $2.62½). They further agreed to submit a new request for approval, together with additional facts to support it, to the Wage Stabilization Board. A memorandum of agreement was drawn up and signed by the parties to this effect. This agreement was later approved by the Wage Stabilization Board.

CASE NO. 25, 26, 27. AEC INSTALLATIONS: K–25 Plant, X–10 Laboratory and Y–12 Plant, Oak Ridge, Tenn.; PARTIES: Company: Carbide and Carbon Chemicals Co.; Unions: K–25 Plant—The United Chemical Workers, CIO, Local 288 (Case No. 25); X–10 Laboratory—The Atomic Trades and Labor Council, A. F. of L. (Case No. 26); Y–12 Plant—The Atomic Trades and Labor Council, A. F. of L. (Case No. 27).

The Carbide and Carbon Chemicals Co. operated the three main facilities at Oak Ridge: the Oak Ridge National Laboratory (X–10), and the K–25 and Y–12 production plants. Cases number 25, 26, and 27 all involved the Carbide and Carbon Chemicals Co. and the unions representing the employees in these facilities. Since the principal issue in dispute was identical in these cases, they are reported here under one heading. For previous history of the Panel's participation in the labor relations of these facilities, see the accounts in our previous reports for cases numbered 3, 11, and 12.

Case No. 25 pertains to the K–25 plant where Local 288 of the United Chemical Workers, CIO, is the bargaining agent. The wage clause of the agreement was reopenable on July 1, 1951. The Panel was first informed that a dispute existed by a telegram sent to it on June 30 by Martin Wagner, international president of the union. In this message he urged the Panel to take jurisdiction.

An investigation revealed that practically no bargaining had taken place. The Panel therefore took official cognizance of the dispute but asked both parties to continue their discussions without Panel intervention until the first week in August. On August 3 the Panel was informed by the Federal Mediation and Conciliation Service that negotiations were still in progress under its direction and that it was preparing an interim report for the Panel. When this report was received, it stated that the deadlock was caused at least in part by uncertainty over the application of Wage Stabilization Board policies as to the amount of the increase permissible. Since a clarification by the Wage Stabilization Board of its policies was momentarily expected, the Panel wrote to the parties asking that negotiations be resumed under the aegis of the Federal Mediation and Conciliation Service as soon as this clarification became available.

When, on September 6, the Panel received word that the dispute remained unresolved, a meeting in Oak Ridge was immediately arranged for September 8.

The wage reopening clause under which the parties were negotiating specified that "the only question to be open for negotiation is whether there should be an across-the-board revision in wage rates." This language stemmed directly from the Panel's recommendations issued in 1950. It is unlikely that this provision would have produced a deadlock had it not been for the changed status of labor relations at the Y–12 plant. Until the spring of 1951 Y–12 was unorganized. The company had maintained a wage structure at the Y–12 plant practically identical to that of the K–25 plant where the CIO is the bargaining agent. When the A. F. of L. won representation at Y–12, foremost in this union's demands was a wage structure comparable to that at the X–10 Laboratory where some of the job classifications, including several skilled crafts, enjoyed a higher rate. Under these circumstances the CIO was reluctant to settle for an across-the-board increase, fearing that a more advantageous settlement at Y–12 would leave it in an unfavorable position.

The Panel viewed the rate structure question, insofar as it pertained to interplant X–10, Y–12, and K–25 comparisons, as one which could only be resolved on an Oak Ridge-wide basis. It therefore set this matter aside for the moment and turned to the task of resolving the other issues. Some of the items were settled in mediation and the remaining ones were made the subject of an interim set of recommendations issued on October 10. These contained an 8-cent across-the-board wage increase effective July 1 and a midcontract wage reopener.

In respect to the interplant wage controversy, the company wished to see the rate structure remain unchanged in all three plants for the duration of the existing agreements at K–25 and X–10, i. e., July 1, 1952. The company preferred the K–25 type of noncraft rate structure but recognized that any move toward uniformity under the political realities of Oak Ridge unionization was more likely to be in the direction of the X–10 type of rate structure. On the other hand there was open recognition by the company that a trend toward uniformity of some sort was both desirable and inevitable. The A. F. of L.'s position was that the Y–12 rates (the plant which had just recently been organized by it), should be brought into line with those at X–10 where the union had enjoyed bargaining rights since 1948. In addition to being to the advantage of the employees at Y–12, a settlement of this nature might prove advantageous to the A. F. of L. in furthering its organizing objectives in Oak Ridge. The CIO also wanted to raise those rates at K–25 which were presently below comparable jobs at X–10. Although the wage reopening clause referred to above appeared to block an adjustment of this type, the CIO strongly argued that the change in the Oak Ridge bargaining picture fully warranted such a departure.

After canvassing the various alternatives, the Panel came to the conclusion that in view of all the circumstances attempts should be made to achieve a more nearly uniform rate structure among the three facilities at Oak Ridge. Accordingly the Panel asked for and received a voluntary agreement by all of the parties concerned to submit to its jurisdiction the question of the internal rate structures with the understanding that the Panel would recommend a procedure for bringing these rates into line with one another. A statement to this effect was included in the interim recommendations issued on Oct. 10, 1951.

Case No. 26 pertains to the X–10 Laboratory where the Atomic Trades and Labor Council, A. F. of L. is the bargaining agent. The wage reopening clause at this Laboratory was the same as that covering K–25. In this case, however, the union was not requesting any change in the structure but instead was seeking in another negotiation at the Y–12 plant, to equate the structure there with the X–10 Laboratory.

The Panel received official notification of a dispute at X–10 from the company in a telegram sent on July 6. This telegram said that the union had rejected the management's "final" offer and that a strike was threatened for August 1. Between that date and the end of August, the Panel handled this case procedurally the same as it did K–25, and thus negotiations continued through the months of July and August without active Panel intervention. On August 28 the parties reached a tentative agreement on all matters which were written into a stipulation signed by the parties subject only to ratification by the membership of the Atomic Trades and Labor Council.

The Panel was therefore never directly involved in the negotiations at X–10. When, however, it appeared that the negotiations at the other plants could not be resolved without equalization of the rates at all three facilities, the Panel obtained the same agreement from the parties at X–10 to submit to it the question of the rate structure as it had obtained from the parties at the other two facilities.

Case No. 27 pertains to the Y–12 plant where the Atomic Trades and Labor Council, A. F. of L. was negotiating a first agreement. As already stated above, one of the principal issues was the union's demand for a wage structure identical to that at the X–10 Laboratory.

The Panel received a request for intervention in this matter from the union on July 25. The Panel urged the parties to continue negotiations as it had done in the other two cases.

When the Federal Mediation and Conciliation Service informed the Panel that it could make no further progress, a meeting was arranged in Oak Ridge for September 8. In this case, as in the K–25 case, the Panel decided to leave aside for the time being the union's demand in respect to claimed Oak Ridge inequities and turned to the other unresolved items.

Many of the unresolved items were settled in mediation. In respect to the open matters, other than claimed Oak Ridge inequities, the Panel issued an interim recommendation on October 10.

These recommendations included a general across-the-board increase of 8 cents per hour effective July 1, 1951, suggested language for the clause pertaining to "protective clothing," suggested language for the clause pertaining to the settlement of jurisdictional disputes, a vacation clause granting 1 week vacation for service over 1 year and less than 2 years, 2 weeks vacation for service between 2 years and 15 years, 3 weeks vacation for service between 15 years and 25 years, and 4 weeks for service over 25 years.

On October 16 the Panel received from the Atomic Trades and Labor Council a telegram which "emphatically protests the recommendation made by the Panel" with special reference to the protective clothing clause and the clause covering the settlement of jurisdictional disputes. The Panel acknowledged this telegram and advised the union that it was planning to hold meetings in Oak Ridge on November 3 and 4 in order to obtain further data upon which to base its recommendations for a uniform wage structure and that at that time it would be willing to discuss the contents of the union's telegram with them.

The Panel did meet with the union in Oak Ridge on November 3, at which time the contents of the Panel's recommendations were thoroughly discussed with a union committee consisting of approximately 40 members.

On November 20 the Panel issued to the parties at all three facilities its recommendations for individual job rates. With each recommendation the Panel attached a schedule entitled "Consolidated Statement of Panel Recommendations for K–25, X–10 and Y–12 Wage Structures." This statement set forth the Panel's groupings of job titles at the three facilities and the recommended uniform rate for the jobs in each group at all of the facilities.

CASE NO. 28. AEC INSTALLATION: Oak Ridge, Tenn.; PARTIES: Roane-Anderson Co.; United Gas, Coke & Chemical Workers of America, CIO, Local No. 439.

On August 3 the Panel was asked by the local union officers of the United Gas, Coke & Chemical Workers, CIO, to intervene in a dispute between it and the Roane-Anderson Co. at Oak Ridge over the terms of a new contract covering various custodial employees. The Panel learned that the Federal Mediation and Conciliation Service were still handling this case and that, as yet, no international officers had participated. The Panel advised the international office of the Chemical Workers of these facts. On August 8 counsel for the international renewed the union's request for Panel intervention, asserting that all possible steps had been taken to resolve the controversy. Further check by the Panel showed that due to the absence of negotiators on both sides only one joint conference under the jurisdiction of the Mediation Service had been held and that further meetings were scheduled. The Panel therefore again declined to interfere in the negotiations. Shortly thereafter a contract between the parties was signed.

CASE NO 29. AEC INSTALLATION: Dana Project, Newport, Ind.; PARTIES: Girdler Corp.; United Association of Plumbers & Pipefitters, A. F. of L., Local No. 157.

During the summer months, a series of work interruptions occurred on construction at two new atomic energy facilities—one at Paducah, Ky. and the other at the Dana Construction Project, Newport, Ind. As reported in connection with Case No. 24, Gordon Dean, Chairman of the Atomic Energy Commission, felt the situation to be sufficiently serious on September 26 to warrant direct action on his part. On that day he issued a letter to the union and contractors involved calling on them to resume production in the national interest. Not since the summer of 1948, when David Lilienthal then AEC Chairman went directly to the top councils of the A. F. of L. to forestall a strike at the X–10 Laboratory, had the chief executive of the Atomic Energy Commission participated officially in the labor relations of the atomic energy program.

On October 5 the Atomic Energy Commission informed the Panel that a work stoppage of approximately 1,500 pipefitters had been in progress for over a month at the Dana Project and asked that the Panel intervene. On the following day the Panel sent telegrams to both parties setting a date for a meeting and calling upon the United Association of Plumbers and Pipefitters, A. F. of L. to return its members to work.

On October 8, Martin Durkin, president of the United Association, replied by asking the Panel the following questions:

"I wish to know if Building Trades Union have a right to strike on atomic energy projects * * * I wish to know if Building and Construction Trades Department on behalf of the international unions members thereof agreed to submit cases involving building and construction on atomic energy projects to your Panel?"

The Panel replied as follows:

"The Panel has never questioned anyone's right to strike but the Panel has understood that the A. F. of L has voluntarily agreed to defer strike action pending mediation efforts of the Panel. The Panel has also understood that this agreement covers construction and in fact this has never been challenged. Under these circumstances we now repeat our request that you get the men to return to work at Dana and thus put an end to a critical and immediate national emergency. The Panel can then discuss with you on Wednesday the question raised in dispute."

By October 10, the date set for the Panel meeting, full activity had been resumed on the job.

The main issue in this dispute was over the retroactive payment of travel pay. The Girdler Corp. increased its pipefitter rate last spring to $2.47½ per hour, the maximum it considered allowable under wage stabilization regulations. The union contended that the rate should be $2.50 as negotiated by the Master Plumbers of Terre Haute. The union also demanded in addition the 5 cents per mile travel pay which was area practice. Before giving the union an answer the corporation asked for a ruling from the Wage Stabilization Board whether the payment of this travel allowance was permissible. On April 17 a ruling was received which indicated that this benefit could not be approved. On May 3 the Pipefitters walked off the job in a "wildcat" strike. Negotiations were resumed after the men returned to work on May 7 and a settlement was reached on June 1 for a rate of $2.60 an hour, such rate to be *paid without additional compensation* for travel expenses. This new agreement was then submitted to the Construction Industry Stabilization Commission of the Wage Stabilization Board and on August 21 the CISC denied approval of the $2.60 rate and approved in its place a rate of $2.50 an hour plus the payment of 5 cents a mile travel expense. The corporation started paying this new rate and travel expense on August 21. The union claimed that the corporation should have paid the 5 cents per mile travel pay retroactive to March 19 (the date of the area contract which established the $2.50 rate plus the 5 cents per mile allowance). The dispute before the Panel was over the retroactivity claimed by the union between March 19 and August 21.

During its mediation efforts the Panel explored the possibility of reviving the original $2.60 agreement, believing that further development of the facts might obtain CISC approval. The Panel was prepared to urge this settlement but discovered that it was no longer acceptable. Since agreement could not be obtained in mediation, the Panel recommended a retroactive date of June 1, 1951 (the day on which the rate of $2.60 was agreed to in lieu of travel pay) for payment of the 5 cents per mile travel pay. After further negotiation, both parties agreed to this arrangement and the Construction Industry Stabilization Commission approved it.

During the Panel meeting of October 10, Martin Durkin repeated the questions contained in his telegram of October 8 with reference to the Panel's jurisdiction over construction. He made it clear that the officers of the United Association of Plumbers and Pipefitters had not felt themselves bound by the no-strike pledge given to the Panel by A. F. of L. president William Green, and he further voiced the opinion that this view was held by other crafts of the Building Trades Department. President Green's pledge, according to Durkin, applied solely to production which is under the jurisdiction of the Metal Trades Department.

Panel Chairman Davis accepted Mr. Durkin's statement as an accurate expression of the Building Trades' understanding of the Green pledge. At the same time he made it clear that the Panel itself had been under the impression that the pledge had covered all essential atomic energy programs. Since the Panel plan rests solely upon voluntary agreement, this honest misunderstanding was in itself sufficient to modify the pledge so far as the Building Trades were concerned. At the same time, the practical test of history had shown that the responsible officials of the Building Trades unions had on all occasions responded wholeheartedly to the Panel's request to keep essential production going whenever such request had been made. If this record of responsible union leadership continues, Mr. Davis said, the practical effect of the Panel's operation will be as effective under this ad hoc arrangement as under the original intent of the plan.

CASE NO. 30. AEC INSTALLATION: Hanford Works Project, Richland, Wash.; PARTIES: Guy F. Atkinson Co. and J. A. Jones Construction Co.; Sheet Metal Workers International Association, Local No. 99.

On October 19 the Atkinson-Jones Construction Co. notified the Panel that a dispute existed between it and Local No. 99 of the Sheet Metal Workers International Association, A. F. of L. at Hanford which had resulted in strike action that morning. The company asked the Panel to assume jurisdiction. The Panel sent a telegram to the parties involved on October 16 stating that it had taken jurisdiction and that a meeting would be arranged as soon as the men had returned to work. On the same day the Panel received a telegram from Robert Bryon, international president of the union, which said that he had instructed the local business agent to return the men to work. Accordingly a meeting was scheduled for November 2 in Washington.

One of the issues in this dispute involved isolation pay. The Hanford building crafts brought this question to the Panel in the spring of 1951 (see case No. 23 summarized both in this report and in the previous report of the Panel). A dispute over this same issue arose again last August when the Hanford Master Agreement covering most of the trades was reopened. Since many of the other crafts on the project had already referred this dispute to the Wage Stabilization Board, the Panel's suggestion to the parties that they submit this question to the Wage Stabilization Board along with the other crafts involved was accepted.

In the dispute over the wage rate the company offered a rate of \$2.47½ which is equivalent to the current Spokane rate. The union asked for a considerably higher rate and supported this demand on two premises: (1) that a more applicable comparison is with the higher rates paid in the Seattle area, and (2) that the Spokane agreement did not fully exhaust the permissible amount applicable under wage stabilization regulations. As discussions continued the dispute therefore narrowed down to the following considerations: (1) what is the appropriate area to be considered for the establishment of Hanford rates, and (2) what is the maximum amount allowable without a special ruling under Wage Stabilization Board regulations. In respect to the latter consideration, the union's position was that the July 1, 1950, base date rate was $2.35 and that 10 percent over this rate would automatically allow a new rate of $2.58½. The company did not dispute this computation but pointed out that the $2.35 rate was not put into effect until August 1, 1950.

After hearing these arguments the Panel analyzed the problem as one which involved wage stabilization policy. In this connection the Panel stated that it would take no action which would result in a piercing of the ceiling established by the Wage Stabilization Board. At the same time the Panel said that it was aware of its responsibility as the custodian of a no-strike arrangement. In such a situation the Panel would utilize its mediation offices to seek a voluntary agreement; failing that, it would try to obtain voluntary consent of the parties to submit their wage dispute to the Wage Stabilization Board; and failing that the Panel would, if necessary, issue recommendations which would fall within the regulations of the Wage Stabilization Board so far as the Panel was able to interpret them. Under each of the above alternatives the parties were reminded that Wage Stabilization Board approval would be required.

After further negotiation the Panel proposed the following six points for resolving the dispute:

(1) The issue of wages shall be submitted to the Wage Stabilization Board for final determination;

(2) Vacation time shall be computed at the rate of four hours per month;

(3) The company agrees to put into effect a welfare fund equivalent to 7½ cents per hour similar to that negotiated in Spokane, such plan to be submitted to the Wage Stabilization Board for approval;

(4) The question of isolation pay shall be submitted to the Wage Stabilization Board and consolidated with the cases now pending before that Board from the Hanford Project;

(5) The effective date of the agreement shall be August 1, 1951;

(6) The question of travel and subsistence pay outside the barrier shall be settled by further negotiations at the local level.

The substance of these points were later agreed to by the parties and incorporated into a memorandum of agreement.

CASE NO. 31. AEC INSTALLATION: Hanford Works Projects, Richland, Wash.; PARTIES: Guy F. Atkinson Co. and J. A. Jones Construction Co.; International Association of Machinists, Lodge No. 1743.

On October 18, the Panel was asked by the Atkinson-Jones Construction Co. to assume jurisdiction of a dispute between it and Lodge No. 1743 of the International Association of Machinists, A. F. of L. The Panel accepted jurisdiction and set up a meeting in Washington for November 2.

The matter of isolation pay, by agreement, was submitted to the Construction Industry Stabilization Commission of the Wage Stabilization Board. (For details in a similar case, see case No. 30 above.)

The principal issue remaining in this dispute was the wage rate for precision machinists. The union rested its arguments on the relationship of precision machinists to other crafts on other construction jobs. Since the union did not have available sufficient data to support this claim, the following procedure was suggested by the Panel and accepted by the parties:

MEMORANDUM of the Atomic Energy Labor Relations Panel to Parties International Association of Machinists—Atkinson-Jones Dispute.

The parties agreed before the Panel on Friday, November 2, to gather facts on the following criteria:

1. The historical relationship of machinists to other construction workers;
2. Customary crafts relationships of machinists in construction today;
3. "Within craft", "out-of-shop" differentials;
4. Evaluation of "in-shop" fringes on machinists;

The foregoing criteria will be gathered in the area defined as the Northwest.

The Panel said it would retain jurisdiction of the dispute while these facts were being gathered. Panel member Godfrey P. Schmidt was appointed to aid the parties in preparing a report based on the facts. If an agreement is not then reached in direct negotiations, the Panel will issue recommendations. As of December 1 this case is still open.

CASE NO. 32. AEC INSTALLATION: Knolls Atomic Laboratory, Schenectady, N. Y.; PARTIES: General Electric Co.; International Brotherhood of Teamsters, A. F. of L. Local No. 294.

On October 19 the Panel received a letter from the vice president of Local No. 294 of the International Brotherhood of Teamsters, A. F. of L., in Schenectady requesting its intervention in a dispute between that union and the General Electric Co. at the Knolls Atomic Laboratory. The Panel replied, advising the local that a request for intervention should be channeled through the international office. On October 26 a letter from local counsel advised the Panel that Local No. 294 "is entirely autonomous in these negotiations." The Panel then sought from the Atomic Energy Commission advice as to whether a strike of the Teamsters at this facility would "threaten to interfere with an essential part of the atomic energy program." The Atomic Energy Commission replied that "a strike of Teamsters would not immediately affect these essential programs although a continued failure to transport the (essential) materials would have serious consequences. Hence we would not now regard this dispute as constituting a threat to the essential work at Knolls."

Accordingly, on October 31, the Panel advised the parties that "in accordance with the procedures outlined in Section 5c of the Report of the President's Commission on Labor Relations in the Atomic Energy Installations the Panel hereby announces that it does not intend to take jurisdiction of this dispute at this time, being informed by the Atomic Energy Commission that this dispute does not now threaten an essential part of the atomic energy program."

The Panel understands that a strike was called by the Teamsters at Knolls during the second week of November and, on December 1, was still in progress.

CASE NO. 33. AEC INSTALLATION: Sandia Base, Albuquerque, N. Mex.; PARTIES: Sandia Corp.; Atomic Projects and Production Workers, Metal Trades Council, A. F. of L., Office Employees International Union, A. F. of L. Local No. 251.

This case pertains to the joint negotiations of the Atomic Projects and Production Workers, Metal Trades Council, A. F. of L. and Local No. 251 of the Office Employees International Union A. F. of L. with the Sandia Corp. On October 26 the Panel received a request from the two unions involved to intervene in a dispute between them and the corporation over the terms of a contract renewal. For a summary of prior Panel participation at Sandia, see cases numbered 16 and 22.

After being informed by the Federal Mediation and Conciliation Service that it could make no further progress, the Panel assumed jurisdiction and announced meetings to be held in Albuquerque commencing November 17. The parties were asked to prepare briefs in advance of these meetings.

There were 20 open issues when the Panel entered the case. The most complex issue, and the one which was the major block to an agreement, arose over the operation of the corporation's job evaluation plan.

The Panel spent most of its time in Albuquerque on November 17 and 18 in listening to the arguments presented by both sides. In the discussions, it was evident that some of the unions' grievances arose from insufficient or erroneous facts. To rectify this, the corporation was asked to prepare a list of items concerning the operation of the job evaluation and job grading plan for presentation both to the Panel and to the unions. It was also evident that the proposals submitted by the unions were not in a form which could be clearly understood by the corporation. The unions were therefore asked to rework its proposals for presentation both to the Panel and to the corporation.

Since it would take some time for both sides to comply with these requests, the hearings were adjourned until December 1 in Washington, D. C.

This case, as of December 1, is still open.

WILLIAM H. DAVIS, *Chairman.*
FRANK P. DOUGLASS, *Member.*
JOHN T. DUNLOP, *Member.*
AARON HORVITZ, *Member.*
GODFREY P. SCHMIDT, *Member.*
EDWIN E. WITTE, *Member.*

DONALD B. STRAUS, *Secretary.*

Dec. 13, 1951.

APPENDIX 8

PUBLICATIONS OF THE UNITED STATES ATOMIC ENERGY COMMISSION [1]

In general, the AEC has encouraged project scientists to make their own arrangements for the publication of nonsecret research results in the established journals of scientific and technical communication. There are, however, a number of special publications concerning atomic energy which the AEC has sponsored or helped sponsor which are available to the general public.

SEMIANNUAL REPORTS TO CONGRESS

The semiannual reports which the AEC is required to make to the Congress are also made available to the public. These describe the progress in various phases of the Commission's program. An alternate title, indicating the principal subject of the report, has been given to each of the later reports. Indexes to all except this, the Eleventh Semiannual Report, are now available.

First Semiannual Report, January 1947.[2]

Second Semiannual Report, July 1947.[2]

Third Semiannual Report, January 1948.[2]

Fourth Semiannual Report, *Recent Scientific and Technical Developments in the Atomic Energy Program of the U. S.*, July 1948. 35 cents.[3]

Fifth Semiannual Report, *Atomic Energy Development, 1947–1948*, January 1949. 45 cents.[3]

Sixth Semiannual Report, *Atomic Energy and the Life Sciences*, July 1949. 45 cents.[3]

Seventh Semiannual Report, *Atomic Energy and the Physical Sciences*, January 1950. 50 cents.[3]

Eighth Semiannual Report, *Control of Radiation Hazards in the Atomic Energy Program*, July 1950. 50 cents.[3]

Ninth Semiannual Report, *AEC Contract Policy and Operations*, January 1951. 40 cents.[3]

Tenth Semiannual Report, *Major Activities in the Atomic Energy Program, January-June 1951*, July 1951. 35 cents.[3]

Index to the Semiannual Reports to Congress, January 1947–January 1951, April 1951. 20 cents.[3]

Index to the Tenth Semiannual Report to Congress, November 1951. 10 cents.[3]

GENERAL REPORTS AND GUIDES

Selected Readings on Atomic Energy, August 1951, is a bibliography of official publications, books, magazines, pamphlets and teaching units for educators, and indexes and bibliographies on atomic energy, 23 pages, 15 cents.[3]

---

[1] Listed as of December 31, 1951.
[2] No longer in print.
[3] Available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Isotopes—A 3-Year Summary of Distribution—With Bibliography of Uses, August 1949, summarizes the Oak Ridge isotopes production, distribution, and training program, with statistics on the distribution and use of isotopes by state and institution, by field of use, by foreign country, and contains an extensive bibliography of published literature on isotopes, 201 pages, 45 cents.[3]

Prospecting for Uranium, revised October 1951, is a nontechnical booklet prepared by the United States Geological Survey and AEC describing the uranium-bearing minerals, where to look for them, and instruments to use in prospecting and in laboratory testing and analysis of ores. It contains six color plates of principal minerals. Laws, regulations, and price schedules for uranium-bearing ores are included, 128 pages, 45 cents.[3]

Contracting and Purchasing Offices and Types of Commodities Purchased, revised March 1951, lists the types of items the AEC must procure, procurement officers, and location of the purchasing offices. Included are responsibilities of the AEC operations offices and major research centers for whom the materials are procured, and security requirements that must be met by firms supplying certain materials to AEC, 20 pages, 15 cents.[3]

A Guide for Contracting of Construction and Related Engineering Services, revised January 1951, gives AEC policy on awarding contracts for construction and architect-engineering services, procedures followed when requests for bids are formally advertised and when prices are fixed, and when contracts are negotiated. Operations offices and officials responsible for letting such contracts are listed, 16 pages, 15 cents.[3]

TECHNICAL PUBLICATIONS, PERIODICALS, AND CATALOGS

THE ITEMS LISTED BELOW, TOGETHER WITH THE NATIONAL NUCLEAR ENERGY SERIES DESCRIBED IN THE NEXT SECTION, ARE THE PUBLICATIONS OF SCIENTIFIC AND TECHNICAL INTEREST.

Sourcebook on Atomic Energy, Samuel Glasstone, D. Van Nostrand Co., N. Y., 1950, presents a comprehensive, technical description of the theory, history, development, and uses of atomic energy. Chapters are included on the structure of the atom, radioactivity, isotopes, neutron research, acceleration of charged particles, and other phases of nuclear science, 546 pages, $3.40.

The Effects of Atomic Weapons, 1950, prepared for the Department of Defense and the AEC by a board of editors under the direction of the Los Alamos Scientific Laboratory, presents a technical summary of the results to be expected from the detonation of atomic weapons, with chapters describing an atomic explosion, the shock from air, underwater, and underground bursts; blast, radiation, and fire effects; methods of protecting personnel; and decontamination methods, 456 pages, $1.25.[3]

Handbook on Aerosols, 1950, contains chapters from the National Defense Research Committee Summary Technical Report, Division 10, declassified by the Army at the request of AEC, on the properties and behavior of aerosols, principles and instruments used in meteorology studies, and information useful in studies of the disposal of gaseous radioactive wastes, the dispersal of insecticides, the disposal of industrial gases, etc., 147 pages, 60 cents.[3]

---

[3] Available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Liquid-Metals Handbook, R. N. Lyon, et al., (being revised) compiled by the Department of the Navy and AEC, summarizes current information on the physical and chemical properties of liquid metals, their present industrial uses, and their use and potentialities as heat-transfer media, 188 pages, $1.25.[3]

Manual of Analytical Methods for the Determination of Uranium and Thorium in Their Ores, C. J. Rodden and J. J. Tregoning, 1950, presents a number of tested methods of analyzing ore samples for their uranium and thorium content. It is intended to be an aid to assayers, commercial laboratories, and others interested in raw material assay work, 55 pages, 20 cents.[3]

Handling Radioactive Wastes in the Atomic Energy Program, revised August 1951, reports on the sources and types of radioactive wastes in atomic energy operations, methods developed for their safe handling and disposal, and methods specified for the safe handling of radioisotopes by private users, 30 pages, 15 cents.[3]

Trilinear Chart of Nuclear Species, W. H. Sullivan, John Wiley & Sons, Inc., N. Y., 1949, shows physical data for all the nuclear species known as of June 1949, $2.50.

Periodicals and Catalogues

Nuclear Science Abstracts, issued twice a month by the AEC Technical Information Service, contains abstracts of all current AEC declassified and unclassified reports, of non-AEC reports related to atomic energy, and of articles appearing in both the foreign and domestic periodical literature, $6 per year.[4]

Guide to Russian Periodical Literature, a monthly title list prepared by the Brookhaven National Laboratory of available current scientific papers and with complete translations of significant articles, 20 cents.[4]

Isotopes—Catalog and Price List, Isotopes Division, United States Atomic Energy Commission, Oak Ridge, Tenn., March 1951, lists and describes radioactive and stable isotopes available from Oak Ridge, and includes prices and instructions for ordering the isotopes.

Radiation Instrument Catalog No. 2, 1950, compiled by the Radiation Instruments Branch, AEC, lists most of the commercially available radiation instruments, accessories, and components, $2.[4]

THE NATIONAL NUCLEAR ENERGY SERIES

These volumes were written by the scientists who performed the research and development on the atomic energy enterprise under the Manhattan Engineer District and later under the Atomic Energy Commission. The following volumes have been published for the AEC by the McGraw-Hill Book Co., New York, N. Y.

Division I: The Electromagnetic Separation Process

Vacuum Equipment and Techniques, vol. 1, edited by A. Guthrie and R. K. Wakerling, 1949, describes the development and study of high vacuum equip-

[3] Available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

[4] Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

ment and high vacuum systems for the large-scale separation of isotopes by the electromagnetic process, 264 pages, $2.50.

The Characteristics of Electrical Discharges in Magnetic Fields, vol. 5, edited by A. Guthrie and R. K. Wakerling, 1949, covers most of the significant studies by the University of California Radiation Laboratory on electrical discharges, with emphasis on studies of electrical discharges in vapors of uranium compounds, 376 pages, $3.50.

Division II: Gaseous Diffusion Project

Engineering Developments in the Gaseous Diffusion Process, vol. 16, edited by M. Benedict and C. Williams, 1949, describes a number of mechanical, electrical, and chemical engineering developments related to the operation and handling of materials used in the gaseous diffusion process—principally special plant instruments, vacuum engineering, development of heat-transfer equipment, and absorption of uranium hexafluoride and fluorine, 129 pages, $1.25.

Division III: Special Separations Project

The Theory of Isotope Separation, vol. 1B, by Karl Cohen, 1951, presents the theory of cascades as generally applicable to the problems of isotope separation. Different types of centrifuges and other methods of separation are also discussed, 165 pages, $2.

Spectroscopic Properties of Uranium Compounds, vol. 2, edited by G. H. Dieke and A. B. F. Duncan, 1949, presents data compiled from a comprehensive study of the absorption and fluorescence spectra of uranium compounds and describes the experimental techniques used in the studies, 290 pages, $2.75.

Physical Properties and Analysis of Heavy Water, vol. 4A, by I. Kirschenbaum, 1951, describes the physical properties of heavy water, chemical equilibria or exchange reactions and methods for isotopic analysis, 438 pages, $5.25.

Division IV: Plutonium Project

Radiochemical Studies: The Fission Products, vol. 9, edited by C. D. Coryell and N. Sugarman, 1951, presents 336 original research papers on the techniques and results of radiochemical studies of uranium and plutonium fission products, 2,086 pages (in 3 parts), $18.50.

The Transuranium Elements, Research Papers, vol. 14B, edited by G. T. Seaborg, J. J. Katz, and W. M. Manning, 1949, includes 163 research papers on neptunium, plutonium, americium, curium, and several of the heavy elements related to them, and historical summaries of transuranium element research, 1,733 pages (in 2 parts), $15.

The Chemistry and Metallurgy of Miscellaneous Materials; Thermodynamics, vol. 19B, edited by L. L. Quill, 1949, contains 10 research papers on thermodynamic properties of the elements and several of their compounds, 329 pages, $3.

Industrial Medicine on the Plutonium Project, vol. 20, edited by R. S. Stone, 1951, describes the medical program established for the care and protection of workers on the plutonium project, 511 pages, $6.25.

Biological Effects of External Beta Radiation, vol. 22E, edited by R. E. Zirkle, offers a collection of original reports on the effects of beta rays applied to the surface of the mammalian body, 242 pages, $3.25.

Histopathology of Irradiation from External and Internal Sources, vol 22I, edited by W. Bloom, 1948, is an advanced treatise on the histopathological and cytological effects of total-body irradiation, 808 pages, $8.

Toxicology of Uranium, vol. 23, edited by A. Tannenbaum, 1950, describes the studies made on the distribution, accumulation, excretion, and chemical and physiological effects of uranium and uranium compounds in the animal body, 323 pages, $3.

Division V: Los Alamos Project

Electronics: Experimental Techniques, vol. 1, edited by W. C. Elmore and M. L. Sands, 1948, describes a number of complete circuits and circuit elements developed at Los Alamos for making nuclear and other physical measurements, 417 pages, $3.75.

Ionization Chambers and Counters: Experimental Techniques, vol. 2, edited by B. Rossi and H. Staub, 1949, describes the physical principles of ionization chambers and counters, and includes previously unpublished project developments by scientists at the Los Alamos Laboratory, 243 pages, $2.25.

Division VI: University of Rochester Project

Pharmacology and Toxicology of Uranium Compounds, parts I and II, vol. 1, edited by C. Voegtlin and H. C. Hodge, 1949, summarizes the results of 3 years' research on the toxicity of uranium compounds and the mechanism of uranium poisoning, and includes a section on the toxicology of fluorine and hydrogen fluoride, 1,084 pages (in 2 parts), $10.

Biological Studies with Polonium, Radium and Plutonium, vol. 3, edited by R. M. Fink, 1949, describes the studies made of the biological effects of these alpha-emitting elements in the animal body, air monitoring precautions, and equipment used in atomic energy laboratories where work with these elements is carried on, 411 pages, $3.75.

Division VII: Materials Procurement Project

Preparation, Properties, and Technology of Fluorine and Organic Fluoro Compounds, vol. 1, edited by C. Slesser and S. R. Schram, describes developments in the large-scale manufacture of fluorine, and purifying and handling fluorine. It describes the preparation and the chemical and physical properties of various fluorocarbon compounds, 868 pages, $10.50.

Division VIII: Manhattan Project Chemistry

Analytical Chemistry of the Manhattan Project, vol. 1, edited by C. J. Rodden, 1950, describes methods of analyzing the many different materials used in the atomic energy project—with emphasis on analytical methods for the determination of uranium and thorium, 748 pages, $6.75.

Chemistry of Uranium. Part I. The Element, Its Binary and Related Compounds, vol. 5, by J. J. Katz and E. Rabinowitch, 1951, is a detailed discussion of the physical and chemical properties of uranium, its occurrence in nature and extraction from ores, and preparation and physical properties of its binary compounds, 609 pages, $7.25.

APPENDIX 9

Patents Issued to the Commission Which Are Available for Licensing [1]

The following 71 U. S. Letters Patents owned by the U. S. Government as represented by the U. S. Atomic Energy Commission have been made available for licensing and are supplemental to the 277 listed in Appendix 9 of the Tenth Semiannual Report. Licenses are granted on a nonexclusive, royalty-free basis. Abstracts of patents available for licensing are published in the *U. S. Patent Office Official Gazette.*

PAT. NO.	TITLE	INVENTOR	RESIDENCE
2,502,074	Method and apparatus for pumping corrosive mediums.	H. S. Brown and H. H. Hubble.	Oak Ridge, Tenn.
2,506,438	Electrolytic process for production of fluorine.	G. C. Whitaker	Brookly Heights, Ohio.
2,514,909	Carrier for radioactive slugs	G. Strickland	Medford, N. Y.
2,558,919	Method for measuring radiation of neutrons.	W. H. Zinn	Chicago, Ill.
2,559,259	Method of making a source of beta rays	J. R. Raper	Lake Geneva, Wis.
2,559,345	Casting method and composition	J. S. Church H. R. Tyler	Los Alamos, N. Mex. St. Louis, Mo.
2,559,564	Pneumatic and air sweep closure	C. C. Sperling	Oak Ridge, Tenn.
2,560,166	Pulse analyzer	W. E. Glenn, Jr.	Birmingham, Ala.
2,560,167	Pulse shaping circuit	do	Berkeley, Calif.
2,561,526	Production of pure ductile vanadium from vanadium oxide.	R. K. McKechnie A. U. Seybolt	Ballston Lake, N. Y. Scotia, N. Y.
2,562,122	Preparation of uranium bromide	J. E. Powell	Ames, Iowa.
2,562,150	Electrical contact for electrolytic cells	S. G. Osborne	Niagara Falls, N. Y.
2,562,153	Vacuum distillation	T. I. Taylor	New York, N. Y.
2,562,159	Production of xylene hexafluoride	B. H. Wojcik and A. H. Maude.	Niagara Falls, N. Y.
2,562,637	Position indicating control apparatus	C. W. Park J. C. Kilpatrick	Oakland, Calif. Berkeley, Calif.
2,562,645	Electrical scaling circuit	B. Schloss and S. Robinson.	New York, N. Y.
2,563,587	Method for mitigating radioactive contamination.	J. DeMent	Portland, Oreg.
2,563,626	Ion source	F. S. Stein J. E. Binns C. R. A. Rice S. Bashkin	New York, N. Y. Upton, N. Y. Oak Ridge, Tenn. Madison, Wis.
2,563,718	Shielded container	J. F. Gifford	Richland, Wash.
2,563,729	Method and apparatus for control of boundary between electrolytic fluids.	L. G. Longworth	New York, N. Y.
2,564,024	Method of making halocarbon polymers	W. T. Miller	Ithaca, N. Y.
2,564,241	Extraction process for cerium	J. C. Warf	Los Angeles, Calif.
2,564,626	Measuring device and method of measuring.	A. M. McMahan A. H. Snell	Houston, Tex. Oak Ridge, Tenn.
2,566,052	Process for photochemical chlorination of hydrocarbons.	W. S. Beanblossom	Niagara Falls, N. Y.
2,566,066	do	A. Loverde and W. S. Beanblossom.	Do.
2,566,665	Zirconium and hafnium separation process.	E. H. Huffman and L. J. Beaufait, Jr.	N. Richmond, Calif.
2,566,684	Segmented ionization chamber	C. A. Tobias	Walnut Creek, Calif.
2,567,145	Method of preparing uranium pentafluoride.	C. J. Carignan	Cranston, R. I.
2,567,518	Preparation of beryllium nitride	A. S. Langsdorf, Jr	Chicago, Ill.
2,567,519	Pressure monitoring device	R. Livingston	Oak Ridge, Tenn.
2,567,661	Zirconium and hafnium recovery and purification process.	J. A. Ayres	Schenectady, N. Y.
2,567,668	Apparatus for the measurement of radioactivity.	J. Hecomovich	San Mateo, Calif.
2,567,759	Fluorination of high molecular compounds.	A. F. Benning	Woodstown, N. J.
2,568,061	Rotary shaft driven tapper	G. J. Evans	New York, N. Y.
2,568,642	Production of dichlorododecafluoroheptane and derivatives thereof.	K. W. Krantz	Wilmington, Del.

[1] Patents listed as of Nov. 20, 1951. Applicants for licenses should apply to the Chief, Patent Branch, Office of the General Counsel, U. S. AEC, Washington 25, D. C., identifying the subject matter by patent number and title.

PAT. NO.	TITLE	INVENTOR	RESIDENCE
2,568,660	Fluorination process	R. Rosen	Elizabeth, N. J.
2,569,225	Method of forming uranium monocarbide	J. H. Carter A. H. Daane	Blacksburg, Va. Ames, Iowa.
2,569,232	Filter	R. Deliban	Menlo Park, Calif.
2,569,644	Organic fluorine composition and method of making.	F. B. Stilmar	Woodstown, N. J.
2,569,646	Electrical simulator	E. J. Wade J. W. Simpson	Schenectady, N. Y. Wilkinsburg, Pa.
2,569,854	Drill tool	A. P. Hatcher	Knoxville, Tenn.
2,570,119	Recovery of carnotite from its ores	R. W. Handley C. W. Sawyer	Denver, Colo. Butte, Mont.
2,570,120	Process for recovery of pitchblende and similar uranium minerals from ores of same by special flotation practice.	R. W. Handley C. W. Sawyer	Denver, Colo. Butte, Mont.
2,570,435	Catalytic vapor phase fluorination apparatus.	F. B. Downing J. B. Roberts	Carney's Point, N. J. Wilmington, Del.
2,570,984	Ambient pressure responsive clamping means.	A. J. Reyenga	Oakland, Calif.
2,571,237	Adsorption separation of zirconium and hafnium.	R. S. Hansen	Ames, Iowa.
2,571,302	Sampler for highly radioactive substances.	W. Q. Smith	Charleston, W. Va.
2,571,439	System for determining tube characteristics.	F. M. Glass	Oak Ridge, Tenn.
2,571,926	Preparation of organic materials	A. Murray, III, and A. R. Ronzio.	Los Alamos, N. Mex.
2,571,965	Process for production of radioactive iron	J. A. Swartout	Oak Ridge, Tenn.
2,572,156	Process for producing uranium hexachloride.	F. A. Jenkins	Berkeley, Calif.
2,572,600	Mass spectrometer	A. J. Dempster	Chicago, Ill.
2,573,069	Method and apparatus for measuring strong alpha emitters.	E. G. Segre	Santa Fe, N. Mex.
2,573,639	Manufacture of porous articles from trifluorochloroethylene polymer.	M. A. Coler	New York, N. Y.
2,573,649	Gas analyzer	A. O. C. Nier	Minneapolis, Minn.
2,574,268	The manufacture of uranium tetrachloride.	M. D. Kamen	Berkeley, Calif.
2,574,619	Process for the preparation of fluorocarbons.	G. H. Cady	Leonia, N. J.
2,574,626	Uranium-cobalt alloys	A. H. Daane W. K. Noyce	Ames, Iowa. Fayetteville, Ark.
2,574,627	do	A. H. Daane W. K. Noyce	Ames, Iowa. Fayetteville, Ark.
2,574,632	Radiation detection and measuring apparatus and methods.	D. W. Engelkemeir N. Sugarman	Santa Fe, N. Mex. Chicago, Ill.
2,574,649	Alkyl ether of chlorofluoroheptene	E. T. McBee and W. S. Barnhart.	West Lafayette, Ind.
2,574,655	Apparatus for focusing high-energy particles.	W. K. H. Panofsky and W. R. Baker.	Alameda, Calif.
2,574,681	Materials and methods for radiography	W. H. Zinn	Chicago, Ill.
2,574,841	Timing apparatus	W. M. Powell and A. W. Hughes.	Berkeley, Calif.
2,574,842	Method and apparatus for purifying and packaging uranium hexachloride.	C. H. Prescott, Jr	Do.
2,575,759	Counter chronograph	W. A. Higinbotham	Ithaca, N. Y.
2,575,760	Preparation of heavy metal borohydrides	H. R. Hoekstra J. J. Katz	Park Forest, Ill. Chicago, Ill.
2,576,616	Monitor for fission gases	R. Livingston and H. A. Levy.	Oak Ridge, Tenn.
2,576,601	Method of accelerating ions	E. E. Hays	Upton, N. Y.
2,576,600	A device for generating neutrons	A. O. Hanson	Grand Forks, N. Dak.
2,576,661	Pulse shaping circuit	L. F. Wouters	Oakland, Calif.

APPENDIX 10

Amendment to the Atomic Energy Act of 1946 [1]

Public Law 235—82d Congress

Chapter 633—1st Session

AN ACT

To amend the Atomic Energy Act of 1946, as amended.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That section 5 (a) (3) of the Atomic Energy Act of 1946, as amended, is amended to read as follows:

"(3) Prohibition.—It shall be unlawful for any person to (A) possess or transfer any fissionable material, except as authorized by the Commission; or (B) export from or import into the United States any fissionable material; or (C) directly or indirectly engage in the production of any fissionable material outside of the United States, except, subject to the limitations and conditions contained in section 10 (a) (3), as authorized by the Commission upon a determination by the President that the common defense and security will not be adversely affected thereby."

Section 10 (a) is hereby amended by inserting the following subsection 10 (a) (3) after subsection 10 (a) (2):

"(3) Nothing contained in this section shall prohibit the Commission, when in its unanimous judgment the common defense and security would be substantially promoted and would not be endangered, subject to the limitations hereinafter set out, from entering into specific arrangements involving the communication to another nation of restricted data on refining, purification, and subsequent treatment of source materials; reactor development; production of fissionable materials; and research and development relating to the foregoing: *Provided,*

"(1) that no such arrangement shall involve the communication of restricted data on design and fabrication of atomic weapons;

"(2) that no such arrangement shall be entered into with any nation threatening the security of the United States;

"(3) that the restricted data involved shall be limited and circumscribed to the maximum degree consistent with the common defense and security objective in view, and that in the judgment of the Commission the recipient nation's security standards applicable to such data are adequate;

"(4) that the President, after securing the written recommendation of the National Security Council, has determined in writing (incorporating the National Security Council recommendation) that the arrangement would substantially promote and would not endanger the common defense and security of the United States, giving specific consideration to the security sensitivity of the restricted data involved and the adequacy and sufficiency of the security safeguards undertaken to be maintained by the recipient nation; and

"(5) that before the arrangement is consummated by the Commission the Joint Committee on Atomic Energy has been fully informed for a period of thirty days in which the Congress was in session (in computing such thirty days, there shall be excluded the days on which either House is not in session because of an adjournment of more than three days)."

Approved October 30, 1951.

---

[1] Previous amendments to the Atomic Energy Act of 1946 can be found in Appendix 10 of the Ninth Semiannual Report to Congress, January 1951.

APPENDIX 11

Executive Orders Pertaining to the U. S. Atomic Energy Commission [1]

E. O. 10291—Establishing an Airspace Reservation over the Las Vegas Project, Las Vegas, Nev.

By virtue of the authority vested in me by section 4 of the Air Commerce Act of 1926 (44 Stat. 570), the airspace above the following-described portion of the United States is hereby reserved and set apart for national defense and other governmental purposes as an airspace reservation within which no person shall navigate an aircraft except by authority of the United States Atomic Energy Commission:

All that area within the United States lying within the following-described boundaries:

LAS VEGAS PROJECT, LAS VEGAS, NEVADA

Beginning at latitude 37°16'00'', longtitude 115°56'00''; thence due south to latitude 36°41'00'', longitude 115°56'00''; thence due west to latitude 36°41'00'', longtitude 116°13'00''; thence due north to latitude 37° 16'00'', longitude 116°13'00''; thence due east to latitude 37°16'00'', longitude 115°56'00'', the point of beginning.

Any person navigating an aircraft within this airspace reservation in violation of the provisions of this order will be subject to the penalties prescribed in the Civil Aeronautics Act of 1938 (52 Stat. 973), as amended.

February 28, 1951

E. O. 10291—Establishing an Airspace Reservation Over the Savannah River Plant of the U. S. Atomic Energy Commission

By virtue of and pursuant to the authority vested in me by section 4 of the Air Commerce Act of 1926 (44 Stat. 570), the airspace above the following-described portion of the United States is hereby reserved and set apart for national defense and other governmental purposes as an airspace reservation within which no person shall navigate an aircraft except by authority of the United States Atomic Energy Commission:

All that area in the States of Georgia and South Carolina lying within the following-described boundaries:

SAVANNAH RIVER PLANT

Beginning at latitude 33°22'45'', longitude 81°24'30''; thence south to latitude 33°14'30'', longitude 81°24'00''; thence southerly to latitude 33°08'30'', longitude 81°22'36''; thence southwest to latitude 33°05'00'', longitude 81°32'00'' at Millettville; thence southwest to latitude 33°02'40'', longitude 81°42'48'' at Girard; thence northwest along the old Savannah-Augusta Highway to Telfairville at latitude 33°05'18'', longitude 81°48'48''; thence northwest to latitude 33°25'00'', longitude 81°53'30''; thence northeast to latitude 33°27'30'', longitude 81°48'55'';

[1] Previous Executive Orders pertaining to the U. S. Atomic Energy Commission can be found in Appendix 11, Fifth Semiannual Report to Congress, January 1949.

thence due east to latitude 33°27'30'', longitude 81°33'55''; thence southeast to latitude 33°22'45'', longitude 81°24'30'', the point of beginning.

Any person navigating an aircraft within this airspace reservation in violation of the provisions of this order will be subject to the penalties prescribed in the Civil Aeronautics Act of 1938 (52 Stat. 973), as amended.

This order shall become effective on October 3, 1951.

APPENDIX 12

Institutions Receiving Isotopes for Plant Science Research, Aug. 1, 1946, to June 30, 1951 [1]

This list of projects completed, currently underway, or actively contemplated in plant science research was compiled from records of the AEC's Isotopes Division, Oak Ridge, Tenn. All investigators had an opportunity to edit the material included here. When the statement of purpose of a project and its status were not returned by the investigator, the information as compiled from Oak Ridge records was retained. These projects are indicated by footnote 3. Approximately 86 percent of the statements sent out for review were returned.

Indicated by footnote 2 is the work being carried out during the 1951 growing season by institutions in 29 states, Puerto Rico, and Canada with labeled fertilizer material furnished through the AEC–USDA (Bureau of Plant Industry, Soils and Agricultural Engineering, Beltsville, Md.) contract. The work of the various states and BPISAE is coordinated through the phosphorus subcommittees of the four regional soil research committees. These groups are set up in each of the four land grant college regions and are composed of State and Federal soil research scientists. They function under the auspices of the National Soil and Fertilizer Research Committee.

STATE AND INSTITUTION	INVESTIGATOR	PROJECT AND ISOTOPE	STATUS OR REFERENCE
ALABAMA			
Alabama Polytechnic Institute, Auburn; Agronomy and Soils.	L. E. Ensminger, R. W. Pearson, H. B. Carr.	P 32. (1) Study the residual value of previously applied phosphorous on cotton. (2) Determine the relative availability of phosphorus from superphosphate and rock phosphate to crimson clover. (3) Compare the efficiency of superphosphate and mixture of superphosphate and rock phosphate in greenhouse pots.[2]	(1) Under way. (2) Under way. (3) Under way.
Southern Research Institute, Birmingham; Biochemistry.	R. K. Allison and H. E. Skipper.	C 14. Study photosynthesis with algae.	Under way.
University of Alabama, University; Biology.	B. C. Williams	P 32. Determine differential uptake of phosphorus by seedlings; develop technique for locating radioactivity within individual cells; and make histological studies of plants roots.	Do.
ARIZONA			
U. S. Department of Agriculture, Forest Service, Southwestern Forest and Range Experiment Station, Tucson; Forestry.	B. O. Blair	I 131. Determine whether or not the organic hormone 2, 4, D–5–1 moves in mesquite seedlings with reserve food to new growing points, the amount of movement to different parts when applied as a foliage spray to the leaves, and the effect of wetting agents on absorption and translocation to different parts of seedlings.	Completed.

[1] This list was selected from "Isotopes—A 5-Year Summary of Distribution," prepared by the Isotopes Division, Oak Ridge, and which includes isotope distribution for all fields of research. The 5-year report will be available in March 1952 from the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Work of the national laboratories in plant science is not included in this Appendix. Plant science research being done under AEC contract is identified in Appendix 5.

[2] Participating in AEC–USDA (BPISAE, Beltsville, Md.) project to study during the 1951 growing season, the uptake and use of various fertilizers by different crops from varying types of soils.

STATE AND INSTITUTION	INVESTIGATOR	PROJECT AND ISOTOPE	STATUS OR REFERENCE
ARIZONA—continued			
University of Arizona, Tucson; Chemistry and Soils.	W. H. Fuller and W. T. McGeorge.	P 32. Compare the phosphorus uptake from potassium hydrogen phosphate, superphosphate, calcium metaphosphate, and ammonium phosphate by cotton and alfalfa.[1]	Under way.
	W. H. Fuller	P 32. Study the nature of organic compounds in calcareous soils and determine the availability of phosphorus in various biological tissues (micropopulation and organic debris) to plants under normal soil conditions.	Do.
ARKANSAS			
Robert L. Dortch Seed Farms, Scott; Agronomy.	L. M. Humphrey	Service Irradiation. Irradiation of cottonseed and soybean seeds in order to study gene mutations in an effort to produce new breeding material for the improvement or development of new varieties.	Do.
University of Arkansas, School of Medicine, Little Rock, Biochemistry.	J. M. Siegel	C 14. Investigate carbon dioxide assimilation and synthetic reactions in photosynthetic bacteria, and analogous processes in heterotrophic bacteria.	Do.
CALIFORNIA			
California Institute of Technology, Pasadena; Biology.	J. Bonner, J. Thurlow, and F. W. Went.	C 14. Study carbon dioxide fixation in the dark by leaves of succulents and study translocation of sucrose and other compounds in plants.	Arch. Biochem., *19*, 509 (1948); *Ibid.*, *31*, 234 (1951). J. Chem. Education, *26*, 628 (1949).
	J. Bonner	P 32. (1) Study phosphate turn-over in growing plant tissue. (2) Classroom demonstration to show transport of phosphate ion in stem of green plant.	(1) J. Biol. Chem., *180*, 273 (1949). (2) Under way.
		C 14. Study protein turn-over in tissues of higher plants.	Under way.
Plant Physiology	H. M. Hull and F. W. Went.	C 14. Study translocation of labeled sucrose in tomato and sugar beet.	Do.
Shell Development Co., Emeryville; Physics.	J. W. Otvos	P 32. Measure phosphorus uptake in plants under various conditions.	Do.
Stanford University, Stanford; Chemistry.	L. Cunningham	C 14. Study metabolism of algae with reference to irreversible incorporation of isotope.	Do.
U. S. Department of Agriculture, Southwestern Irrigation Field Station, Brawley.	B. A. Krantz	P 32. Field experiments involving uptake of phosphorus by cotton, castor bean, corn, cantaloups, and tomatoes.[1]	Do.
University of California, Berkeley; Plant Biochemistry.	H. A. Barker	C 14. Study carbon dioxide utilization, fatty acid metabolism, and other metabolic processes in microorganisms and carbohydrate synthesis, transformation, and other biochemical reactions in higher plants.	Arch. Biochem., *17*, 149 (1948); *Ibid.*, *21*, 256 (1949). J. Biol. Chem., *167*, 619 (1947); *Ibid.*, *173*, 785, 803; *175*, 913 (1948); *Ibid.*, *178*, 677, 891; *180*, 1085, 1169, 1237; *181*, 221 (1949). J. Bact., *56*, 777 (1948). AM. J. Botany, *35*, 12 (1948). Arch. Biochem. Biophys., *31*, 326 (1951).
	W. Z. Hassid	C 14. (1) Synthesis of labeled sugar for tracer studies in another institution. (2) Plant nutrition studies with labeled d-glucose.	(1) Under way. (2) Under way.
	C. C. Delwiche	C 14. Study the mechanism of virus formation and the effect of radiation within the virus molecule upon properties and infectivity.	Under way.

[1] Participating in AEC-USDA (BPISAE, Beltsville, Md.) project to study during the 1951 growing season, the uptake and use of various fertilizers by different crops from varying types of soils.

STATE AND INSTITUTION	INVESTIGATOR	PROJECT AND ISOTOPE	STATUS OR REFERENCE
CALIFORNIA—continued			
University of California, Berkeley—Continued			
Plant Nutrition	C. P. Sideris	Fe 55, 59. Study distribution of iron in pineapple plants.	Under way.
	L. Jacobson	S 35. Study sulfur metabolism in plants and the mechanism of the control of plant rusts by sulfur treatment.	Nature, *165*, 973 (1950).
	T. C. Broyer, E. Epstein, L. Jacobson, C. M. Johnson, G. A. Pearson, and P. R. Stout.	Fe 55, Zn 65. Determine nutritional factors influencing uptake and distribution of iron and other inorganic elements within plant tissues and in specific organic compounds synthesized by the plant.	Soil Sci., *72*, 47 (1951). Soil. Sci. Soc. Am. Proc., *12*, 91 (1947). Science, *108*, 471 (1948). Plant Physiol., *25*, 367 (1950). Plant Soil, *3*, 51 (1951).
	J. P. Bennett	Ca 45. Study influence of a gradient in oxidation potential as a possible prerequisite for metabolic accumulation of calcium by plants.	Under way.
	D. I. Arnon	C 14. Study certain aspects of photosynthesis in green plants.	Do.
	H. A. Barker and W. Z. Hassid.	C 14. Study chemical activities of plants and bacteria.	Arch. Biochem. Biophys., *31*, 326 (1951).
Plant Pathology	C. E. Yarwood	S 35. Measure differential absorption of sulfur by parasite and host in plant diseases caused by fungi.	Nature, *165*, 973 (1950).
	A. H. Gold	C 14. Study metabolic changes in tobacco plants induced by virus infection.	Under way.
Soils	J. M. Blume, H. Jenny, L. Jacobson, J. C. Martin, and R. Overstreet.	P 32, Cs 137, Ca 45, Cb 95, Sr 90. Study absorption and metabolism by plants and fixation by soils.[3]	Do.
	R. Overstreet	Ba 140, Fe 55, 59. Study adsorption and exchange reactions in clay and soil systems.[3]	Do.
	L. Jacobson and R. Overstreet.	P 32, Cs 137. Study absorption by root sections, evaluating factors affecting rates of such absorption.[3]	Do.
Citrus Experiment Station, Riverside; Entomology.	R. C. Dickson	P 32. Study the flight pattern of labeled melon aphids in citrus orchards.	Do.
Plant Physiology	F. M. Turrell	S 35. Determine the nature of the chemical reactions set up when elemental sulfur is used for dusting citrus (lemon) trees.	Citrus Leaves, April 1949.
Plant Physiology and Entomology	F. A. Gunther, R. M. March, R. L. Metcalf, F. M. Turrell, and R. T. Wedding.	P 32. Study absorption, translocation, distribution, metabolism, and elimination in plants, insects, and mice in relation to insecticidal and mammalian toxicity.	Under way.
	F. A. Gunther, R. M. March, R. L. Metcalf, and F. M. Turrell.	C 14. Compare distribution of DDT in injected house flies of both nonresistant and highly DDT-resistant strains.	Contemplated
	L. A. Rich and R. T. Wedding.	C 14. Study translocation of labeled carbohydrates in citrus plants.	Under way.
Soils and Plant Nutrition.	E. F. Wallihan	P 32. Measure rate of phosphorus absorption by plants as affected by other ions and physical conditions.	Do.
College of Agriculture, Davis; Physics.	L. L. Skolil	D 2. Tracer studies in soils and plants	Do
		H 3. Determine rate of uptake and distribution of tritium oxide by growing plants.[3]	Contemplated.
University of Southern California, School of Medicine, Los Angeles; Biochemistry.	R. J. Winzler	O 18. Study mechanism of oxygen activation in plant and animal tissues.	Under way.

[3] Project listing not reviewed by investigator.

STATE AND INSTITUTION	INVESTIGATOR	PROJECT AND ISOTOPE	STATUS OR REFERENCE
COLORADO			
Colorado A & M College, Colorado Experiment Station, Fort Collins; Agronomy.	S. R. Olsen and W. R. Schmehl.	P 32. Study the nature and availability to plants such as alfalfa, wheat, barley, sugar beets, and potatoes of phosphorus in calcareous soils and in various fertilizer materials such as calcium metaphosphate, superphosphate, ammonium phosphate, dicalcium phosphate, and alpha tricalcium phosphate.[2]	Soil Sci., *68*, 163 (1949). Colo. Agric. Exp. Sta. Tech. Bull. 42 (1950).
	S. R. Olsen	Ca 45. Study relationships between calcium and phosphate ions in kinetic exchange reactions between solutions and mineral surfaces both in soils and in synthetic calcium phosphates.	Under way.
		P 32. Study nature and availability to plants of phosphorus in calcareous soils, and study exchange reactions of phosphorus between solutions and mineral surfaces in soils and synthetic calcium phosphates.	Completed.
U. S. Department of the Interior, Bureau of Reclamation, Denver; Research and Geology.	H. E. Hosticka	I 131. Study translocation of labeled 5 iodo-2,4-dichlorophenoxyacetic acid in aquatic weeds. Study metabolites of plants treated with 5 iodo-2,4-dichlorophenoxyacetic acid.	Under way.
CONNECTICUT			
Connecticut Agricultural Experiment Station, New Haven; Plant Pathology and Botany.	A. E. Dimond	P 32. Investigate use of ionizing radiation in control of plant diseases.	Do.
University of Connecticut, College of Pharmacy, Storrs; Pharmacy.	M. L. Adams and D. M. Skauen.	C 14. Synthesize labeled alkaloids from the plant *Colchicum autumnale*.	Do.
FLORIDA			
University of Florida, Agricultural Experiment Station, Gainesville; Animal Industry Nutrition Laboratory.	G. K. Davis	Co 60. Study the function of cobalt in ruminant metabolism.	Contemplated.
	R. W. Bledsoe and G. K. Davis.	K 42. Study utilization by greenhouse plants.	Under way.
	C. L. Comar, G. K. Davis, J. C. Driggers, H. C. Harris, and R. L. Shirley.	Ca 45. Study translocation of calcium by root and gynophore of peanut plant; investigate calcium metabolism in chickens and rats.	Science, *109*, 329 (1949). Anal. Chem., *22*, 1003 (1950).
	R. W. Bledsoe, G. K. Davis, and J. R. Neller.	P 32. Study phosphorus uptake as influenced by fumigation, cover crops, and rates of fertilizer application.[2]	Soil Sci., *64*, 379 (1947). J. Animal Sci., *10*, 335 (1951).
	C. L. Comar, G. K. Davis, R. Kulwich, R. L. Shirley, and L. Singer.	Cu 64, P 32, Mo 99. Study dietary role of copper and metabolic interrelationship of iron, cobalt, phosphorus, copper, and molybdenum in large animals, rats, and plants.	Soil Sci., *64*, 379 (1947). J. Biol. Chem., *174*, 905 (1948); *Ibid.*, *180*, 913 (1949). J. Animal Sci., *9*, 4 (1950). J. Dairy Sci., *33*, 878 (1950).
GEORGIA			
University of Georgia, Agricultural Experiment Station, Experiment; Agronomy.	R. L. Carter, W. S. Harms, L. C. Olson, and M. Stelly.	P 32. Study the uptake of phosphate fertilizers such as superphosphate, dicalcium phosphate, calcium metaphosphate, and alpha tricalcium phosphate by peanuts, corn, and alfalfa.[2]	Under way.
	R. L. Carter, L. C. Olson, and M. Stelly.	P 32. Determine effect of time of liming on the utilization of phosphorus by plants.[2]	Do.
Chemistry	W. S. Harms	Cl 36. Determine amount of various amino acids in peanut proteins.[3]	Do.

[2] Participating in AEC–USDA (BPISAE, Beltsville, Md.) project to study during the 1951 growing season, the uptake and use of various fertilizers by different crops from varying types of soils.
[3] Project listing not reviewed by investigator.

STATE AND INSTITUTION	INVESTIGATOR	PROJECT AND ISOTOPE	STATUS OR REFERENCE
HAWAII			
Hawaiian Sugar Planters Association, Honolulu; Biochemistry and Physiology.	G. O. Burr	C 14. Study the translocation in plants of labeled 2, 4-D.[3]	Under way.
		S 35, Rb 86, Na 22, Zn 65, Cl 36, K 42, Ca 45. Study the uptake, distribution, and chemical combination in sugarcane plants in culture solution.[3]	Do.
		C 14. Study rate of photosynthesis and transport in plants. Use labeled compounds produced in animal metabolism studies.[3]	Federation Proc., *8*, 217 (1949).
		Co 60. Study rate of uptake and transfer in plants and animals and effect of prolonged exposure to radiation.[3]	Science, *109*, 595 (1949).
		P 32. Measure rate of movement of phosphate in soil, rate of utilization by plants, and rate of entry into various compounds.[3]	Under way.
		Fe 55, 59. Study uptake and transport in plant roots and determine point at which iron is blocked in chlorosis.[3]	Do.
Pineapple Research Institute, Honolulu; Chemistry.	W. A. Gortner	C 14, P 32. Study mealy bug wilt of pineapple; absorption of phosphate when sprayed on pineapple leaves, and from soil as a function of soil pH and fertilizer placement; and absorption, translocation, persistence, and chemical alteration of growth regulators in the growing pineapple plant.	Do.
IDAHO			
University of Idaho, Agricultural Experiment Station, Moscow; Agricultural Chemistry.	J. V. Jordan and C. A. Simkins.	P 32. Study effect of soil moisture levels on phosphorus uptake by potatoes.	Completed.
	J. V. Jordan and G. C. Lewis.	P 32. Study availability and fixation of phosphorus when applied as a fertilizer.	Do.
Agricultural Chemistry and Agronomy.	J. V. Jordan and S. R. Olsen.	P 32. Study utilization by alfalfa of phosphorus from various sources.[2]	Colorado Tech. Bull. 42, December 1950.
School of Forestry, Forest, Wildlife, and Range Experiment Station.	W. K. Ferrell and E. E. Hubert.	P 32. Investigate movement and absorption of phosphorus in seedlings of western white pine.	Under way.
	W. K. Ferrell and E. E. Hubert.	Ca 45, P 32. Compare absorption and translocation in pole blighted and healthy western white pines.	Do.
ILLINOIS			
University of Chicago, Chicago; Biochemistry.	J. Franck and H. Gaffron.	H 2. Study mechanism of photosynthesis and photoreduction with green algae.	Do.
Institute of Radiobiology and Biophysics; Botany.	R. E. Zirkle	C 14. Study mode of growth of cellulose walls of plant cells after supplying glucose residues for the synthesis of cellulose.	Do.
	E. W. Fager, H. Gaffron, and J. L. Rosenberg.	C 14. Study of photosynthesis: early products of carbon dioxide fixation.	Do.
University of Illinois, Urbana; Agronomy.	F. C. Bauer and L. T. Kurtz.	P 32. Determine residual value of superphosphate and rock phosphate fertilizers as influenced by soil genesis and management practices in long-term field experiments.[2]	Do.
Entomology	C. K. Kearns and C. C. Roan.	P 32. Study the distribution and metabolic fate of certain derivatives of diethyl-phosphoric acid when applied as an insecticide to the American roach, *Periplaneta american*.[3]	Do.

[2] Participating in AEC-USDA (BPISAE, Beltsville, Md.) project to study during the 1951 growing season, the uptake and use of various fertilizers by different crops from varying types of soils.
[3] Project listing not reviewed by investigator.

STATE AND INSTITUTION	INVESTIGATOR	PROJECT AND ISOTOPE	STATUS OR REFERENCE
INDIANA			
Purdue University, Lafayette; *Agronomy*.	M. Fried	S 35. Determine with labeled SO_2 whether plants can use atmospheric SO_2 for the synthesis of organic sulfur compounds during growth.	Completed.
	J. E. Christian and M. Fried.	P 32. Determine the contribution of organic phosphorus to the fertility of the soil.	Do.
	A. J. Ohlrogg, W. K. Robertson, and J. White.	P 32. Study placement of fertilizers and the influence of associated fertilizers on phosphorus utilization by corn.	Do.
Horticulture	L. G. Jones	P 32. Determine effect of various methods of application of phosphatic fertilizer on the efficiency of absorption and utilization of phosphorus by field grown tomato plants.[2]	Under way.
University of Notre Dame, Notre Dame; Chemistry.	M. Burton	C 14. Investigate organic compounds found during the irradiation of water-carbon dioxide systems as well as water-hydrocarbon systems with view to estimating possible importance of radiation in the "original" photosynthesis.	Do.
IOWA			
Iowa State College, Ames; Zoology and Entomology.	H. C. Cox and J. H. Lilly.	Co 60. Study movement of insect larvae through soil.	Do.
Agricultural Experiment Station, Ames; Agronomy.	L. B. Nelson, J. T. Pesek, Jr., and G. Stanford.	P 32. Study relative effectiveness of different fertilizers for supplying phosphate to mixed planting of oats and clover.[2]	Soil Sci., *68*, 157 (1949).
	J. M. Heslep	P 32. Study relative movement of phosphorus from different fertilizer materials through soils.[2]	Under way.
	C. A. I. Goring and J. M. Heslep.	P 32. Study biological equilibrium between organic and inorganic phosphorus in soils, and diffusion rates of phosphorus in soils.	Do.
	W. V. Bartholomew.	C 14. Study decomposition rates of organic materials in soil.	Do.
Institute for Atomic Research, Ames; Botany.	S. Aronoff	C 14. Study translocation and transformation of glucose in plants and utilization of carbon dioxide in plant roots.	Science, *110*, 476 (1949). Botan. Rev., *16*, 525 (1950). Arch. Biochem., *28*, 424 (1950); *Ibid.*, *29*, 179 (1950). Chem. Rev., *47*, 175 (1950).
State University of Iowa, Iowa City; Botany.	T. C. Evans and J. R. Weber.	P 32. Determine tolerance dose for germinating tobacco seed.	Completed.
KANSAS			
Kansas State College, Manhattan; Physics and Agronomy.	R. E. Hein, R. H. McFarland, and R. V. Olson.	Fe 55. Study effect of pH, soil cations, and trace soil nutrients on the uptake and translocation of iron by sorghum plants.	Under way.
		P 32. Study availability of fertilizer phosphorus in crop-soil experiments.[2]	Do.
KENTUCKY			
University of Kentucky, Agricultural Experiment Station, Lexington; Agronomy.	W. A. Seay and M. E. Weeks.	P 32. Study effect of time of application on uptake of phosphorus by alfalfa.[2 3]	Do.
	J. G. Rodriguez and M. E. Weeks.	P 32. Study metabolism of phosphorus in 2-spotted spider mite.[3]	Do.
University of Louisville, School of Medicine, Louisville; Pharmacology.	B. J. McIntosh	C 14. Study biosynthesis of labeled morphine and other drugs by plants; study metabolism of morphine in rats.	J. Am. Pharm. Assoc. Sci. Ed., *39*, 512 (1950).

[2] Participating in AEC-USDA (BPISAE, Beltsville, Md.) project to study during the 1951 growing season, the uptake and use of various fertilizers by different crops from varying types of soils.
[3] Project listing not reviewed by investigator.

STATE AND INSTITUTION	INVESTIGATOR	PROJECT AND ISOTOPE	STATUS OR REFERENCE
LOUISIANA			
Tulane University, New Orleans; Botany.	T. T. Earle	C 14. Tracer experiments in aquatic weeds with labeled 2, 4-D.[3]	Under way.
MAINE			
University of Maine, Orono; Agronomy.	P. N. Carpenter and G. L. Terman.	P 32. Greenhouse and field experiments on the utilization of fertilizer phosphate by clover, grain crops, potatoes, and blueberries.[2]	Do.
		Ca 45, P 32. Study utilization of the element by clover grown on soil at various pH levels; and effect of pH and ammoniation on uptake of phosphorus by potatoes.	Do.
MARYLAND			
Army Chemical Corps, Camp Detrick, Frederick; Biological Laboratories.	J. B. Bateman and A. G. Norman.	Rb 86. Study absorption of plant growth regulators by leaves of plants growing under controlled environment conditions.	Completed.
	R. L. Weintraub	C 14. Study metabolism of labeled 2,4-dichlorophenoxyacetic acid in plants and micro-organisms.	Under way.
U. S. Department of Agriculture, Bureau of Plant Industry, Soils and Agricultural Engineering, Beltsville.	J. E. McMurtrey, Jr.	B 10. Compare effects of ordinary boric acid and labeled boric acid on the growth of tobacco in solution cultures.	Do.
Fruit and Nut Crops and Diseases.	T. D. Fontaine, G. W. Irving, Jr., J. W. Mitchell, W. C. Wolf, and J. W. Wood.	I 131. Apply labeled plant growth regulator hormones such as 2,4-dichloro-5-iodophenoxyacetic acid to plants to determine relative rates of transportation and absorption.	Do.
	G. W. Irving, L. W. Labaw, J. R. Magness, H. P. Traub, and J. W. Wood.	C 14. Study the entry, rate of transport, and accumulation of the radioisotope into the leaves and other organs of pineapple plants when applied as a bentonite paste.	Do.
Soils, Fertilizer, and Irrigation.	J. M. Blume, S. B. Hendricks, M. E. Jefferson, and T. Tanada.	P 32, Co 60. Investigate effect of low levels of radiation on plant roots and growth.	Soil Sci., *70*, 415 (1950).
	J. W. Borland, E. Epstein, S. B. Hendricks, M. E. Jefferson, and R. F. Reitemeier.	Ca 45, K 42, Rb 86. Study cation exchange equilibria reaction of soils involving these elements. Determine the mechanism and factors governing the release and fixation of potash in soils. Measure direct and indirect availability of soluble, exchangeable, fixed, and nonexchangeable potash to plants.	Under way.
	M. E. Jefferson, R. C. Menzel, and E. Shaw.	Zn 65. Study zinc nutrition in plants and measure its uptake from soil.	Do.
	J. W. Borland, and M. E. Jefferson.	S 35. Determine the efficacy of calcium sulfate as a source of sulfur for plant growth.	Do.
	S. B. Hendricks, P. C. Jackson, and M. E. Jefferson.	C 14. Study the decomposition of the insecticide DDT (1,1,1-trichloro-2-bis (p-chloro phenyl) ethane) in soils as controlled by various factors and its translocation in plants. Measure the translocation in plants of 2-4-D	
	J. M. Blume, L. A. Dean, S. B. Hendricks, and R. F. Reitemeier.	S 35, Ca 45. Determine rate of leaching of calcium and sulfur through columns of soil.	Do.
	J. W. Borland, M. E. Jefferson, and W. L. Hill.	P 32. Determine amount of lower valence radiophosphorus in various orthophosphates when subjected to neutron irradiation and the effect of neutron flux on the formation of this contaminant.	Soil Sci. Soc. Am. Proc., *14*, 226 (1950). Science, *111*, 492 (1950).

[2] Participating in AEC-USDA (BPISAE, Beltsville, Md.) project to study during the 1951 growing season, the uptake and use of various fertilizers by different crops from varying types of soils.
[3] Project listing not reviewed by investigator.

STATE AND INSTITUTION	INVESTIGATOR	PROJECT AND ISOTOPE	STATUS OR REFERENCE
MARYLAND—continued			
U. S. Department of Agriculture, Beltsville, Md.—Con.			
Soils Fertilizer, and Irrigation.	J. M. Blume and M. E. Jefferson.	Ca 45. Study the movement of calcium in soils, the absorption of calum from soils and solutions by plants, and the effects of such radiation on plants, plant roots, and growth.	Under way.
	M. Fried and M. E. Jefferson.	P 32. Greenhouse investigations on relative efficiency of phosphates.	Do.
	C. E. Hagen and M. E. Jefferson.	Fe 59. Study iron metabolism in plants in lime-induced chlorosis.	Do.
	J. W. Borland and M. E. Jefferson.	P 32. Study analytical separation of phosphorus acid from ortho-, pyro-, and metaphosphoric acids.	Do.
	J. W. Borland, L. A. Dean, S. B. Hendricks, M. E. Jefferson, and R. A. Nelson.	P 32. Study the uptake and utilization of various phosphate fertilizers on many different types of soils and crops in 29 States, Puerto Rico, and Canada.[4]	Plant Food Journal, April, May, June, 1948. Proc. Soil Sci. Soc., *12*, 91 (1947). Anal. Chem., *20*, 559 (1948); *Ibid.*, *21*, 1059 (1949); *Ibid.*, *22*, 489 (1950). Ind. Eng. Chem., *41*, 1328 (1949). Soil Science, *68*, 113 (1949).
MASSACHUSETTS			
Boston Museum of Science, Boston; Education.	B. Washburn	P 32. Demonstration of absorption of phosphates by plants.[3]	Contemplated.
Harvard University, Cambridge; Biology.	J. H. Welsh	Ca 45. Investigate the physiology of cell membranes in invertebrates.	Underway.
	K. V. Thimann	C 14. Determine if sucrose is converted to anthocyanin in aquatic plants.	Do.
MICHIGAN			
Michigan State College, East Lansing; Agricultural Chemistry.	R. L. Shirley	P 32. Determine rate of phosphate removal from aqueous solution of approximately 20 types of Michigan soil.	Do.
Botany	F. L. Wynd	P 32. Prepare radioactive tobacco mosaic virus.[3]	Do.
Horticulture	S. H. Wittwer and L. F. Wolterink.	P 32, K 42, Ca 45. Check phosphate uptake and translocation in plants.	Do.
	H. B. Tukey and L. F. Wolterink.	C 14. Check carbon dioxide assimilation in plants.	Do.
	S. H. Wittwer	P 32, K 42, Ca 45, C 14. Study absorption and utilization of radionuclides applied to leaves of plants.	Do.
		C 14. Study path of carbon into developing embryo of *Prunus*.	Do.
Soil Science	B. Kawin and K. Lawton.	P 32. Study availability and utilization of several phosphatic fertilizers to different crops grown on a number of Michigan soils.[2]	Do.
	A. E. Erickson and J. J. Seigel.	Cl 36, Br 82. Study movement of labeled dichloropropene and labeled ethylene dibromide in soil.	Completed.
University of Michigan, Ann Arbor; Botany.	H. J. Gomberg and F. G. Gustafson.	I 131. Study penetration and course of distribution of 2-4-D in plants.	Underway.
	H. H. Bartlett	Service Irradiation. Study production of aberration and mutation in seeds subjected to neutron bombardment.	Do.
	H. J. Gomberg, R. J. Lowry, and R. C. Williams.	P 32. Study possibility of genetic interchange of radiophosphorus by crossing plants grown in a medium containing radiophosphorus with pollen from normal plants.	Do.

[2] Participating in AEC-USDA (BPISAE, Beltsville, Md.) project to study during the 1951 growing season, the uptake and use of various fertilizers by different crops from varying types of soils.
[3] Project listing not reviewed by investigator.
[4] These projects are indicated by footnote 2.

STATE AND INSTITUTION	INVESTIGATOR	PROJECT AND ISOTOPE	STATUS OR REFERENCE
MINNESOTA			
University of Minnesota, Minneapolis; Botany.	A. H. Brown and A. W. Frenkel.	H 2. Study the mechanism of photosynthesis, photoreduction, and oxyhydrogen reactions in green algae.	Underway.
	A. H. Brown	C 14. Study biochemical intermediates in photosynthesis and related processes. Study of photosynthetic discrimination between isotopic forms of carbon dioxide.	Do.
University of Minnesota, St. Paul; Agriculture.	F. Smith	C 14. Study the paper partition chromatography of carbohydrates.	Do.
University of Minnesota, St. Paul; Soils and Agricultural Engineering.	A. C. Caldwell, A. Hustrulid, and J. M. MacGregor.	P 32. Study effect and relative value of double superphosphate and fused tricalcium phosphate on spring application of alfalfa.[2]	Do.
MISSISSIPPI			
Mississippi State College, State Experiment Station, State College; Agronomy.	W. B. Andrews, H. V. Jordon, and U. S. Jones.	P 32. Study availability of phosphorus to cotton using varying degrees of ammoniated superphosphate on different soils.	Do.
	B. F. Barrentine, H. V. Jordon, U. S. Jones, and L. N. Wise.	P 32. Study root extension by corn in experimental plots with varied history of cropping, and effect of top dressing versus subsurface placement on phosphorus utilization by crimson clover and permanent pastures.[2]	Do.
MISSOURI			
University of Missouri, Columbia; Botany and Zoology.	J. Levitt and D. Mazia.[5]	Ca 45. Determine the path, rate of entry, and movement of calcium in plants and the mechanism of such movement. Trace steps in mechanism of transfer of cations from environment to the cell interior.	Do.
		P 32. Determine path, rate of entry, and movement of phosphorus in plants and the mechanism of such movement.	Science, *112*, 297 (1950).
Washington University Medical School, Mallinckrodt Institute of Radiology; St. Louis; Chemistry.	M. D. Kamen	C 14. Preparation of dicarboxylic acids to study their photoassimilation by photosynthetic bacteria. Study carbon dioxide assimilation in photosynthetic and chemosynthetic organisms. Study enzyme synthesis in cells under normal and abnormal substrate conditions.	J. Biol. Chem., *176*, 299 (1948); *Ibid.*, *182*, 153 (1950). Science, *109*, 558 (1949); *Ibid.*, *113*, 302 (1950). J. Bact., *58*, 239 (1949); *Ibid.*, *59*, 693; *60*, 595 (1950); *Ibid.*, *61*, 215 (1951). Federation Proc., *9*, 543 (1950); *Ibid.*, *10*, 190 (1951).
MONTANA			
Montana State College, Agricultural Experiment Station, Bozeman; Agronomy and Soils.	J. C. Hide, A. J. M. Johnson, and W. E. Larson.	P 32. Determine the relative availability to plants of the native phosphorus on a number of soil types.[2]	Under way.
NEBRASKA			
University of Nebraska, Lincoln; Agronomy and Chemistry.	W. E. Militzer, R. A. Olson, and L. B. Nelson	P 32. Measure the uptake of fertilizer phosphorus by oats grown on Nebraska soils.[2 3]	Do.
NEW HAMPSHIRE			
University of New Hampshire, Durham; Horticulture.	R. Eggert and A. F. Yeager.	P 32. Determine if labeled phosphates absorbed into roots and translocated to their reproductive structures will produce mutations.	Do.
	R. Eggert, L. T. Kardos, and R. D. Smith.	P 32. Compare relative absorption of phosphorus by apple trees and fruits from foliar sprays and from soil applications of fertilizer.[2]	Do.

[2] Participating in AEC-USDA (BPISAE, Beltsville, Md.) project to study during the 1951 growing season, the uptake and use of various fertilizers by different crops from varying types of soils.
[3] Project listing not reviewed by investigator.
[5] Present address—University of California.

STATE AND INSTITUTION	INVESTIGATOR	PROJECT AND ISOTOPE	STATUS OR REFERENCE
NEW JERSEY			
Rockefeller Institute for Medical Research, Princeton; Plant and Animal Pathology.	C. A. Knight	S 35. Incorporated into nutrient media used to feed plants infected with cucumber virus 4 in an attempt to isolate an unknown sulfur constituent of the virus with properties unlike any of the known sulfur containing amino acids.	J Am. Chem. Soc. *71*, 3108 (1949).
Rutgers University New Brunswick; Engineering Research.	R. K. Bernhard	Co 60. Determination of soil density	Am. Soc. Testing Materials, Proc., *50*, 1337 (1950).
	O. W. Davidson	P 32. Determine rate of absorption and distribution of nutrients from liquid fertilizers applied to roots of ornamental plants.	Under way.
Soils	S. J. Toth	Cl 36, Ca 45, Mn 54, Co 60, Zn 65. Determine soil factors affecting the availability of the element to plants. Study distribution, translocation and accumulation of the element in selected plant species.	Do.
NEW YORK			
Brooklyn College, Brooklyn; Biology and Chemistry.	H. G. Albaum	P 32. Study phosphorus turn-over in adenine nucleotides during growth of plant tissues.	Do.
Cornell University, Ithaca; Agronomy.	C. D. McAuliffe	P 32. Determine quantity of phosphorus fixation in soil.	Completed.
	D. J. Lathwell and C. S. Brandt.	P 32. (1) Obtain yield and chemical data on meadow and pasture herbage top dressed with different rates of superphosphate. (2) Determine contribution of different organic phosphorus fractions in the soil to the phosphorus nutrition of plants and if phytin is synthesized and subsequently decomposed by soil micro-organisms.[2]	(1) Completed. (2) Under way.
	A. S. Hunter and C. D. McAuliffe.	Ca 45. Study the absorption of calcium by alfalfa and other legumes as influenced by soil reaction, amount of exchangeable calcium, degree of calcium saturation, presence of Mn, Fe and Al, and method of application.	Completed.
	M. Peech	P 32. Study utilization by plants of phosphorus in farm manures.	Soil Sci., *68*, 179, 185 (1949). Anal. Chem., *21*, 1059 (1949).
Botany	O. F. Curtis and G. H. Ellis.	C 14, P 32. Study translocation of sugars and certain minerals in plants.[3]	Under way.
	J. R. Johnson and L. Knudson.	C 14. Determine mechanism whereby the natural rubber plant produces rubber and study fixation of nitrogen by leguminous plants.[3]	Do.
	D. G. Clark	P 32. Demonstrate use of tracer technique in studying salt transport in plants.[3]	Do.
	L. Knudson	P 32. Measure rate of movement of salts and identify phosphate esters in *Cryptostegia*.[3]	Do.
	C. S. Brandt	Co 60. Study factors influencing uptake of cobalt by plants.[3]	Do.
Plant, Soil and Nutrition.	do	Fe 59. In vitro study of the uptake of iron by blood erythrocytes and study uptake by plants.	Completed.
Pomology	do	C 14. Study mode of entry and translocation of urea in foliage sprays.	Under way.
Fordham University, New York; Chemistry.	M. Cefola	C 14. Determine pathways of carbohydrate metabolism in certain fungi with special reference to the liberation of acetate in fat formation.	Do.
New York State Agricultural Experiment Station, Cornell University, Ithaca; Food Science and Technology.	R. W. Holley	C 14. Study absorption, distribution, and modification in the plant of 2, 4-dichloro-phenoxyacetic acid, 3-indoleacetic acid and other labeled hormone-like substances.	Arch. Biochem., *27*, 143 (1950).

[2] Participating in AEC-USDA (BPISAE, Beltsville, Md.) project to study during the 1951 growing season, the uptake and use of various fertilizers by different crops from varying types of soils.
[3] Project listing not reviewed by investigator.

STATE AND INSTITUTION	INVESTIGATOR	PROJECT AND ISOTOPE	STATUS OR REFERENCE
NEW YORK—continued			
Rockefeller Institute for Medical Research, New York; Physical Chemistry.	S. Granick	C 14. Studies on precursors in the synthesis of green and yellow pigments of chlorella.	Contemplated.
University of Rochester, Rochester; Botany.	F. C. Steward	Cs 137. Study salt absorption by growing plant tissue cultures.	Under way.
		C 14. Study carbon dioxide fixation by growing plant tissue cultures.	Do.
NORTH CAROLINA			
North Carolina State College of Agriculture and Engineering, Raleigh; Agronomy.	N. S. Hall	P 32. (1) Study phosphate adsorption on surface of soil particle as related to time-rate equilibrium; form of phosphate in relation to particle surfaces and to availability to growing plants. (2) Study effect of fertilizer placement, rate, and soil type on utilization of applied phosphate to ladino clover, potatoes, cotton, corn, and tobacco. (3) Study efficiency of fertilization of fall seeded crops and for comparison of fused rock phosphate with other forms of phosphate fertilizer. (4) Determine location and activity of corn, cotton, and tobacco plant roots throughout their growing season. (5) Evaluate sources of phosphorus for tobacco plant utilization. (6) Study migration of tobacco horn worm moth. (7) Investigate role of aphids in the transfer of materials in the tobacco plant.	(1) Soil Sci., *68*, 113, 151 (1949). (2) Soil Sci., *68*, 123, 137, 171, (1949). Proc. Am. Soc. Hort. Sci., *55*, 27 (1950). (3) Completed. (4) Under way. (5) Completed. (6) Under way. (7) Under way.
		Ca 45, P 32. Use in field studies to determine fraction of tobacco plant calcium originating from each of three sources of calcium (monocalcium phosphate, gypsum, and calcium carbonate) in a typical tobacco fertilizer; distribution within the plant and during several stages of growth; and compare the utilization of calcium and phosphorus from monocalcium phosphate.[2]	Under way.
	N. S. Hall and O. R. Lunt.	Ca 45, K 42, P 32. Determine influence of sodium on uptake and distribution of potassium, phosphorus, and calcium over short time intervals.	Completed.
	N. S. Hall and D. Satchell.	Fe 55, 59. Study rate of interaction and movement of iron associated with various soil compounds, particularly phosphate and oxide combinations.	Do.
	N. S. Hall and P. Reid.	Ca 45. Determine effect of associated anion on dissociation from an absorbed surface (clays) and on calcium movement through isotopic exchange mechanisms.	Under way.
Botany	D. B. Anderson and W. M. Duggar, Jr.	S 35. Develop new technique in radioautographic work for plant tissues.	Completed.
	D. B. Anderson, W. M. Duggar, Jr., and N. S. Hall.	C 14. Study permeability to carbon dioxide of certain cutinized epidermal membranes of leaves and fruits of several plants; make similar studies with uncutinized epidermal walls of roots.	Do.
	D. B. Anderson and D. E. Moreland.	P 32, S 35, Ca 45. Study absorption of phosphorus, calcium, and sulfur through root tips of conifers and hardwood trees.	J. Elisha Mitchell Sci. Soc., *66*, 175 (1950).
NORTH DAKOTA			
North Dakota Agricultural College, Fargo; Physics and Soils.	E. B. Norum and D. Q. Posin.	P 32. Study uptake of labeled phosphorus by various plants as a function of amount and distribution of fertilizer, and determine amount of available phosphate in the soil.[2]	Under way.

[2]Participating in AEC-USDA (BPISAE, Beltsville, Md.) project to study during the 1951 growing season, the uptake and use of various fertilizers by different crops from varying types of soils.

STATE AND INSTITUTION	INVESTIGATOR	PROJECT AND ISOTOPE	STATUS OR REFERENCE
NORTH DAKOTA—con.			
U. S. Department of Agriculture, Bureau of Plant Industry, Soils and Agricultural Engineering, Northern Great Plains Field Station, Mandan; Soil Management and Irrigation.	D. Grunes, H. R. Haise, and R. H. Yamaga.	P 32. Compare phosphorus uptake from soils at Red Field Development Farm, South Dakota; Bowbells and Mandan Development Farms for sugar beets; determine relative phosphate availability of various soils of North Dakota.[2]	Under way.
OHIO			
Antioch College, Charles F. Kettering Foundation, Yellow Springs; Physics.	H. V. Knorr and P. Rothemund.	C 14, Fe 55, 59. Study chlorophyll and related compounds in plants.	Do.
Ohio Agricultural Experiment Station, Wooster; Agronomy.	J. D. Sayre and P. J. Zwerman.	P 32, Cl 36, As 76, Zn 65. Study movement, accumulation, utilization, and distribution of these elements in growing corn plant; distribution and movements in relation to corn rust and bacterial leaf blight; feeding habits of insects on corn leaves.	Do.
	J. D. Sayre	P 32. (1) Study possible genetic changes from beta irradiation; distribution of phosphorus in wheat grains; phosphorus requirements of fungi causing plant diseases; corn root distribution through soils; phosphorus accumulation in corn plants; possible mutations in corn from large amounts of radioactive phosphorus introduced into pollen grains and seeds; feeding habits of red mites on corn leaves. (2) Study phosphorus requirements of leaf blight, effect of radiations on mutations of fungi, and accumulation of phosphorus in spores.	(1) Under way; (2) Under way.
		Ca 45. Study calcium relations in base exchange soil cultures.	Under way.
		S 35, Ca 45, Se 75, Co 60, Ag 110, Ni 63, Tl 204, Cs 134, Cr 51, Fe 59, Hg 203, Sb 124, W 185, Ir 192, Sc 46, Ta 182. Study movement, distribution, and accumulation in corn leaves.	Do.
Ohio Agricultural Experiment Station, Wooster; Agronomy.	H. V. Eck, C. E. Evans, and J. D. Sayre.	P 32. Study utilization of superphosphate and calcium metaphosphate by corn on plots of pH levels from 5.5 to 7.5.	Completed.
Agronomy, Botany, Entomology, and Dairying.	R. S. Davidson, J. W. Hibbs, W. D. Pounden, and J. D. Sayre.	P 32. Study phosphorus requirement of organism causing leaf blight in corn plants; calcium phosphorus relations in blood of dairy cattle having milk fever; transfer of phosphorus from bean plants to red mites.	Ohio State Univ. Studies, Eng. Exptl. Sta. Bulletin, *20*, 54 (1948).
Botany and Plant Pathology.	R. S. Davidson	P 32, S 35. Study genetics and physiology of micro-organisms when grown in presence of various radioisotopes.[3]	Under way.
Entomology	R. W. Rings	P 32, Sr 89. Activate the plum curculio. Trace movements of beetles within orchards and locate specific sites of hibernation.	Do.
Ohio State University, Columbus; Agricultural Biochemistry.	J. E. Varner	C 14. Study mechanism of metabolism and photosynthesis of a succulent-type plant.	Arch. Biochem., *25*, 280 (1950).
The B. F. Goodrich Co., Akron and Brecksville; Physical Research.	W. L. Davidson	Zn 65. Study utilization of zinc in metabolism of growing plants.	Under way.
OKLAHOMA			
Oklahoma Agricultural and Mechanical College Research Foundation, Stillwater; Botany.	R. M. Chatters	K 42, P 32, Cl 36, S 35. Trace ions in plant tissues by radioautographic techniques.	Do.
University of Oklahoma Research Institute, Norman; Plant Sciences.	E. L. Rice and L. M. Rohrbaugh.	C 14. Determine rate of movement of 2, 4-D applied to plants under conditions of light and darkness.	Do.

[2] Participating in AEC-USDA (BPISAE, Beltsville, Md.) project to study during the 1951 growing season, the uptake and use of various fertilizers by different crops from varying types of soils.
[3] Project listing not reviewed by investigator.

STATE AND INSTITUTION	INVESTIGATOR	PROJECT AND ISOTOPE	STATUS OR REFERENCE
OREGON			
Oregon State College, Corvallis; Agricultural Chemistry.	J. S. Butts, and A. V. Logan.	C 14. Investigate the mode of action of labeled 2, 4-dichlorophenoxyacetic acid and isopropylphenylcarbamate in plants.	Arch. Biochem. Biophys., *32*, 249 (1951).
	J. S. Butts	P 32 (1) Study the course of phosphorus in plants. (2) Determine radiophosphorus uptake by plants after treatment with 2,4-dichlorophenoxyacetic acid.	(1) Under way; (2) Under way.
		C 14. Study the breakdown products of DDT when applied to insects.	J. Econ. Entomol., *44*, 397 (1951).
Botany and Plant Pathology.	R. O. Belkengren	C 14. Study effect of the virus of Little Cherry disease on the physiology of the diseased plant.	Underway.
Soils	A. S. Hunter	P 32. Determine the effect of nitrogen levels and irrigation on the uptake of fertilizer phosphate by sugar beet plants.	Completed.
PENNSYLVANIA			
Atlantic Refining Co., Philadelphia; Research and Development.	F. W. Melpolder	P 32. Study effect of certain chemicals on the propagation of phosphate through soil and increase in availability of phosphate in plant life.	Underway.
PUERTO RICO			
Insular Experiment Station, Rio Piedras; Soils.	A. R. Riera	P 32. Determine what part of the phosphorus fertilizer added to the soil is taken up by the sugarcane plant and what part is fixed by the soil.[2 3]	Do.
SOUTH CAROLINA			
Clemson Agricultural College, Clemson; Agronomy.	W. R. Paden	P 32. Evaluate phosphorus utilization by plants.[2]	Do.
	R. W. Pearson and E. H. Stewart.	P 32. Study effect of rate of lime application and method of phosphate application on phosphorus utilization by clover.	Do.
SOUTH DAKOTA			
South Dakota Agricultural Experiment Station, Brookings; Agronomy.	L. O. Fine	P 32. Study the uptake of phosphorus from three soils in the State of South Dakota by oat and sugar beet plants.[2]	Do.
Chemistry	E. I. Whitehead	Se 75. Study the metabolic reactions and pathways of selenium in plants.	Do.
TENNESSEE			
University of Tennessee, Knoxville; Botany.	S. L. Meyer	H 2. Study the effects of various concentrations of deuterium oxide on the germination of radish, tobacco, vetch, and clover.	J. Tenn. Acad. Sci., *25*, 171 (1950).
Agricultural Experiment Station, Knoxville; Agricultural Chemistry.	W. H. MacIntire	P 32. Trace phosphorus from mono-, di-, and tri- calcium phosphates in growing plants in Neubauer and greenhouse cultures.[3]	Under way.
Agricultural Research Program, Oak Ridge; Metabolic Research.	C. L. Comar	Fe 55, Ca 45, P 32, I 131, S 35, Co 60, Zn 65, Mo 99, Ta 182, Sr 89, Cs 131, Cu 64. Study mineral metabolism in animals such as rats, rabbits, chickens, swine, and cattle, and in soil and plants.	Nucleonics, *8*, No. 3, 19 (1951); *Ibid.*, *9*, No. 1, 13; No. 2, 38 (1951). Science, *113*, 328 (1951). J. Animal Sci., *10*, 88 (1951).
TEXAS			
Texas Agricultural Experiment Station, College Station; Agronomy.	H. E. Leap and R. W. Pearson.	P 32. Study effects of ordinary phosphorus and labeled phosphorus, alone and in combination with nitrogen and potassium, on yields, chemical composition of forage and uptake of oats and Dixie Crimson Clover in pure and mixed stand.[2 3]	Under way.
	H. E. Leap	P 32. Determine effects of amounts and placement of phosphate on efficiency of utilization of fertilizer phosphorus by cotton.[2 3]	Do.

[2] Participating in AEC-USDA (BPISAE, Beltsville, Md.) project to study during the 1951 growing season, the uptake and use of various fertilizers by different crops from varying types of soils.

[3] Project listing not reviewed by investigator.

STATE AND INSTITUTION	INVESTIGATOR	PROJECT AND ISOTOPE	STATUS OR REFERENCE
TEXAS—continued			
Texas Research Foundation, Renner; Radiochemistry.	R. J. Speer and S. E. Allen.	P 32. Study exchange reactions of commercial phosphate fertilizers in Rendzina soils, Houston clay, and Susquehanna sandy loam; and evaluate various phosphatic fertilizers in terms of availability.[2]	Under way.
		Zn 65. Investigate fate of zinc nutrient when added to Houston black clay.	Do.
University of Texas Austin; Botany.	G. S. Rabideau	P 32. (1) Study phosphorus uptake in bean roots and phosphorus transport and metabolism by the plant. (2) Investigate distribution of phosphorus in inbred and hybrid lines of corn.	(1) Bull. Torrey Botan. Club, *77*, 382 (1950). (2) Am. J. Botany, *37*, 100 (1950). Botan. Gaz., *112*, 214 (1950).
		C 14. (1) Study rate of deposition in cellulose fraction of apical cell of the bean plant and investigate the intermediary products of photosynthesis. (2) Determine role of nicotinic acid in metabolic changes accompanying growth of isolated root tissue. (3) Study sugar relationships in the root and shoot apices of corn.	(1) Under way. (2) Contemplated. (3) Under way.
UTAH			
American Smelting and Refining Co., Salt Lake City; Agricultural Research.	R. H. Hendricks and M. D. Thomas.	S 35. Study sulfur nutrition of plants[3]	Soil Sci., *70*, 19 (1950).
		As 76. Study absorption of arsenite and arsenate through the roots of plants.[3]	Under way.
University of Utah, Salt Lake City; Chemistry and Biology.	J. D. Spikes	S 35. Follow the path of sulfur metabolism in photosynthetic bacteria.	Do.
		C 14. Study carbon fixation by cell-free preparations of plants.	Do.
Zoology	R. C. Pendleton	P 32. Study of root distribution and competition and study aquatic food chains and predation relationships.	Do.
Utah State Agricultural College, Logan; Agronomy.	J. L. Haddock, R. Perry, and D. W. Thorne.	P 32. Compare value of different forms of phosphate fertilizers on alfalfa; determine influence of irrigation practice on phosphate uptake from superphosphate fertilizer by sugar beets.[2]	Do.
	D. W. Thorne and F. B. Wann.	Fe 55, 59. Follow movement of iron through plants and determine effect of other elements, plant characteristics and environmental conditions on iron metabolism under conditions conducive to chlorosis.	Do.
	D. W. Thorne	Zn 65, 69. Study effect of phosphate availability on absorption, translocation, and assimilation of zinc by plants.	Do.
VIRGINIA			
Virginia Agricultural Experiment Station, Blacksburg; Agronomy.	W. W. Moschler, S. S. Obenshain, and C. I. Rich.	P 32. Study influence of phosphate placement on root penetration; effect of ammoniation of superphosphate on its availability to corn, wheat, and oats; absorption of phosphorus by alfalfa from surface applications of superphosphate, efficiency of rock phosphate in reducing need for superphosphate by crops; methods of applying superphosphate to pastures; and influence of granulation of superphosphate on uptake.[2]	Do.

[2] Participating in AEC-USDA (BPISAE, Beltsville, Md.) project to study during the 1951 growing season, the uptake and use of various fertilizers by different crops from varying types of soils.
[3] Project listing not reviewed by investigator.

STATE AND INSTITUTION	INVESTIGATOR	PROJECT AND ISOTOPE	STATUS OR REFERENCE
WASHINGTON			
General Electric Co. Hanford Works, Richland; Biology.	J. H. Rediske	Y 91. Study absorption and translocation of yttrium by plants.	Under way.
State College of Washington, Pullman; Botany.	O. Biddulph	Ca 45, Ba 140, Sr 89, Ru 106, S 35, P 32, Zn 65. Study absorption, translocation, and disposition of various elements in plants.	Do.
		H 3. Determine whether radiophosphorus and water move together in the phloem of plants or whether minerals diffuse on cytoplasmic surfaces independent of water.	Do.
		P 32, Fe 55, 59. Study interrelationship between iron and phosphorus in induction and cure of chlorosis in plants.	Proc. Auburn Comf., p. 90 (1947).
	O. Biddulph and N. Higinbotham.	Rb 86. Measure rate of absorption of rubidium by excised potato tuber tissue, rate of movement through tissue under different conditions; and study effects of intermediary metabolites and sucrose on translocation in plants.	Under way.
Botany and Biochemistry.	O. Biddulph and C. M. Stevens.	S 35. Study sulfur metabolism on penicillin-producing molds, and study translocation of sulfur in plants.	Do.
Soils	C. O. Stanberry	P 32. Determine uptake of phosphorus from labeled phosphate fertilizers by field beans and alfalfa as influenced by phosphorus carrier, placement of fertilizer, and moisture level.[2]	Do.
WISCONSIN			
U. S. Department of Agriculture Forest Service, Madison; Research.	R. C. Weatherwax	Na 22. Determine if sodium hydroxide is absorbed on, or chemically combined with the active hydroxyls of cellulose.	Do.
University of Wisconsin, Madison; Botany.	F. Skoog	C 14. Study sensitivity of plant tissues to plant growth regulators.	Do.
Plant Pathology	R. H. Burris and A. J. Riker.	I 131, Rb 86, Ag 110. Study the possibility of root grafts providing a pathway for oak wilt infection from tree to tree and trace metabolic processes in plants.	Do.
Soils	M. L. Jackson and A. W. Peterson.	P 32. Study utilization by oats of superphosphate, calcium metaphosphate, dicalcium phosphate, and alpha tricalcium phosphate; effect of superphosphate placement on utilization by corn.[2]	Do.
	M. L. Jackson, P. Mikola, G. K. Voigt, and S. A. Wilde.	P 32. Study influence of micorrhizal association on uptake of phosphorus by conifer seedlings.[2]	Do.

[2] Participating in AEC-USDA (BPISAE, Beltsville, Md.) project to study during the 1951 growing season, the uptake and use of various fertilizers by different crops from varying types of soils.

O