UNITED STATES ATOMIC ENERGY COMMISSION

PROGRESS IN PEACEFUL USES OF ATOMIC ENERGY

July–December 1957

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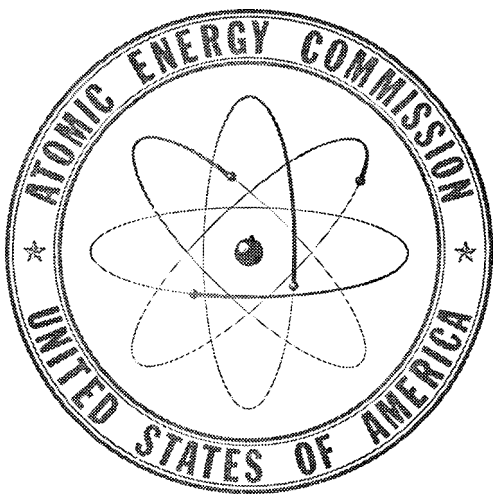

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FOREWORD

Rapid progress was made during the July–December reporting period of 1957 in development of nuclear reactors to produce electric power, and in international cooperation.

The Commission, during this 6 months, brought to completion the first full-scale power reactor, the 60,000-kilowatt Pressurized Water Reactor at Shippingport, Pa., and two other experimental power reactors: the Organic Moderated Reactor Experiment, and the Homogeneous Reactor Experiment No. 2. The Sodium Reactor Experiment was brought to full power in this reporting period. The Experimental Boiling Water Reactor had been operating successfully and supplying electricity to Argonne National Laboratory.

In the international field, besides continuing expansion of bilateral relationships between this country and single nations, the United States joined with 58 other nations in establishing the International Atomic Energy Agency, proposed by the President in December 1953.

These gains, the Nation's other atomic achievements for peaceful purposes since 1954, and the Commission's contributions to those gains, are described in a special section, incorporated in this report, entitled "Progress in the Peaceful Uses of Atomic Energy—A 3-Year Summary." In addition to Chapter I, which chronicles the actions and gains for 1957 and preceding years, Chapter II describes Progress With Radioisotopes; Chapter III, Progress With Power Reactors; Chapter IV, Growth of the Atomic Energy Industry; Chapter V, Progress in International Cooperation; and Chapter VI, Progress With Physical Research.

Equally important gains have been made in production of special nuclear materials, which equaled or exceeded established goals for 1957, and in nuclear weapons. The test series started last spring at the Nevada Test Site was concluded. It incorporated a number of unique features, including detonations of devices suspended from balloons and one in a winding tunnel beneath a mesa; fallout from weapons was consequently reduced. Safety tests and civil effects tests were conducted. The Commission announced that it had projects underway to develop peaceful uses for nuclear explosives.

The Commission describes the precautions taken to safeguard the public against adverse effects of weapons detonations, and gives the list of maximum exposures in various localities—all below the operational guides established in advance. The studies on fallout were expanded; current data on accumulated levels in the United States are given.

Standards of long-time radiation exposure were revised in accordance with recommendations of the National Committee on Radiation Protection and Measurement.

The operation of military reactors went forward during the reporting period, and design and construction of other facilities was underway. The Army Package Power Reactor, completed in April, was nearing the end of a second test run after 8 months of successful operation. The nuclear submarines USS *Nautilus* and USS *Seawolf* cruised thousands of miles, of which half or more were while fully submerged; the USS *Skate* successfully completed sea trials. With 16 additional nuclear submarines, an aircraft carrier, and a guided missile cruiser, authorized through the fiscal year ending June 30, 1958, the Commission had three land-based naval prototype reactor plants under construction.

Administrative arrangements between the U. S. Air Force and the Commission for the aircraft reactor program were further consolidated to streamline efforts in this field.

The President dedicated the Commission's new headquarters at Germantown, Md., and the Commission moved Washington staff there during January. In community operations, sale of residential and commercial properties continued.

Construction activities centered on reactor work during the 6-month period—total construction costs incurred were about $150 million—and total capital investment in atomic energy facilities was estimated, as of December 31, at $7.06 billion. Appendix 14 gives the Commission's financial report for the fiscal year ended June 30, 1957.

John F. Floberg was sworn in as Atomic Energy Commissioner on October 1 to serve until June 30, 1962, and John S. Graham was sworn in as Atomic Energy Commissioner on September 12 to serve until June 30, 1959.

David F. Shaw resigned as Assistant General Manager for Manufacturing, and T. H. Johnson resigned as Director, Division of Research.

The Fermi Award of 1957 was presented to Ernest O. Lawrence, Director, University of California Radiation Laboratory, "For his invention and development of the cyclotron and for his many other contributions in nuclear physics and atomic energy."

The Division of Civilian Applications was abolished and its functions were reassigned to a new Division of Licensing and Regulation with Harold L. Price as Director, and to an Office of Industrial Development with Frank K. Pittman as Director.

Part One

Progress in the Peaceful Uses of Atomic Energy—A 3-Year Summary

I

THREE YEARS OF PROGRESS

Since 1953, and especially since passage of the Atomic Energy Act of August 30, 1954, the United States has advanced steadily in the development of the various applications of nuclear sciences and technologies for the benefit and progress of mankind.

Since 1953, engineers and scientists have continued and broadened the use of radioactive isotopes of the natural elements, and with the use of this atomic tool have accomplished increased efficiency and economy in various industrial processes and advanced industrial research, have facilitated medical research and the diagnosis and treatment of specific diseases, and have assisted agricultural methods and helped create varieties of plants and improve breeds of animals.

Even without the expected benefits from ample, cheap electric power produced with atomic energy, the new science has paid, and will continue to pay, sound dividends through the use of radioisotopes alone. The savings to industry from use of radioisotopes already is estimated at hundreds of millions a year.

Eight experimental civilian power reactors were in operation, during 1957, one of these a full-scale, 60,000-electric-kilowatt station. Four additional full-scale prototype power reactors of various types were under construction, 2 financed by industry alone, 2 by industry and Government.

The Nation's commitments for research and development and construction of power reactors for all purposes has since 1953 risen steadily; for the fiscal year ending June 30, 1958, they would exceed a half billion dollars and, on the basis of existing plans, would continue above that level through the following fiscal year.

The Commission believes that the progress made in the power-reactor field and the supporting atomic-energy industry, since the Atomic Energy Act of 1954 made one possible, is without precedent. No other major scientific discovery has ever before been applied so quickly to so many practical uses.

Parallel with the growth of the industry in the United States has been the expansion throughout the free world of organized effort to put atomic science, atomic tools, and atomic technology to work for human betterment and economic expansion. During the 3½ years since the Atomic Energy Act gave legislative support to the Presi-

dent's Atoms For Peace program, 37 nations have joined with the United States in bilateral agreements to share atomic advantages, 31 nations which previously lacked a Government organization to promote atomic progress now have established authorities and commissions, and 59 nations have joined in an international atomic energy agency to promote peaceful uses of atomic energy.

In this report to the Congress, the Commission assesses and summarizes the progress made in various peaceful efforts, and describes the steps it has taken to help achieve these gains.

A Summary of Progress

Progress With Radioisotopes

The use of radioisotopes by United States industry is estimated to be earning in industrial savings the equivalent of a 7-percent yearly dividend on the more than $7 billion tax money that the Federal Government has invested on atomic energy plant and equipment between 1942 and 1958. This estimated $500 million a year of savings results from prevention of waste, improvement of products and industrial processes, increased efficiency of operations, and greater uniformity of product. It represents a 400-percent increase in savings since 1953.

The 1,600 organizations authorized to use radioisotopes for industrial purposes include 250 of the 500 largest corporations in the United States, and this 1957 total was nearly double the number that had been authorized up to 1953.

Radioisotopes were licensed for use by 1,900 medical institutions and physicians, more than double the 1953 total, and estimates were that radioisotopes are being used to assist more than a million patients a year.

Gains continued to be made in broadened knowledge and improved management of crops and livestock, and of diseases and pests that afflict both. Research pointed the way to better use of fertilizers, insect and weed killers, and growth regulators, and benefits were in sight from widening experiment with plants and animals.

Specific results of research in benefits to industry and industry's customers, to the progress of medical and biological knowledge, and to agricultural sciences, have been reported to the Congress through the years as discovered and developed. Recent gains are summarized in Chapter II, Progress With Radioisotopes; the increase of the radioisotope business is covered in Chapter IV, Growth of the Atomic Energy Industry.

Progress With Power Reactors

Since 1953, the Commission and its contractors have completed design and construction of six experimental power reactors, industry with its own funds put a seventh in operation; an eighth constructed for the Army has civilian uses. Further, an experimental reactor is operating with a new type of core. This is in addition to the successful demonstration of three nuclear-powered submarines, and the major program to build a nuclear-powered Navy.

The experimental reactors were built to advance the technology of various types of powerplants, but one—the Experimental Boiling Water Reactor—is providing power and lights for a national laboratory; another, the Army Package Power Reactor, is providing electricity for a military establishment; and two others, the Sodium Reactor Experiment and General Electric's Vallecitos powerplant, are feeding kilowatts into commercial lines. The other experimental reactors, all built by Commission contractors, are the Homogeneous Reactor Experiment No. 2, the Organic Moderated Reactor Experiment, the Boiling Reactor Experiment No. 4, the Experimental Breeder Reactor No. 1 (Mark III core), and the Pressurized Water Reactor. Private utilities contributed financially to both the Sodium and Pressurized Water Reactors.

These reactors are not, of course, producing power at costs that are competitive with those of powerplants using conventional fuels. But one, the Experimental Boiling Water Reactor, has operated at 2½ times its design power level. These, and other plants of advanced design being designed or built, will help determine the technical feasibility and economic promise of various reactor types.

Four full-scale prototype power reactors are under construction: 2 by industry exclusively, 2 under cooperative arrangements between industry and the Commission. Besides these, the Commission and industry have agreed to construct two additional reactors, and are studying or negotiating on others.

Contracts have been awarded for the first nuclear-powered merchant ship, and other studies undertaken for this economically promising use of nuclear energy.

Chapter III, Progress With Power Reactors, reports in detail on the progress made, and the plans underway, for development of safe, efficient, and economic power reactors. Supporting research and development work in this and related broad scientific fields is reported also in Chapter VI, Progress in Physical Research.

Growth of the Atomic Energy Industry

Since 1953, an atomic energy industry has come into being, though still on relatively small scale for a major industry in the United States, and a foundation has been laid for healthy growth and expansion.

Basically, the industry has two main divisions—that which purchases and uses atomic energy products, such as the companies processing radioisotopes, and the manufacturers of such devices as thickness or density gages that incorporate radioisotopes; and the section which designs, constructs, and operates or sells research and power reactors, plus the suppliers of materials, components, and services for Federal or private reactors. The radioisotope part of the industry is older and better developed, and still is rapidly expanding. The reactor part, a composite of Federal and private activities, is mostly new since 1953, but already has attracted considerable risk capital.

Private companies have entered many phases of the reactor part of the industry, particularly where there was a promising market for products or services. Industry has assumed heavy outlays in designing, building, and operating nuclear reactors to produce electric power. A foreign market is developing for United States built research and power reactors. Heavy expense has been incurred in nuclear research, development, and engineering.

Private organizations and Government were constructing 89 reactors as of the end of 1957. Including 7 critical assemblies, there were 43 research, training and test reactors (11 of them for the foreign market). The 46 power reactors, of which 36 were military machines, included 10 civilian powerplants, 1 for overseas sale. The program of 17 submarine powerplants for 16 submarines and 10 other naval reactors was, of course, a major factor in the United States power reactor list.

Expenditures or obligations by the Federal Government for research and development and construction of civilian and military power and propulsion reactors are estimated at more than $500 million for the fiscal year ending June 30, 1958. Estimates were that private industry was spending about $64 million on civilian power reactors during the same period.

Some private suppliers and processors of the industry already are well established: in mining and milling uranium ores (in mills alone, there is a present and projected private investment of some $132 million); in the manufacture of radiation detection and measurement instruments (the annual gross sales of 120 firms in this line is estimated at $35 million); in processing and marketing radioisotopes and compounds and devices (more than 100 different concerns are in this business).

At Commission invitation, or on their own initiative, firms that process uranium for the Commission also will produce for the commercial market, a private firm will prepare feed materials for Federal plants, and other companies have begun or agreed to collect and process unirradiated uranium scrap, manufacture fuel elements, and handle disposal of low-level radioactive wastes.

It has not been possible, of course, for a fully grown and independent atomic energy industry to be created in the past 3 years. Many private industrial developments still require positive Government assistance, or rely on the Federal market for at least part of their output. Considering the magnitude of the task of building a new and highly technical industry, the Commission believes that since 1953 industry has made close to the maximum degree of the progress that was possible, and that the United States is well on the way toward development of a major industry that will take its place beside other notable achievements of the competitive private enterprise system of the United States.

Late in 1957, some readjustment was going on in that part of the atomic energy industry concerned with civilian power reactors. Some firms had dropped out, or reduced their undertakings. Current economic trends undoubtedly were a partial factor in some cases. While this adjustment may temporarily deter new firms from entering the industry, the hard core of the atomic energy business is already established and growth is steady. Much of this growth depends on military utilization of nuclear reactors for propulsion.

In military use, the unique capabilities of atomic energy plants easily outweigh the present higher cost of this energy source as compared to alternates. Applications of atomic energy to the generation of electric power, on the contrary, must be directly compared to the cost of alternates. Despite the unfavorable position of nuclear energy costs at this time, the promise that atomic energy holds for the future is such that private industry has made major commitments to help develop central station nuclear powerplants.

In the atomic energy industry, as is the rule in a competitive, capitalistic society, many companies, new or old, were expected to attempt to break into the new market or to use the new technology. Not all companies will be successful in atomic energy, or any other new field. However, much of the growth of the United States economy has been due to these continuous attempts of old and new companies to enter new fields of endeavor; any outside attempts to select the entrants, or to control their numbers, would be to the detriment of the economy as a whole, and against the traditions of a free society.

Progress in International Cooperation

Parallel with the Commission's efforts to promote an atomic energy industry in the United States so as to facilitate peaceful uses of the new science and technology, the United States has sought since 1953 and especially since 1954 to support the efforts of friendly nations. Not all countries were equally prepared for industrial development; in some, the science was almost wholly new. Nevertheless, with United States leadership through its Atoms For Peace program, the free world since 1953 has organized itself to begin the wholesale exploitation of nuclear energy science—through research for human benefits, through using the products, technologies, and equipment to develop stronger, more diversified economies.

The extent of the interest and the efforts to put atomic energy to work is reflected in the number of countries involved.

Fifty-nine nations have joined in the International Atomic Energy Agency which the President proposed in December 1953, and that Agency is now established and organized, and is being staffed for worldwide promotion of peaceful uses of atomic energy.

Thirty-seven nations now have 39 agreements for cooperation with the United States in full force and effect.

Fifty nations have organized special government agencies to promote the use of atomic energy, as compared with only 19 such agencies in effect in 1953.

Seventeen countries have received 70 shipments from the United States of reactor and research materials.

Six reactors manufactured in the United States were in operation in other countries, 5 of them started up in the last 6 months, and construction or plans are underway for 22 others, of which 6 would generate power.

The United States is assisting 4 regional programs designed to promote the use of atomic energy, 2 in Europe, 1 in Asia, and 1 for Central and South America.

Another indicator of the scope of interest in the Atoms For Peace program is the fact that 2,459 visitors from 72 countries have visited Government and industrial installations on atomic energy business since 1955. In the last 3 years, 273 students from 44 nations have attended Commission reactor courses, and 228 from 46 nations have taken radioisotope courses.

The Commission believes that, with expanding permanent research organizations, with growth of facilities for industrial promotion, with an increasing pool of trained manpower, and a quickening exchange of nuclear technology and scientific findings, the free world is moving steadily and successfully toward realization of those humanitarian

goals which the President presented before the assembled United Nations in his historic address of December 8, 1953.

A Summary of Commission Actions

The Atomic Energy Act of 1954 laid down the principles that have guided the Commission's policies and actions in fostering development of a private atomic energy industry, and in furthering worldwide cooperation in peaceful uses of atomic energy. It placed upon the Commission the responsibility to see that "the development, use, and control of atomic energy shall be directed so as to promote world peace, improve the general welfare, increase the standard of living, and strengthen free competition in private enterprise." [1]

The two broad undertakings—domestic and foreign—presented quite different problems, but many of the actions taken to assist United States industry have had parallel advantages for cooperating nations, and the expansion of interest overseas has resulted in a steady flow of orders, particularly for research reactors, to the domestic industry. In the following pages, the Commission summarizes separately its policies and actions in these two fields.

Assisting the United States Atomic Energy Industry

The Commission has relied upon industry to exert its initiative in the atomic energy industry and, as the record shows, private companies have moved ahead in many aspects of the industry. Moreover, industry at all times has supported the Commission through consultation and advice in planning actions and policies to encourage further participation by industry.

Private concerns had to overcome a number of obstacles even with Commission assistance. Unique among United States industries was the previous extensive Federal monopoly over atomic energy development and the secrecy imposed over many aspects by the necessity of protecting the common defense and security, and the fact that the technology developed almost exclusively under this monopoly and behind the security barrier. Despite the changed emphasis on civil uses of the new science, the broader scope of activities, and the volume of declassified information, the continued Federal interest in military applications continues to create special problems: controls are necessary to avert the danger of misuse of the special nuclear materials, to maintain military secrets, to maintain world leadership in weapons and other military uses, and to continue military priorities over

[1] Sec. 1, Declaration of Atomic Energy Act of 1954.

technology, materials, facilities, and equipment. Because of these factors, and the special problems radiation creates for public health and safety, the industry has had to be regulated and licensed from the beginning, and Federal ownership maintained over special nuclear materials.

Partly arising from this background, and partly because of the newness of the technology, private companies entering the atomic energy industry initially found that information on many cost factors either was not available because of lack of experience or, if available, had to be handled as classified information; that nuclear scientists and engineers were scarce and were predominantly already employed by experienced Commission contractors; that much of the technology needed could be used only on a classified basis by Government-investigated and cleared individuals. Moreover, large capital investment often was necessary considerably in advance of commensurate income, and industry had to make outlays in developmental research. Essential materials and equipment are subject to Federal priorities or, in the case of special nuclear materials, Federal ownership.

On the other hand, there was widespread curiosity among industrial managers about the opportunities in this new field, the future undoubtedly was promising, considerable prestige was associated with atomic energy activities, competitive advantages might be lost by failure to enter, there was a prospect of a foreign as well as a domestic market which the latter included an increasing volume of Federal contracts, and a considerable number of companies had gained nuclear experience, and developed trained staffs, as contractors of the Commission.

From the beginning, private participation in the Federal program had been quite widespread. Under the Atomic Energy Act of 1946, the Commission looked toward the ultimate development of a private, self-sustaining industry, and maintained a basic policy of steadily broadening private participation. The Manhattan Engineer District, the Army's wartime operator of the program, began the practice of using academic and industrial contractors to operate Federal plants. Where feasible, both the Manhattan District and the Commission encouraged independent private commercial and industrial activities, for example, in the mining and milling of ores, in the manufacture of radiation detection instruments, and in the manufacture and distribution of radioisotopes for research and other uses.

The private corporations and organizations associated with various aspects of the Commission's programs—they included the 81 companies that from 1951 to 1955 undertook studies on possible power reactors—constituted a nucleus around which industrial growth could take place.

This was the situation, the advantages, the disadvantages, and the limiting conditions, under which the Commission undertook, with the guidance of the Atomic Energy Act of 1954, to formulate and carry out its program for assisting private enterprise to enter the atomic energy field. As initial objectives, the Commission undertook to—

Arouse and sustain industrial interest in a commercial non-Federal atomic energy industry;
Disseminate accumulated technology in a base broad enough to promote competitive enterprise in this field without compromising the interests of national security;
Provide the new industry with material and services, increase the supply of nuclear scientists and engineers, and produce new research and development data until the industry became self-sufficient;
Assist the industry by all reasonable means to become self-sufficient; and
Regulate industry in the interest of the health and safety of the public as well as of the national defense and security.

In seeking these objectives, the Commission has attempted to develop uses and to promote applications of radioisotopes; sought to assist private industry toward design and operation of economic power reactors; and in various ways increased the participation of industry in the Federal program.

In assisting the use of *radioisotopes*, the Commission has—

- Issued general licenses for use of radioisotopes in various devices.
- Reduced prices and increased the availability of key isotopes and of such radiation sources as cobalt 60.
- Reduced the restrictions on obtaining and using radioisotopes for research while maintaining ample safeguards over health and safety.
- Conducted research in uses of radioisotopes and published information on utilization of radioisotopes to increase their application in industry, medicine, and in research of all kinds.
- Undertaken to participate with industry in a program to achieve rapid development of the full industrial potential of radioisotope usage.

To assist in the task of designing and operating *power reactors* that would be safe, reliable, and economic, the Commission has—

- Established the declared policy that the Commission should develop power-reactor technology to the point where industry can carry the task forward with a reasonable prospect of economical operation.
- Financed a program of experimental power reactors, and explored other power-reactor concepts, with a view to determining those most economical in various uses, and to producing a rich technology that

may be used to reduce costs of electricity generated by nuclear energy.
- Assisted, in concert with publicly and privately owned utilities, in financing power reactors based on technology developed by the Commission, with a view to increasing technical and economic knowledge.
- Sponsored and conducted general engineering and development work in support of many kinds of reactors and on related problems of reactor safety, fuel element fabrication, chemical processing, waste handling, and similar matters to the end of reducing costs and promoting economically successful operation of power reactors.
- Encouraged private insuring of nuclear reactor operations for workman's compensation, property damage, and public liability, and sought legislation to provide further ample indemnification of nuclear facility operators for public damage in the unlikely event of a nuclear accident.

Many steps that the Commission took assisted both the development of *power reactors* and the general *growth of the industry,* or tended to build a foundation for future growth. In this category of actions, the Commission—

- Increased the volume of domestic mining and milling on a commercial basis, and of imports of uranium, with the result that a firm supply of fuel is available for nuclear power operation.
- With adequate supplies of raw materials and completion of comparable production facilities, recommended to the President and obtained his designation of large supplies of fissionable uranium 235 for the domestic program, and for research and power reactors in other countries, many of which are being designed and built by the United States firms.
- Provided certain research facilities, services, and certain supplies, equipment, and materials, where these were not commercially available, for use in advancing private industrial utilization of atomic energy.
- Publicly established charges for fuels and reactor materials, for purchase of special nuclear materials produced with United States fuels, for processing used fuel elements, and for other services, to assist in estimates of costs by reactor builders.
- Promoted the distribution and use on a competitive basis of inventions and technological information by obtaining basic patents and licensing their use on a nonexclusive, royalty-free basis, and by arranging for exchange of patents and equal treatment for United States concerns under Canadian and United Kingdom jurisdictions.
- Arranged for hundreds of private organizations and businesses outside the Federal program to have access to classified information

according to their needs after they complied with certain security requirements.

- Conducted a vigorous program of downgrading and declassifying technical documents, at the same time maintaining strict safeguards over data essential to the common defense and security.
- Prepared and arranged for distribution of research studies and reports and compilations of information in critical fields, through selling printed material, through libraries, through symposiums, through exhibits and through conferences.
- Provided a firm structure of regulations, licensing, and inspection, to help assure safe and secure operation of nuclear facilities.
- Sponsored and financed programs designed to increase the immediate supply of technical personnel trained in nuclear technology, and joined other Federal and private efforts to broaden the scientific educational base of the nation.

In its efforts to broaden and place in commercial channels, the supply base of the private *atomic energy industry*, the Commission has—

- Announced the future cutoff date of its purchase of uranium ores, planning instead to purchase concentrates from mills, closed Federal ore-buying stations, ceased Federal drilling for exploration, and taken other steps to reduce Federal participation in the mining and milling portion of the industry.
- Offered to cease Federal activity in such fields as processing fuel elements and providing certain research facilities, and has generally announced the policy that the Commission would withdraw from specified fields of servicing or supplying private industry whenever private activity could fill the gap at reasonable prices.
- Invited industry to make proposals for supplying the Federal Government and industry with special reactor materials, and to take over other tasks, by contracting for production of supplies or services in privately owned facilities.

Furthering International Cooperation

Efforts to promote international cooperation in development of atomic energy, launched by the United States in 1945 soon after the first military use of fission in weapons, had come to complete deadlock by 1953, stalled by the failure to achieve international accord on control of weapons. That deadlock was broken by the creative thrust of a new idea, presented by the President in his address before the United Nations General Assembly late in 1953, that the world could

cooperate in peaceful uses of atomic energy despite the military stalemate.

The President's proposal was indorsed by the United Nations, given force and organization by the Atomic Energy Act of 1954, and by other legislation approving ratification and United States participation in the international agency suggested by the President. The Commission has played a major role in helping to establish atomic energy programs throughout the free world, in promoting cooperation among nations and men of science, and in disseminating information on peaceful uses of atomic energy.

The steps the Commission has taken to assist the domestic industry often have promoted expansion of activity among cooperating nations. These include the Presidential designation of generous supplies of nuclear materials for use in reactors; establishment of charges for fuel, materials, and services; declassification and distribution of scientific and technical information; and the education and training program. In addition, of course, the research programs, and all efforts to improve the economic operation of power reactors, will directly assist cooperating countries.

Specifically, to assist and broaden international cooperation in the peaceful uses of atomic energy, the Commission has—

- Promoted a program of bilateral cooperation between the United States and other nations throughout the free world, framing executive agreements covering exchange of information, and construction and operation of research and power reactors, while maintaining safeguards against diversion of special nuclear materials to military ends.
- Lent assistance to the Department of State in the technical aspects of negotiations, leading to organizing and establishing the International Atomic Energy Agency.
- Proposed and assisted in obtaining United Nations sponsorship for the first worldwide International Conference on the Peaceful Uses of Atomic Energy, and joined in and sponsored many other conferences on various aspects of atomic energy development, as well as other means of exchanging scientific and technical information.
- Established a school of reactor technology to assist the training of foreign nationals and enlarged radioisotope research courses to include foreign nationals.
- Approved research reactor projects in other countries for financial grants and undertaken to assist in obtaining United States loans for power reactors.

Highlights of Commission Actions, 1953–57

The highlights of Commission policies and activities in support of the growth of the atomic energy industry, and of international cooperation, during the years 1953–57, are reported in the following pages. The features of those years are described in the later chapters dealing with major aspects of the atomic energy peaceful program.

During 1953, the Commission—

- Began preparations to support and execute the program of international cooperation, including establishment of an international agency, to promote peaceful uses of atomic energy, as proposed by the President on December 8 of this year before the General Assembly of the United Nations.
- Presented to the Joint Committee on Atomic Energy its views that attainment of economically competitive nuclear power was a goal of national importance and that advances in nuclear power technology made this goal attainable within the foreseeable future. The statement stressed the desirability of bringing industry increasingly into the program, and made recommendations for legislation.
- Published the declassifiable portions of analyses made by four industrial power groups which during the preceding 2 years undertook studies, in collaboration with the Commission, of designs for reactors intended to produce electricity.
- Demonstrated with the Experimental Breeder Reactor No. 1, the first nuclear reactor to generate electricity (December 21, 1951), that breeding of nuclear fuels in a reactor was definitely feasible, and that the reactor was producing at least as much fissionable material as it consumed.
- Operated successfully the first homogeneous reactor, the Homogeneous Reactor Experiment No. 1, at Oak Ridge National Laboratory, with the generation of useful amounts of electricity.
- Launched a project for design and construction of the first full-scale nuclear powerplant, the reactor afterwards to be built as the Pressurized Water Reactor.

During 1954, the Commission—

- Received with the President's signature on August 30 of the Atomic Energy Act of 1954, a new charter from the Congress, the first complete revision of the statute since 1946. The new act adds emphasis on development of peaceful uses of atomic energy, and provides authority for greater international cooperation, increases participation by private enterprise, and effective dissemination of both scientific and industrial information.

- Undertook a basic revision of classification guides to determine what information could be released without restriction, and what could be placed in lower categories of restriction, in view of the broadening need, and the benefits of increased industrial participation.
- Set up task forces to draft regulations and licensing requirements for industrial and other users of atomic energy facilities and materials, as required under the new Act.
- Established, on a classified basis, schedules of basic charges for materials and services needed by private developers of atomic energy and provided by the Commission, and schedules of fair prices the Commission would pay for certain products.
- Announced that charges for materials and services would be assessed on the basis of full cost plus overhead, and that charges would be maintained on as stable a basis as possible, although subject to periodic adjustment if substantial changes occurred in the wholesale price index.
- Proposed to Congress and received authorization in March for undertaking a 5-year, 5-reactor program of research and development with experimental power reactors in an effort to lay the groundwork for reactors that would produce economically competitive electric power. The proposal included a plan for increased participation by contractors and by additional new groups not at that time working in the atomic energy program.
- Broke ground for the Pressurized Water Reactor at Shippingport, Pa., and attained an agreement with a privately owned utility company that it would construct power generation equipment and assist in financing the design and construction of the reactor.
- Announced a Power Demonstration Reactor Program under which publicly or privately owned organizations would assume the risk of construction, ownership, and operation of power reactors, and the Commission would provide under contract specified research and development work, and would waive a portion of the fuel charges. The objective of the program is to bring private resources into the development of engineering and economic information on performance of promising types of power reactors.
- Agreed to the establishment of an additional 11 industrial teams studying reactor design in collaboration with the Commission, raising to 18 the number of study teams. Industrial concerns would have invested an estimated $8 million in this work by the end of 1954.
- In the field of international cooperation, proposed the world's first comprehensive international conference on the science and technology of peaceful uses of atomic energy, and supported the Department of State in its successful efforts to have the United Nations accept the proposal and undertake to sponsor the conference.

- Supported the Department of State, and gave technical advice, in first steps toward establishing an international atomic energy agency as proposed to the United Nations by the President.
- Established a reactor training school at Argonne and took other steps to provide scientific and technical training for foreign nationals, and launched a program of donating technical libraries to foreign countries.
- Recommended to the President a first designation of 100 kilograms of uranium 235 for the international program.

During 1955, the Commission—

- Announced for the first time that the United States had become one of the leading uranium-producing countries of the world.
- Established on a classified basis the schedule of charges for materials supplied by the Commission, and the prices it would pay for special nuclear materials produced in power reactors; announced publicly charges for enriched uranium to cooperating nations under Atoms For Peace program.
- Issued two separate invitations for publicly or privately owned organizations to undertake to design and build power reactors in cooperation with the Commission under its Power Demonstration Reactor Program. By April 1, the first deadline, several proposals for reactors were received.
- Operated a second boiling water reactor experiment, intended to lead to a power reactor of this type, went ahead with construction of the Pressurized Water Reactor at Shippingport, Pa., and continued work on a second Homogeneous Reactor Experiment, a second Experimental Breeder Reactor, a Sodium Reactor Experiment, and carried out studies on a liquid metal-fueled reactor, and a reactor moderated and cooled with an organic fluid—all intended to assist in achieving economic power reactors.
- Operated the third boiling water reactor experiment, BORAX 3, the first in this series to produce power, to supply the town of Arco, Idaho, with all its power and light requirements on an experimental basis on the night of July 17.
- Received 7 applications for licenses to build and operate reactors, 2 for power, 5 for research.
- Announced that it was conducting several classified research projects in an effort to control thermonuclear reactions so that this process might be used to produce power.
- Negotiated on a contract with a private utility company to install power equipment and to buy heat from the Sodium Reactor Experiment to produce electricity. The company will share with other utilities the information gained from the operation.

- Undertook to build and operate an Engineering Test Reactor, required to assist research and development on power reactors.
- Received applications from three companies for licenses permitting manufacture of reactor fuel elements.
- Requested proposals from industry to build privately owned facilities and to produce feed material for Federal gaseous diffusion and metal-fuel plants.
- Requested authorization for construction of the reactor for a nuclear-powered merchant ship as proposed by the President.
- Issued for discussion proposed regulations covering licensing of production and utilization facilities, distribution of special nuclear facilities, and safeguarding of restricted data.
- Issued a new guide to declassification of atomic energy data, opening to the public large areas of information previously classified, and carried out an accelerated review of all classified documents to downgrade and declassify those reduced in classification or removed from security restrictions by the new guide.
- Inaugurated accelerated industrial information program to provide written and graphic material, classified and unclassified, on nearly every phase of nuclear science and technology except weapons and other defense-sensitive areas.
- Inaugurated a program for granting access permits for industrial and other private individuals to receive classified information needed in their businesses after Federal investigation of the individual concerns and certain other security requirements; granted 602 permits in first 8 months; conducted seminars and other meetings with industrial representatives to provide information on activities their companies might wish to enter; accepted additional study groups in the power reactor program, raising the total to 25, including 81 individual firms.
- As prescribed by Congress, made radioisotopes for biomedical and agricultural research, and for research in medical therapy and diagnosis available to domestic users at 20 percent of the previous price.
- Inaugurated program to expand education and training of engineers and scientists in nuclear technology, to continue assistance to nonprofit and educational institutions in building and operating reactors, and in providing other facilities, to conduct summer institutes for faculty, in addition to its operation of schools at two national laboratories in which foreign nationals are accepted.
- In the field of international cooperation, negotiated agreements for cooperation in the Atoms For Peace program with 27 nations.
- Assisted in drafting the preliminary statute of the proposed International Atomic Energy Agency, which was circulated to United Nations members for comment.

- Organized and headed United States participation in the United Nations first International Conference on the Peaceful Uses of Atomic Energy, at which the United States installed and operated a research reactor.
- Authorized presentation of technical libraries to 23 nations and to the United Nations at Geneva.
- Announced with the President the second designation of uranium 235 for Atoms For Peace programs, raising the total to 200 kilograms or 440 pounds, and prepared to execute the President's pledge that the United States would help finance research reactors in cooperating countries.
- Agreed to sell heavy water to Australia, France, India, and Italy.
- Issued through September 3,480 export licenses for various instruments and components for atomic energy research, and on September 26 relinquished controls and turned the activity over to the Department of Commerce.
- Announced a general authorization for United States firms and individuals to engage in unclassified activities in atomic energy in foreign countries without specific authorization from the Commission.

During 1956, the Commission—

- Again increased its supply of raw materials, making production figures public for the first time, and, with completion of its expanded plant for production of special nuclear materials, attained the highest levels of production in its history.
- Announced with the President the designation of 40,000 kilograms—88,000 pounds—of the rare fissionable isotope of uranium (uranium 235) for use, half and half, in domestic reactors and in those of cooperating nations.
- Completed and operated the Experimental Boiling Water Reactor and the Borax-4 reactor; pushed ahead with construction of three other experimental power reactors—the Pressurized Water Reactor, the Sodium Reactor Experiment, and the second Homogeneous Reactor Experiment; advanced plans for the Organic-Moderated Reactor and the second Experimental Breeder Reactor; and pressed studies on four other reactors of more advanced types, as well as research on fuel processing, reactor safety, and waste handling.
- Signed the first contract under its Power Demonstration Reactor Program to cooperate with Yankee Atomic Electric Co. in designing and building a 134,000-electrical-kilowatt reactor, with the company making by far the larger share of the investment; continued to negotiate with two other groups proposing to build large power reactors in response to the Commission's first invitation; received 7 proposals to build smaller power reactors in response to the second invitation, and accepted 4 as basis for contract negotiation. This was in addi-

tion to the 7 power reactors, 4 of them aggregating more than 750,000 electrical kilowatts, which private companies announced that they would build without Federal cooperation or financial support. Two of these were granted construction permits.

- Began contract negotiations for design and construction of a pressurized water powerplant for the first nuclear-powered merchant ship and, with the Maritime Administration, let contracts for feasibility studies on five other types of reactors.
- Issued basic regulations, and amended others, to complete provision of the Federal ground rules for the atomic energy industry; granted permits for access to restricted data to an average of 50 private companies or individuals a month, reaching a total of 1,145 by the year's end.
- Received shipment of fuel elements for a Federal reactor, the first manufactured in privately owned facilities; selected a contractor to manufacture in private facilities feed materials for Federal plants; invited private industry to undertake processing of scrap from Federal feed materials plants, and to process irradiated fuel elements; announced programs and contracts to increase commercial production of special reactor materials.
- Opened certain research facilities to authorized individuals and concerns when private facilities were not available; pushed construction of the Engineering Test Reactor.
- Issued general licenses for use of radioisotopes in static eliminators, spark gaps and electronic tubes, lightmeters, and ion-generating tubes, all using sealed radiation sources of limited strength.
- Received notice of formation of three insurance syndicates, following its consultations with the industry, which would underwrite workmen's compensation, property damage, and up to $65 million public liability per installation for reactor operators; proposed to Congress that further indemnification of private liability, which the reactor industry deems necessary, above even this unprecedentedly large coverage offered by insurance syndicates.
- Completed accelerated review of classified documents on the basis of 1955 declassification guide, declassifying entirely nearly 11,000 out of 30,000 documents, and downgrading 8,000 more; issued a subsequent declassification guide late in the year which resulted in removing from security restrictions nearly all industrial information, but maintaining safeguards over military information; announced a second accelerated review of remaining classified material; undertook with the United Kingdom a study of the restrictions they mutually place on information about controlled thermonuclear reactions; permitted limited access to classified information on thermonuclear studies under the access permit program.

- Broadened its program for distributing information by holding symposiums on selected technical subjects with industrial groups and publishing proceedings; by planning technical progress reviews on 10 categories of research; by adding 17 more technical libraries throughout the country and planning classified libraries at geographical centers; by preparing and revising existing volumes on technology, of which 21 were underway.
- Concluded a patent and patent application interchange agreement with Canada and the United Kingdom under which each nation may acquire and license within its boundaries patents and patents applications sought in the other countries prior to November 15, 1955.
- Pushed ahead with a five-point program to increase the supply of trained manpower, including expanded operation of two reactor schools which doubled capacity through cooperation of universities, increased assistance in providing nuclear equipment for technological training, and an enlarged fellowship program.
- Announced, in the program of international cooperation, six steps taken to assist development abroad: established full schedule of charges for uranium 235; gave assurances that future supplies of uranium would be made available for power reactors; established prices to be paid for plutonium or uranium 233 produced from United States fuel; announced Commission stood ready to purchase all plutonium and uranium 233 so produced at established prices until June 30, 1963; announced Commission would ask congressional approval of its making commitments 7 years ahead for such purchases; announced Commission would consider exchanging uranium 235 for source materials such as uranium ores or concentrates from cooperating nations.
- Negotiated 12 additional agreements for cooperation with other nations, and undertook new negotiations with others looking toward installation of power reactors abroad. As of the year's end, 32 agreements, of which 4 covered power, were in effect.
- Participated in drafting a statute, in which the Soviet Union concurred, for an International Atomic Energy Agency, which later won the unaminous approval of a conference of 82 nations summoned to consider it. The International Agency would become a reality after ratification of this approval by a stipulated number of nations concerned.
- Announced that 10 cooperating countries have plans for 15 reactors, including 3 power reactors, to be built by United States firms; issued a regulation to assist industrial activities of United States firms in this field; received word that United States concerns have contracted to build 7 reactors abroad, and contracts for 3 additional reactors are being considered; made first shipments of heavy water to other

countries, announced commitments to deliver 129 tons to 6 different nations.

- Simplified procedures so that foreign scientists could more easily obtain radioisotopes from the United States.
- Authorized the first grants under the Atoms For Peace program toward the cost of research reactor projects, $350,000 each to four different nations; agreed with the Export-Import Bank on plans for loans to assist other nations in building reactors.
- Launched a three-part program to assist development of atomic energy applications in the Americas, including a symposium for Latin American representatives, a Spanish-language nuclear center at the University of Puerto Rico, and assistance to the Turrialba Agricultural Institute in Costa Rica.
- Enlarged reactor schools for foreign nations, assisted development of a program for an Asian Nuclear Center, facilitated atomic energy development by exchanges of information, establishing special technical groups for coordinating information, interchanging scientific visits, and participating in conferences; accepted responsibility for preparing for second International Conference on the Peaceful Uses of Atomic Energy, scheduled for Geneva, Switzerland, by the United Nations in September 1958; presented nine additional technical libraries to other countries.

During 1957, the Commission has—

- Placed in operation 4 experimental power reactors and one full-scale prototype power reactor in addition to the 2 experimental plants that achieved criticality in December 1956. Four of these reactors were producing useful electricity; two fed kilowatts into commercial circuits.
- Licensed operation of General Electric's Vallecitos power reactor, pilot plant for a large commercial central power station. The Vallecitos Boiling Water Reactor is the first entirely commercial power reactor to become critical and is producing electricity on an experimental basis which is distributed by Pacific Gas & Electric Co. Two major private nuclear powerplants were under construction: the Commonwealth Edison Co. 180,000-electric-kilowatt Dresden plant near Joliet, Ill., and the Consolidated Edison Co., 275,000-kilowatt combined nuclear and conventional Indian Point, N. Y., plant.
- Signed a contract for design and construction of a nuclear powerplant for the first atomic-powered ship the N. (Nuclear) S. *Savannah*.
- Issued a third invitation under its Power Demonstration Reactor Program asking proposals from publicly and privately owned organizations to build reactors in cooperation with the Commission, and expressing special interest in natural uranium power reactors moderated with heavy water, and in aqueous or slurry-fueled homogeneous

reactors. A contract was signed on one proposal made in response to this invitation; three other proposals were being studied. The final 2 contracts, making 3 in all, were signed, and a second construction permit issued, on power reactors proposed under the Commission's first invitation, issued in January 1955. Three proposals under the second (September 1955) invitation were being studied; negotiations on a fourth have been deferred. Changes in cost estimates and the Congress' provision in the Authorization Act for 1958 for Commission ownership of power reactors to be operated by publicly owned utilities necessitated renegotiations on these proposals.

- Announced with the President an increase to 100,000 kilograms—220,000 pounds—the designation of contained uranium 235 to fuel research and power reactors: half for domestic use, half for use in cooperating nations.
- Conferred with a total of 132 representatives of industry in a 3-day series of meetings on civilian power reactor programs.
- Undertook to process used fuel elements from reactors in this country and abroad pending establishment of commercial facilities charging reasonable prices, and published a schedule of charges. Guaranteed purchase prices were announced for fissionable materials generated in reactors here and from United States fuel in cooperating countries.
- Received 44 applications for construction of research reactors, and 4 critical experiments. Seven applications from one company covered construction of 42 research reactors intended to be sold "off the shelf" in this country and abroad. In addition, there were 15 applications to export research reactors, 1 of these duplicating a construction permit.
- Reduced prices of radioactive cobalt 60, used in teletherapy and in many industrial operations, a step made possible through improved production techniques and increased markets, about 300,000 curies per year being manufactured. Receipts from sales of radioisotopes increased by $500,000 during 1957, reaching a total of $2.7 million by the year's end. Total shipments rose from 109,500 curies in 1956 to 160,000 curies in 1957. Thirteen additional foreign countries began to buy United States isotopes during this year.
- Sought legislation to provide for Federal indemnity of reactor operations for private liability resulting from nuclear incidents above certain protection provided by normal commercial insurance. A temporary regulation was issued by the Commission September 11 after the legislation passed with Congressional changes and was signed September 2.
- Undertook an accelerated review of 18,000 classified documents pursuant to the new declassification guide promulgated in December

1956, and declassified an additional 9,000 documents. As of the year's end, 1,404 access permits were in force, of which 57 percent allowed access to secret and confidential classified information, and the remainder for access to confidential information only.

- Issued seven texts, the first under its accelerated program of compiling and issuing technical volumes for industrial use, and a guide to published literature, published proceedings of 6 symposiums and conferences, and released the first of its technical progress reviews designed to help keep users abreast of current developments in various technical areas. Sales of classified and unclassified material totaled 81,000 copies costing $36,700. Four conference proceedings, 99 articles, and abstracts of 553 papers were translated from the Russian language and placed on sale. Thirteen additional domestic technical libraries were provided, making 79 in all and six classified libraries were authorized.
- In its programs to increase the supply of nuclear scientists and engineers, made grants of $3.4 million to 34 colleges and universities to provide facilities for nuclear technology courses, awarded 85 fellowships for the current school year, helped sponsor five summer institutes attended by 80 faculty members from 52 institutions, gave training courses for 101 high school teachers.
- In the field of international cooperation, participated in the successful United States efforts to organize the International Atomic Energy Agency, formally established in Vienna, Austria, during October, almost 4 years after the President first proposed the agency.
- Put into effect 7 more agreements for cooperation, making a total of 39 in force with 37 nations, 10 of which have provisions covering power reactors.
- Proffered assistance to Euratom, a new atomic energy organization formed by six European nations. A report of the organization recommended construction by 1967 among the member nations of nuclear reactors with a capacity of 15 million kilowatts of electricity.
- Sponsored establishment of an Inter-American Atomic Energy Commission within the Organization of American States, conducted a symposium at Brookhaven National Laboratory on Latin American utilization of atomic energy, made grants to the University of Puerto Rico and conducted a symposium there looking toward establishment of a Spanish-language atomic energy center, assisted in a program at the Inter-American Institute of Agricultural Sciences at Turrialba, Costa Rica.
- Approved three grants of $350,000 each for research reactor projects in cooperating countries, and joined with the Export-Import Bank in a plan to make loans for nuclear powerplants in other countries.

II

PROGRESS WITH RADIOISOTOPES

The use of radioisotopes is estimated to be currently returning to American industry annual savings equivalent to some 7 percent on the $7 billion of tax money invested by the Federal Government in atomic energy plant and facilities. The estimated $500 million and more a year in industrial savings comes from speeded-up manufacturing operations, improvement of products and industrial processes, and in savings through uniformity of quality, and other means.[2] This is a 400-percent increase since 1953 when savings were estimated at $100 million. The results reported here were calculated from an analyses made in July 1957, based on interviews with many industries using radioisotopes.

The Commission has every reason to believe that industrial use of radioisotopes will expand considerably in the future. The industrial organizations presently authorized for radioisotope utilization represent only about six-tenths of 1 percent of the total number of manufacturing and mining concerns counted by the Bureau of the Census. Commission studies indicate that at least 8 to 10 percent of the firms can profitably use radioisotopes.

As of December, about 1,667 industrial organizations were authorized in 1,200 licenses [3] to use radioisotopes for industrial purposes, compared with 893 in May 1954, an increase of about 80 percent. The licensees included 250 of the 500 largest industrial corporations in the United States.

The industrial savings, capable of being calculated in dollar terms, are in addition to the benefits resulting from doctors use of radioisotopes to diagnose or treat the ailments of an estimated 1 million patients a year. Medical scientists are using radioisotopes to learn more about the physiology and functions of the body, more about diseases, and drugs. As of December, there were 1,900 medical institutions and private practicing physicians authorized in 1,575 licenses to use radioisotopes, as compared with 748 authorized 3 years before—an increase of 150 percent.

[2] The figure given here is an estimate based on major cost savings studies made in late 1954, and late 1956, and an interim study made in June 1957. Increase in the number of radioisotope users indicates that the industrial savings previously reported (for table presenting breakdown of earlier estimate, see p. 35, Twenty-second Semiannual Report to Congress (January-June 1957), now has increased to approximately $500 million.

[3] In place of the former authorization procedure in which, for example, separate facilities required individual authorization, the Commission now is issuing licenses which often consolidate previous multiple authorizations (see appendix 4).

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In agricultural research, scientists using this unique tool are improving the application of fertilizers, creating new varieties of crop plants, improving breeds of livestock, studying the effects and efficiency of insecticides and weed killers, and increasing the sum of human knowledge about plant growth and plant-growth processes.

In basic biological research, and in many other fields of physical, chemical, and metallurgical science, the use of radioisotopes is adding annual increments to man's knowledge of his environment.

In the 3-year period 1955–57, the number of colleges and universities licensed to use radioisotopes increased 29 percent, Federal and State laboratories showed a 46-percent increase, foundation and institutions licensed to use radioisotopes showed a 33-percent increase, and miscellaneous licensees increased from 18 to 54, a 200-percent increase.

The $500-million-a-year savings are being returned by what is essentially a byproduct of atomic energy activities—the radioactive isotopes of the natural elements created in nuclear reactors. By various means, over 900 different kinds of radioactive atoms now can be manufactured—more than three times the number of stable and radioactive atoms found in nature. Some of the isotopes, stable and radioactive, are produced in particle accelerators—the so-called "atom smashers."

The development of the Commission's radioisotope production and distribution program, and the growth of private laboratories which purchase Commission isotopes in wholesale quantities, and manufacture and retail compounds useful in research, are described in Chapter IV, Growth of the Atomic Energy Industry. In the following pages, the Commission reports on the results of using radioisotopes in industry, and on research using radioisotopes which promises, to produce even larger dividends in human welfare and economic advances.

INDUSTRIAL CONTRIBUTION OF RADIOISOTOPES

The hundreds of industrial applications of radioisotopes are summarized here according to eight different ways in which radioisotopes can be used. Representative examples are reported for each of the following categories: penetration of radiation, reflection of radiation, luminescence, ionization, stimulation of chemical reactions, radiation pasteurization and sterilization, isotope batteries, and tracers.

Penetration of Radiation

The ability of atomic radiation to penetrate matter as do X-rays has led to the most extensive of all industrial uses of radioisotopes. A part of the radiation always is stopped by the material it penetrates;

the amount depends partly upon the type and energy of the radiation being used, and partly upon the density and thickness of the material and the presence of flaws in the material.

Radiography with radium or X-rays is a comparatively old method for inspecting metal castings and welds for possible flaws not detectable except with the radiation and film technique. Reactor-produced cobalt 60, cesium 137, and iridium 192 now are used in much the same way as radium, but are much cheaper and more effective. Iridium 192 is especially useful for radiographing thin materials, and low-density objects.

More than 550 firms are licensed to perform radiography with radioisotopes. Through this technique, the firms are able to assure the integrity of many materials and equipment whose soundness and durability must be known in advance. Equipment failure, which in certain instances may prevent loss of thousands of dollars and even of human lives, is thus reduced.

One military tank manufacturer, for example, experienced failure of the mount supporting the large gun. Failure of the mount permitted the heavy gun to recoil into the tank, causing severe damage and endangering the occupants. The decision was made to radiograph all gunmounts as a matter of routine, and the configuration was such that only radioisotopes with high specific activity could be used. The radiographic check of gun mounts revealed that several had internal flaws not detectable by other means. Elimination of faulty mounts virtually ended the failures.

Thickness gaging is another application of the radiation penetration principle. Thickness gages are being used routinely on production lines to help produce more uniform paper, aluminum, copper, tinplate, plastics, rubber, glass, and numerous other items. This continuous method of gaging which does not involve the gage's contact with the material is especially useful where products are moving rapidly, where temperatures are high, and where products are soft and easily marred.

The material whose thickness is to be gaged is passed between a source of radiation and a radiation detector connected to an amplifier and recording device. In many cases, the signal caused by the radiation transmitted through the material is used to make automatic corrections in the production process. Such nuclear gages have taken many interesting and ingenious forms, and thousands are in use.

Typical of thickness gages are some 400 used in paper mills. These gages automatically adjust gates regulating the inflow of materials to maintain accurate basic weight and thickness of rolls of paper. Savings to the manufacturer result from faster adjustments of weight changes in paper stock, fewer rejections of reels as offweight, less

breakage of reels in changes of weight, faster startup time on reels after change, faster machine speeds, and greater total yield from a given quantity of raw materials.

Density gaging. In the type of thickness gage described, the amount of radiation picked up by the detector is dependent upon the amount of material between it and the radioactive source: the density of the material per unit of thickness remains constant.

Conversely, if the thickness or size of the material is held constant, the same kind of gage may be used to measure density—the amount of material in that thickness. Examples of such an application are the monitoring of the density of a process fluid flowing through a pipe, or the moisture content of sand or other material. The amount of silt in streams and lakes can be quickly and accurately determined with a silt-density gage.

More than 3,000 density gages are in use to measure and control cigarette density, the quantity and the tightness of packing. Savings in tobacco alone from use of these gages have been estimated at more than $40 million per year.

A variation of the radioactive density gage is used to determine the hydrogen-to-carbon ratio in an analysis of hydrocarbon compounds, including jet plane fuels and fuel oils. The principle involves differences in absorption of beta rays caused by variations in electron density resulting from variations in hydrogen-to-carbon ratio. The percentage of hydrogen in a hydrocarbon, or the hydrogen-to-carbon ratio, can be used to furnish information in controlled thermal cracking of heavy hydrocarbons, such as fuel oils to produce lighter hydrocarbons, such as gasoline stocks; and for rapid analyses of hydrocarbon mixtures.

Analysis for hydrogen is important in many technical operations of refinery processes involving changes in the hydrogen content of the stock. For example, catalytic refining removes hydrogen from paraffin and naphthenes to produce aromatics. Catalytic hydrogenation adds hydrogen to olefins to form paraffins and to aromatics to form naphthenes. Solvent extraction selectively separates aromatic hydrocarbons from paraffins of higher hydrogen content.

The hydrogen-carbon index is thus of fundamental significance, but was not widely used until the gage became available. The failure to use the index previously was probably due to the fact that an operator could analyze only 4 to 10 samples a day using the old combustion technique. The radioisotope instrument can analyze samples with a precision comparable to that of the combustion techniques, and do it in about 5 minutes.

Liquid level gage. The radioactive liquid level gage is based on measuring the change in intensity of a beam of radiation from a fixed source. In this application the source is usually mounted on one side of a tank or vessel containing the liquid and the radiation detector on the other side. When the liquid rises to a certain level, it cuts off or reduces the beam. This particular adaptation has been found advantageous in measuring the height of molten metal in a cupola and helps eliminate problems of corrosion and heat damage.

Reflection of Radiation

When a beam of radiation is directed toward a material, some radiation is reflected. The amount reflected depends upon the type and energy of radiation and upon the composition, density, and thickness of the material.

Radiation reflection is serving a useful industrial purpose in the accurate measurement of the thickness of coatings laid over a base metal. For example, it is possible to measure the thickness of gold plated over copper, or rubber over steel.

In this technique the beta particles from a radioisotope strike the base metal, and the intensity of the reflected beam is measured. The metal then is coated or plated with a different material (either metal or nonmetal) and the reflected radiation is again measured. The change in reflection is proportional to the thickness of the coating, up to a certain limiting value, and to the difference in the atomic numbers of the material and the coating. It can be measured directly in millionths of an inch. Automatic adjustments in coating thickness can be made without stopping or cutting the sheet of moving stock.

Soil moisture and density gages are used in fieldwork, instead of slower laboratory determinations, to select suitable sites for aircraft runways, highway roadbeds, and waterway dams. Each gage uses a radioactive source, a radiation detector, and an electronic recorder.

One type of gage houses both source and detector in a tubular probe which can be lowered through a 1-inch-diameter steel tube driven into the ground. The *soil density probe* uses a cobalt 60 source inserted in the tip of the probe. Gamma rays from the cobalt bombard the soil surrounding the tube and are scattered by it. Some radiation returns to a Geiger counter mounted in the top of the probe and shielded against direct radiation from the cobalt 60. The amount of reflected radiation can be translated directly into soil density in weight per cubic unit.

The *soil moisture probe* uses a material which emits neutrons when activated by either alpha or gamma rays from radioactive material.

When fast neutrons from the neutron source strike hydrogen atoms in moisture in the soil, they are slowed down, and after several such collisions some are reflected back to the vicinity of the probe. The top of the probe contains a Geiger counter surrounded by silver foil and shielded against direct radiation from the neutron source. When a reflected slow neutron strikes the foil, a short-lived radioisotope of silver is formed. The radiation from this rapidly decaying silver radioisotope is measured by the counter, and the results can be translated directly into moisture content of the soil.

Luminescence

The ability of radiation to cause certain materials to emit light, or to luminesce, is the subject of a well-developed science, has many present-day applications, and offers much promise for the future. Many special compounds emit light rays when struck by atomic particles. These self-luminous markers can be invaluable in emergency situations and have vitally important military applications.

Routine applications of luminescence include such uses as illuminating dials and clocks, and providing photometric light standards. Luminescent sources have been used also for railway signal lights, safety lamps, equipment markers, airfield ground markers, firebox markers, deck markers, vehicle and road markers, signal lights, aircraft wingtip and tail lights, runway markers, and helicopter rotor blade.

Reactor-produced beta ray radioisotopes offer several advantages over the alpha-emitting radium and polonium used up to now: (*a*) pure beta ray emitters are less hazardous to health; (*b*) reactor-produced isotopes are usually easier to work with; and (*c*) beta radiation has been found to cause less deterioration of the phosphor than by the luminescent material than the alpha particles, leading to a more constant level of light output and longer life.

Ionization

The ability of nuclear radiation to ionize materials it strikes—that is, to knock electrons free from their nuclei, thus converting an atom into a negatively and positively charged particle called an ion—has been put to many beneficial industrial uses.

For example, static electricity in industry can be a menacing problem to production and personnel and may accumulate dangerously whenever the products being manufactured possess insulating properties. Through their ability to ionize molecules of gas in the air at selected points along the moving stock, thus providing a path for

static electricity to drain off continuously, radioisotopes "ground" the stock and help to meet this problem.

In another usage, a small amount of radioactivity inside certain specialized electron tubes keeps the contained gases in a partial state of ionization, assisting more dependable operation of the tubes. Certain radar tubes require a means for keeping the filling gas in a state of partial preionization. Operating characteristics became more dependable when a small source of radioactivity was incorporated instead of relying on cosmic radiation to accomplish ionization.

Special spark plugs utilize radioisotopes on the electrodes to improve firing characteristics. In addition, many lighting industries are doing research on the use of radioisotopes in fluorescent light tubes. It may be possible in the future to eliminate such accessory items as special starters and transformers.

Stimulation of Chemical Reactions

Radiation stimulation of chemical reactions is a growing industrial use of atomic energy.

Chemical reactions "triggered"—in a sense, catalyzed—by penetrating atomic particles include polymerization, cross linking, halogenation, and oxidation.

In *polymerization*, chemical reactions link molecules together in one long molecule or chain called a polymer. Plastics and synthetic rubbers are produced in this way. Nuclear radiations also can rupture molecular bonds to form new points of attachment for additions to the chains and thus produce new materials that are not possible or practical by other means. Reactions which have been studied include the formation of polymers of acrylic acid, styrene, and acrylonitrile.

The initiation of *cross linking* of long-chain polymers by radiation is receiving much attention in research. Molecules of a thermoplastic material such as polyethylene have many carbon-hydrogen bonds which can be broken by radiation. A single high-energy particle can produce this effect in thousands of molecules. The open bonds of one chain then join permanently to those of adjoining chains. Cross linking, as this is called, prevents easy sliding of the molecules and thus changes the melting point, solubility, strength, and other characteristics of the material.

Polyethylene may be irradiated to make it also more heat resistant, more elastic, less soluble, and more resistant to cracking. Polyethylene is used in manufacturing many household utensils, baby bottles, etc., where resistance to the temperature of boiling water is necessary.

In 1957, radiation was used successfully for the first time to *vul-*

canize an automobile tire. This marked the first basic change in the "curing" of rubber products since the discovery of vulcanization in 1839.

Without vulcanization, rubber is sticky in hot weather, brittle in cold, and subject to rapid deterioration. In conventional vulcanization of tires, sulfur and other chemicals are added to rubber and heated to more than 300° Fahrenheit. This treatment realines the molecules to give the material stability, linking the carbon atoms through sulfur atoms, a weak linkage.

Nuclear vulcanization was achieved without the use of heat or sulfur or chemical accelerators. It was done simply by slowly rotating the tire in a steel mold in the radiation from fuel elements removed from a nuclear reactor. The radiation resulted in a direct linkage of the carbon atom chains of the rubber molecules, a strong linkage.

The tread of this new tire showed "above normal" resistance to wear and abrasion. Further comparative tests are being made to determine the results from nuclear vulcanization under all conditions of normal tire usage. When nuclear energy becomes economically practical, tires in the future can be vulcanized "cold" on a production basis much more rapidly than by today's heat processes.

Halogenation reactions, in which chlorine, iodine, or similar halogens are joined to other chemicals to produce new compounds, often are extremely slow but can be greatly speeded up under ultraviolet light. The triggering energy also can be supplied by nuclear radiation.

Oxidation reactions also make up a large group of chemical processes. Modern chemical theory assumes that in many oxidation reactions there is a chain reaction of free radicals (ionized compounds) in the presence of oxygen. Radiation is effective in producing free radicals as well as ions and may lead to easy oxidation of materials difficult to oxidize by other means.

The possibility of thus producing cross-linked, degraded, and formed materials under accurately controlled conditions by the purely physical process of irradiation has valuable commercial possibilities. The extent to which it is used will depend on the cost of the irradiation process, the enhanced value of the material, and the comparative cost of competitive chemical processes if they are available.

Radiation Pasteurization and Sterilization

Gamma radiation in large enough doses can destroy bacteria, parasites, and enzymes in pharmaceutical materials and foodstuffs without raising its temperature significantly. Absence of high temperature is a necessity in processing many items such as antibiotics, drugs, and surgical supplies.

Radiation pasteurization offers a promising new principle of food preparation. Today food industries, research institutions, Government laboratories, and the military are actively engaged in research on radiation processing. The activities of these new groups are being coordinated in the radiation sterilization program of the Quartermaster Food and Container Institute, United States Army. Many believe that this research will lead to changing food containers, preparation and processing methods, and distribution and marketing practices.

Sterilization or pasteurization of foods by irradiation presents several problems as well as many promising aspects. Irradiation of some foods causes changes in texture, color, taste, odor, or nutritional value. Intensive research now is being done to learn why unwanted changes occur and to devise ways to reduce or prevent them.

The success of radiation sterilization and pasteurization is usually determined by the enhanced utility of products treated. When irradiation results in improved or longer lasting products, radiation treatment becomes profitable.

Radioisotope Batteries

Electricity can be produced directly by several methods from the energy released in the decay of radioactive atoms. The energy is extremely minute compared with that from reactors, but can be used for applications requiring tiny amounts of power.

The first of these methods utilizes a basic principle of physics. When beta rays are ejected from an insulated radioactive source, the source is left with an additional positive charge; this is the principle of the *Moseley generator*, developed in 1913, the first successful demonstration of converting ionizing radiation directly into an electric current. This principle has been adapted to a constant current-charger atomic battery.

Another type of battery, called the semiconductor battery, takes advantage of the electron-multiplication principle to produce electricity from radioisotopes. The electricity is generated by the high-energy beta particles emitted from strontium 90. These high-energy electrons are used to bombard a pea-sized silicon *P–N* (positive-negative) junction, formed by the merging of two specialized types of semiconducting silicon. The beta particles bombard the junction area and eject electrons from the molecules, thus causing a current to flow.

The *P–N* junction thus releases about 200,000 slow-moving electrons for each high-speed electron striking it. About one-millionth of a volt is produced, enough to cause an audible signal in a telephone receiver. The battery is about the size of a thimble and has a long life expectancy.

The thermopile battery uses a series of thermocouples to convert into electricity the heat from decay of a radioisotope. The battery contains several curies of polonium 210 sealed in a small capsule. The polonium is in contact with the hot junction of 40 thermocouples while the cold junction is located outside the container. Since a temperature difference of about 450° Fahrenheit is produced between the hot and cold junctions, a current is caused to flow through the device. The battery is about 0.2 percent efficient.

A fourth type of atomic battery, known as the contact, potential-difference, gas-ionization type, utilizes a radioactive source to ionize the filling gas between two electrodes of dissimilar metallic properties.

The fifth type of battery, the photoelectric, utilizes a radioactivated luminescent source to energize a photoelectric cell, thus producing a small electric current.

Tracing Atoms

The most important industrial application of radioisotopes is their use as tracers. As tracers incorporated into a material, radioisotopes indicate the complicated course of individual batches of atoms in physical transfer or chemical or biological reactions.

The material labeled and traced may be metal particles worn from a piston ring, catalytic beads circulating in a petroleum cracker, the boundary between two types of petroleum products flowing through a cross-country pipeline, the location of acid action to improve oil flow at the bottom of an oil well, water escaping from a leak in an underground pipeline, a pirate color in a textile printing operation which damages cloth, and hundreds of other practical everyday applications. Further tracer uses of radioisotopes undoubtedly will be devised.

RADIOISOTOPES IN MEDICINE AND AGRICULTURE

Knowledge gained by the use of radioisotopes in medical diagnosis and therapy, and in related basic studies, and in many agricultural fields has expanded steadily since 1946 when reactor-produced radioisotopes first were made available in quantity.

Here, this report summarizes current status of radioisotope research in the life sciences.

In the field of *cancer research*, efforts are being made to use radioisotope-labeled antibodies against cancer cells. Work on radiomanganese will continue since this radioisotope has given promising results through its ability to localize in the liver and irradiate can-

cerous tissue there. The substance controlling red blood cell production is under intensive investigation at Argonne Cancer Research Hospital and efforts will be continued to isolate this hormonelike substance. Results of treatment of a limited number of brain tumor patients irradiated at the Brookhaven National Laboratory are being carefully evaluated in preparation for the full-scale use of the new medical reactor now under construction at the Brookhaven Medical Research Center. A number of radioisotopes, including some less common isotopes, will be studied for their effectiveness in relieving the accumulation of fluid in the pleural and abdominal spaces due to cancer.

In the field of general *medical research*, apart from cancer work, the uses of radiation and radioisotopes as a tool in the study of diseases will continue. Some of the major advances—use of the radioactive dye rose bengal in diagnosis of malfunctioning of the liver and of diodrast in kidney cases—are described in a later section on medical research. Studies are underway to utilize radioisotopes for the direct evaluation of blood flow through internal organs, such as the liver and heart. The endocrine function of the pituitary gland will be studied through the use of the 340-Mev proton beam from the Berkeley cyclotron which is capable of selectively destroying minute areas in the structures within the skull. Radioisotope labeled drugs are being studied to elucidate the mode of action of the drugs. Labeling of compounds built into normal body substances, such as proteins and hormones, has led to significant advances in knowledge of the detailed biochemical changes which occur in a variety of diseases.

Biological research includes studies designed to increase knowledge of the life processes in terrestrial and aquatic organisms. Apart from the direct applications of this knowledge required for the activities of the Commission, the use of radioisotopes provides important tools for research on the effects of radiation on plants, animals, and man and helps solve many biological and agricultural problems. Agricultural research already has provided direct benefits.

The *agricultural program* includes studies on farm animals, soil chemistry, crop improvement, and plant physiology. Research on farm animals includes physiological, metabolic and nutritional studies, and investigations of livestock diseases. In soil chemistry, researchers traced the movement and uptake of essential minerals by soils and plants. The mode of action of insecticides was studied as was absorption and distribution of plant-destroying chemicals in plants, knowledge which will assist control of pests, parasites, and weeds. Plant nutrients (fertilizers) and growth hormones were investigated. The use of radiation to induce mutations which may be

beneficial has been applied to such crops as apples, grapes, tomatoes, corn, soybeans, and peanuts. Plant physiology research includes basic metabolic and biochemical studies.

Another area of biological research supported by the Commission is the impact of various atomic energy activities on *man's environment.* Basic information is sought concerning the balance between all forms of life and their environment on land, and in sea- and fresh-water habitats. The answers will assist decisions concerning the rate and extent to which agriculture, industry, and atomic energy activities may occupy an area and lead to general benefit rather than detriment.

In all these studies in which radioisotopes have played their unique role in furthering knowledge of the basic processes of life, and in providing the tools which enable improved diagnosis and treatment of diseases, and improvement of crops, animal husbandry, and food production, the benefits are readily recognizable.

The Commission's *total program* of research in the life sciences is, of course, much broader than that summarized here which deals only with radioisotope studies. The program is concerned with radiation protection and with evaluation of the hazards of radiation, as well as the exploration of beneficial uses of atomic energy. The primary effort at this time is concentrated on problems associated with protecting the populace, including atomic energy workers, from possible hazards of radioactivity. Research continues to progress ahead of developments of practical uses, in general maintaining its normal position leading the way to practical application and contributing to beneficial aspects of nuclear energy.

Expenditures for the biology and medicine program have increased during the past 3 years in keeping with continuing progress in civilian uses. In fiscal year 1954 the program cost, including depreciation of facilities, was $27.2 million. In fiscal year 1957, the equivalent cost was approximately $33.1 million,[4] and for 1958 estimated costs, including depreciation, are $40.5 million.

The major portion of the Commission's research program in biology and medicine is conducted at Commission laboratories and major atomic energy projects at a few universities and laboratories under cost contracts.[5] Support of this research work receives about two-thirds of the appropriated funds. The Commission also uses the talent and facilities of many universities, hospitals, and other institutions for selected research projects. Appendix 9 lists the current research contracts for which a total of about one-third of the funds has been budgeted for participation by about 500 contractors.

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[4] See p. 219, Twenty-first Semiannual Report to Congress (July–December 1956).

[5] See pp. 219–220, Twenty-first Semiannual Report to Congress (July–December 1956).

Cancer Program

The application of radioisotopes to the diagnosis, localization, and therapy of various forms of cancer led in the early days of the Commission to establishment of the medical division at the Oak Ridge Institute of Nuclear Studies, and the Radiological Laboratory at the University of California School of Medicine in San Francisco, both devoted almost exclusively to the study of cancer.

The interests at Oak Ridge include application of cesium 137 and cobalt 60 in teletherapy of cancer patients, clinical studies utilizing iodine 131 and radioactive rare earths, metabolic studies, and problems associated with internally deposited radioisotopes. This group also studies problems associated with instrumentation, including the preparation of brachytherapy devices, thyroid uptake calibration, and teletherapy designs.

The University of California Radiological Laboratory facility devotes much of its effort to treatment of patients with the electron synchrotron which produces 70-Mev X-rays.

After establishment of a medical department at Brookhaven National Laboratory, investigations were undertaken in 1950 of the possible treatment of brain-tumor patients utilizing the neutron flux from the nuclear reactor. This research resulted in construction of a new medical reactor, the first in the United States, planned for completion in 1958.

The latest and largest cancer research facility of the Commission, the Argonne Cancer Research Hospital, is operated by and located on the campus of the University of Chicago. It was authorized in 1949. In addition to considerable research on fundamental problems associated with cancer, the hospital has available for patient treatment, in addition to isotopes, a cobalt 60 source, a 2-Mev Van de Graaff electrostatic generator and a linear accelerator, the last to be completed in 1958.

The Commission supports additional research through contracts with various hospitals, medical schools, and other instutions. This program includes teletherapy work, treatment with radioactive isotopes, studies of factors that cause cancer, and work on methods of diagnosing cancers and locating tumors.

Teletherapy

The fact that elements such as cobalt could be made highly radioactive in reactors led to use of this powerful source of high-energy gamma radiation as a substitute for high-voltage X-ray in certain types of therapy. The first cobalt 60 source was installed in 1952 at

Oak Ridge Institute of Nuclear Studies. In 1957, there were well over 150 installed cobalt 60 sources used for therapy in the United States, ranging in power from 600 to 1,900 curies.

In addition to a University of Michigan program partly supported by the Commission, undertaking to obtain clinical evaluation of cobalt 60, cesium 137, and 250-kilovolt X-ray therapy, the Commission is partly financing four additional teletherapy centers as a source of data on cancer patients for subsequent evaluation. These are at the University of Arkansas, Cedars of Lebanon Hospital, Emory University, and Wayne University.

Use of supervoltage equipment is being evaluated through Commission support of studies at the Radiological Laboratory, University of California, San Francisco, and with the 2-Mev Van de Graaff electrostatic generator at the Argonne Cancer Research Hospital.

To date the period of observation of patients receiving high energy therapy has been much too short, and the number of patients treated too few, to permit conclusions regarding altered rates of survival.

Experimental irradiation of pituitary. At the University of California Radiation Laboratory, Berkeley, 340-Mev protons from the 184-inch cyclotron have been used to irradiate the pituitary gland of cancer patients in order to modify the hormonal balance and thus slow the growth of cancer of the breast. Thirty patients with inoperable breast cancer, who previously had all other types of treatment, were exposed to the high-energy proton beam to destroy the pituitary gland. Two years have elapsed since treatment and there is evidence that the protons have produced all major physiological signs of hypophysectomy (surgical removal of the pituitary) in these patients without undue radiation damage to surrounding tissue.

Pituitary irradiation has also been accomplished at the Argonne Cancer Research Hospital through a unique application of irradiated yttrium pellets implanted surgically in human patients.

Isotope Treatment

Despite the usefulness of radioisotopes in cancer research, no substantial progress has been made in the use of radioisotopes to treat cancers. The use of radiogold in palliative treatment of ascites tumors continues, as does research in the use of radiocolloids and the rare earth elements (lutecium 177, yttrium 90, etc.) in the treatment of various malignancies.

Studies of gastric malignancies include the use of a ruthenium 106 and rhodium 106 source as a possible procedure for alleviating the condition. Data are not complete enough to warrant valid conclusions.

Carcinogenesis

In an effort to obtain all possible information on the cancer-causing, or carcinogenic, effects of radioisotopes on man, the Commission is supporting a well-rounded program. In addition to studying the formation of bone-tumor consequent to ingestion of bone-seeking isotopes, researchers have underway long-term investigations on the effect of tracer and therapeutic doses of iodine 131.

Production of skin cancer in experimental animals following irradiation by both alpha- and beta-emitting isotopes is being studied as is the effect of X-ray, as well as ionizing radiation, on induction of pituitary tumors, and the possible production of lung cancer by inhaled and deposited radioisotopes.

Brain Tumor Work

Phosphorus 32 has been rather widely used in diagnosing many diseased conditions, including malignant eye tumors.

Considerable progress has been made in the diagnosis and localization of brain tumors, especially glioblastomas, by using iodine 131. Recent attention has been focused on using positron-emitting isotopes (i. e., arsenic 74, copper 64, rubidium 84, and manganese 52) instead of iodine. Studies at Massachusetts General Hospital, supported in part by the Commission, aim at improving the detection and localization of intracranial lesions with a technique using coincidence-counting radiation detection equipment.

Results in patients thus far have been encouraging. This aspect of the research is being pursued vigorously and has been extended to positron scanning in organs other than the brain in an effort to detect malignant conditions as early as possible.

Therapeutic work has been conducted at Brookhaven National Laboratory, in cooperation with the Massachusetts General Hospital neurosurgical group, on a small number of brain-tumor patients. They have been given injections of boron salts which concentrate in the tumor and then exposed to the neutron beam of the reactor to make the boron radioactive in an attempt to destroy malignant cells. Although innumerable problems remain, considerable improvement has been made in the techniques of this treatment. When the new Brookhaven Medical Reactor is ready for patient treatment, increased activity is planned. Meanwhile, studies continue on improvement of techniques.

In addition to these uses of radioisotopes in the cancer field, isotopes have proved invaluable in understanding metabolic events in malig-

nant conditions. Without the radioisotope as a tool in cancer research, knowledge of this disease would be far less than it is today.

Summary of Progress

The chief contribution to date of the atomic energy program to the study of cancer has been its provision of the new and serviceable tool, the radioisotopes, at nominal cost for use in all phases of research. Even with this new tool, no significant "breakthrough" is evident at the present time.

The advantages of teletherapy over use of X-ray therapy so far are largely economic—in more rapid treatment of a series of patients, for example. Another 2 to 3 years of treatments will be required before a valid chemical analysis can be made of the different therapeutic approaches.

The treatment of various types of cancer with radioisotopes all have their limitations and rarely effect a total cure; for the most part they are palliative.

One of the most encouraging applications of isotopes has been in the area of brain-tumor localization, and there has been considerable success in defining the size and limits of intracranial lesions using the positron-emitting isotope, arsenic 74, with coincidence-counting scanning technique. The information so obtained has enabled the surgeon to operate with increased certainty as to the tumor limits to help ensure its complete removal.

Radioisotopes in General Medicine

Studies of Blood-Forming System

During the past 3 years the following approaches to studies of the function of the hematopoietic or blood-forming system have yielded significant results: (*a*) the use of radioactive iron to study the physiologic sequences of formation and destruction of hemoglobin in the red blood cells; (*b*) the use of radioisotopes to study hormonal and humoral control of blood formation; (*c*) the use of radiocobalt-labeled vitamin B12; and (*d*) the treatment of diseases of the blood, including polycythemia vera (excessive production of red blood cells), various forms of anemia (deficiency of red cells), and leukemia (cancerous multiplication of white blood cells).

Iron metabolism. The use of tracer amounts of radioactive iron (Fe 59) has led to developing a functional approach to the study of red cells in anemia and polycythemia vera. Tracer measurement of

iron in plasma and red blood cell samples, and the measurement of the uptake of iron by liver, spleen, and bone marrow, make it possible to estimate the rate of red cell production as a reflection of hemoglobin synthesis and to locate the sites of production and destruction of red cells. This work stemmed from the original observation that differences in red cell production rate are qualitatively related to the rate of iron turnover of the blood plasma.

One advance in techniques has been the use in calculating red cell production rate of an electrical analog, an apparatus that permits accurate and rapid analysis of results. Besides the plasma, there appear to be at least two other reservoirs of iron in the body involved in iron turnover. Experimental studies are in process to verify this.

Despite difficult problems, radioiron probably offers the best tool for assaying red cell production. When the data are carefully collected for long periods, and an analog computer used, a precision may be obtained in rate calculations which exceeds that of previous diagnostic procedures.

The blood-forming hormone. The use of radioiron as an indicator of erythropoietic (red blood cell forming) activity, or as a convenient label for determining the volume of cells, has assisted considerable advances in the knowledge of both clinical and experimental hematology. The source of the erythropoietic hormone controlling red blood cell formation has not been established, although some evidence points to the kidney as a likely site.

Pituitary extracts chemically similar to adrenocorticotropin (ACTH), but which may possibly represent a separate substance have been shown to stimulate the activity. However, an erythropoietically active substance has been found in the plasma of animals from which the pituitary has been surgically removed and which have been made anemic, but not in the plasma of animals with the kidneys removed which have been made anemic. This suggests that the kidney may be a possible source of an erythropoietic hormone.

Work now is in progress using parabiotic animals—i. e., animals whose blood circulations have been interconnected—to determine whether kidney removal blocks production of an erythropoietic hormone directly by removal of the source, or indirectly by toxic inhibition of production of the substance elsewhere.

There are indications that the dynamic equilibrium of the hormone was conditioned by the relationship of the oxygen supply in the tissue to the tissue's demand for oxygen, rather than by either factor acting alone. Conditions that reduce the demand for oxygen while the supply remains normal (acute starvation or the condition following hypophysectomy, i. e., pituitary removal), and ones that increase the

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supply while the demand remains normal (transfusion-induced polycythemia or hyperoxia from an excess of red blood cells), all cause a profound decrease in erythropoiesis in rats. Measures that increase the demand for oxygen while the supply remains normal (the injection of dinitrophenol or triiodotyyronine) or that decrease the supply while the demand remains normal (bleeding or phenylhydrazine-induced hemolysis) increase erythropoiesis in rats.

In another phase of investigation, cobalt 60 was used as a tracer to determine the physiologic action of the cobalt ion, which stimulates production of the erythropoietic hormone.

An erythropoietic substance has been found in extracts of plasma from some patients with polycythemia vera and secondary polycythemia but not in extracts from normal subjects.

Both plasma and urine from some patients with aplastic anemia have shown erythropoietic activity by the radioiron incorporation method, and the expansion of red cell volume in animals injected with these substances. Urine from a patient with aplastic anemia, whose plasma had showed the highest erythropoietic activity in one test series, had sufficient activity to double the incorporation of iron into hemoglobin in normal rats when given over a 2-day period, and to produce a significant increase in red cell volume in normal adult rats when given over a 14-day period. Further studies on the isolation and characterization of the urinary factor are in progress.

Survival of cells measured with radiophosphorus. Diisopropylfluorophosphate labeled with phosphorus 32 has been used to study the survival of red and white blood cells and platelets. This substance forms an irreversible bond with enzymes in red and white blood cells and platelets. The survival time of these elements in the circulation can be determined simultaneously in the same blood sample.

Diagnostic applications of radiovitamin B12. Radioactive vitamin B12 labeled with cobalt 60 is being used in the diagnosis of pernicious anemia. External measurement of liver radioactivity after a subject has ingested radioactive vitamin B12 permits accurate estimation of the degree of vitamin B12 absorption and the diagnosis of early or a typical case of pernicious anemia as well as the more easily detected severe cases. A test using radiovitamin B12 is being developed for measuring liver cell damage in hepatitis.

Physiology of circulation. Studies have shown that severe depression of the circulation occurs immediately after a severe burn. Measurements, using colloidal chromic phosphate labeled with phosphorus 32, indicate that both the amount of blood pumped by the heart and the

blood flowing through the liver fall to very low levels several hours before there is a significant fall in blood pressure or reduction of plasma volume.

In shock caused by hemorrhage, however, the blood flow through the liver is directly proportional to the volume of blood in the body. Thus, if one-third the blood is removed by hemorrhage, the liver blood flow falls by one-third. Or, if excess blood is transfused, the liver blood flow increases by a proportional amount.

This observation and the knowledge that the liver inactivates the salt-and-water-retaining hormones have been coupled to evolve a theory for the mechanism by which the body controls the volume of its fluid compartments, including the volume of blood. Thus, the mechanism which operates to restore precisely the original volume of blood following hemorrhage, or destruction of the excess following hypertransfusion, has been elucidated to some extent.

Bone-marrow studies. Failure of the blood cell forming tissue within the bone marrow to produce one of the various cell types may lead to anemia, infection, or hemorrhage. The rapid growth characteristics of bone marrow, its sensitivity to irradiation, the demonstration of the feasibility of transplants of marrow from one individual to another, and the accessibility of bone-marrow's cellular product by blood sampling, are some of the reasons for current investigation on this tissue.

Of the various cellular elements produced by the marrow, the erythrocyte (red blood cell) lends itself best to quantitative measurement. Studies have been directed toward a better understanding of normal red cell production and of the disturbances which occur in anemia.

By the use of radioiron as a tag for nucleated red cells of the marrow, it has been possible to determine the number of erythrocyte precursors in the marrow of animals and man. Thus, for every 1,000 mature red cells in circulation in man, the studies indicate there are about 12 circulating reticulocytes, 12 marrow reticulocytes, and 12 nucleated red cell precursors. To supply the 0.8 to 0.9 percent of circulating red cells required daily to replace cells destroyed, the marrow-nucleated red cells must double their number every 36 hours.

These observations agree with other studies of radioiron turnover within the marrow. In man, this turnover time is 3½ days, half of which time relates to nucleated red cell production and half to maturation. Studies in anemia patients indicate that this turnover time may be shortened to 1 or 2 days. This is accomplished largely by the premature delivery of marrow reticulocytes into circulation. In experimental anemia, the entire marrow reticulocyte pool has been shown to move into the circulating blood.

Composite studies of red cell production and destruction in man indicate that the marrow can acutely increase its production of red cells to 3 times normal, and that production rates of as much as 6 times normal are found in chronic congenital hemolytic anemia. For anemia to occur, red cell destruction, or blood loss, must exceed the indicated rates of production, or marrow response must be impaired.

Three categories of marrow malfunction have been distinguished: (*a*) relative marrow failure where red blood cell production may be increased, but not to the expected levels; (*b*) absolute marrow insufficiency; and (*c*) marrow malfunction where there is evidence of abnormal overproduction of marrow cells, resulting in increased hemoglobin synthesis, but not a corresponding degree of delivery of red cells into circulation. This disparity between total and effective marrow activity was found to be characteristic of both Cooley's anemia and pernicious anemia. It is possible that the red cells in these diseases are so defective that many of them are destroyed in the marrow before being delivered to the circulating blood.

These studies to date have provided a picture of the numerical size of the red cell marrow, its capacity to respond to the stimulus of anemia, and its abnormal behavior in certain diseases of the blood-forming organs.

Transplantation of bone marrow. Recent developments have pointed to the feasibility of transplanting blood-forming cellular elements into an irradiated animal to tide it over the period during which its own marrow function is depressed.[6] In this connection, studies are underway on methods of procuring and preserving bone marrow.

In anticipation of the need for human bone marrow for transplantation work in human beings, attempts have been made to organize a system of procurement that would assure a constant supply of bone marrow for preservation and transplantation. To date, human bone marrow has been obtained principally from surgical sources and transplants have been made into a very limited number of patients with diseases of the blood. No successful acceptance of transplants by the recipient has yet been reported. Successful "takes" in animal experimentation occurred only when the recipient had been given a heavy dose of radiation which knocked out the immune mechanism which determines acceptance or nonacceptance of the transplant.

Efforts also are being made to preserve marrow at low temperatures. Bone marrow removed from the femurs of mice was preserved by slow freezing in a 15-percent glycerol mixture, and later injected into

[6] See p. 120, Twenty-second Semiannual Report (January–June 1957), and pp. 218–219, Twenty-first Semiannual Report (July–December 1956).

lethally irradiated mice. When the marrow was injected within 48 hours after total body irradiation, 90 percent survived.

In studies of preserving human marrow, the material is frozen at variable rates, then thawed rapidly, and then checked for changes in cell motility, morphological appearances, and tissue culture performance as measurements of viability.

Platelet storage. Three cellular elements float free in the blood: The red cells that transport oxygen and other substances; the white cells that fight infections; and the platelets. The platelets are much smaller than the red or white cells, and have the important functions of retaining the blood within the circulation system by initiating the clotting of blood when blood vessels are injured. When the platelets are lacking or greatly diminished, as following large doses of ionizing radiation, blood tends to seep out of capillaries into tissues; bleeding takes place from body surfaces and into the brain; the clotting mechanism is seriously disturbed and the individual may bleed to death from a minor injury.

Work with platelets in the past 5 years has been concerned with attempts to study their chemistry, their physiology with regard to their utilization of oxygen and carbon dioxide, and other indications of their metabolism. Unlike the red cells, the platelets have an active respiration and use up a good deal of oxygen. Preserving platelets is a much more difficult job than preserving red cells, and ordinarily when platelets are required they are given as fresh blood. Large stores of platelets available for transfusion purposes would be desirable.

Platelets stored at icebox temperature (4° C. or 39.2° Fahrenheit), either as whole blood or as separated platelets, when resuspended in plasma, gelatin, or salt solution, show a very rapid and striking loss of the cells, metabolic activities with little or no activity is present after 12 hours. However, storage at deep-freeze temperatures improves the metabolic activity (20° to 40° below zero centigrade, or between minus 4° and minus 40° Fahrenheit). When the platelets are "flash frozen" and stored at these low temperatures, preferably as a platelet-rich plasma, or even when resuspended in salt solution, retain more metabolic activity for at least 1 week. Experiments are underway to test the storage survival of platelet function at even lower temperatures, i. e., −70° C. (−94° Fahrenheit). Increased metabolic activity apparently results from the addition of glucose, and an even greater increase with adenylic acid, an important constituent of platelet metabolism.

Preservation of platelets in their "wet" state at very low temperatures appears to be feasible. From 1 pint (500 cc.) of blood, about

2.5 cc. of platelets can be extracted by centrifugation; indicating that large quantities of platelets in "wet mass" can be stored.

Lyophilized (flash dried) platelets take up considerably less room, and some workers have found they produced a very definite effect when introduced into the blood of patients with a platelet deficiency. Other studies indicate that lyophilized platelets retain little, if any, metabolic activity. "Dry" platelets appear to have the physical characteristics of normal platelets, but retain only some of their physiologic properties.

Platelets, either fresh or preserved, are of value only for emergency use to tide a patient over the first stages of a bleeding crisis due to platelet deficiency.

Bone Research

Radioelement deposition in bone. The crystalline portion of the bone is capable of retaining foreign ions by either an exchange mechanism or by molecular entrapment. The structure and dimension of the bone crystals may affect this propensity and may influence the rates of deposition and the kinds of materials deposited. Electron microscope studies of the minute structure of bone crystals have been undertaken to elucidate the deposition mechanism. Investigators have been able to produce electron micrographs of thin sections of undecalcified dog and human cortical bone which show needle-shaped crystals 40 to 60 angstroms wide and 600 to 700 angstroms long. This result supports the concept of rod- or needle-shaped structures and fails to confirm an earlier concept of the hexagonal "platelet"-like structure of bone crystals. The shape and size of the crystals are an important aspect in the uptake of the elements, which is presumably a surface reaction.

The microscopic pattern of deposition of the calcium-like elements in bone shows a lack of uniformity, and thus sampling and counting techniques are of little use except for average deposition or retention measurements. Autoradiography is being used to investigate quantitatively the metabolism of calcium in bone. The first step is a three-dimensional mapping of some of the regions of most active calcium deposition. Serial sections covering as much as a centimeter of bone have been made from dogs injected with tracer doses of calcium 45, and a diagram was constructed to show the extent and ramifications of the radioactivity. By preparing serial photomicrographs and corresponding autoradiograms, it has been possible to compare the deposition of the calcium 45 with the histological appearance of an area.

Bone grafts. Experiments with radioisotope-labeled rabbit bone transplanted into hosts have shown that the donor tissue can induce the host to fill a defect, to fuse a joint, or to unite a fracture when only one-third or less of its total mass has been absorbed and replaced by the host. The bone matrix and the bone mineral are absorbed together, and interestingly enough the labeled constituents are dissolved and carried into the systemic circulation of the host and not transferred locally.

When a bone graft "takes," the donor tissue is fixed to the host's bone by a layer of cement substance formed by the host. When a bone graft operation fails, the donor tissue does not fix but instead becomes encapsulated in an envelope of fibrous tissue which puts it virtually outside the body.

Ordinarily, the host cells grow into the donor tissue in an orderly pattern and not by haphazard progress; the trabeculae of new bone from the host bed grow into the donor and each one finds a trabecula of dead graft bone on which to fasten itself. Thus the function of the donor tissue in all bone graft operations is to provide an absorbable network of surfaces upon which the host condenses the cementing substance and deposits the new bone.

Skeletal metabolism. Radioisotopes have been very useful in studies of skeletal metabolism. For example, injection of mixtures of carrier-free sulfur 35, calcium 45, and yttrium 91 at various stages of repair into rats having bone fractures has elucidated the sequence and duration of several biochemical events during healing. Cyclotron produced strontium 85, in conjunction with gamma scintillation detectors and pulse height analyzers, has been utilized to follow the very rapid skeletal deposition of strontium and its slow loss over periods of several months, without harm to the test rabbits. These and similar experiments with sodium 24, iodine 131, and chromium 51 have yielded information and techniques which are of clinical value in studying human skeletal disorders.

Radioactive Drugs

The behavior of many important drugs has been studied by using radioisotopes, including the metabolism, detoxification, excretion, and fate of the drugs in experimental animals and selected human patients. Carbon 14 has been the isotope of choice in many of the drug studies. Carbon is present in all organic compounds; in the form of radioactive carbon dioxide, it is readily absorbed into plants. Carbon 14 has a long half-life (over 5,000 years) which makes long-term studies possible; and it emits weak beta rays which can be easily

measured but which in small amounts present only a minor health problem.

One technique employed for obtaining labeled radioactive drugs is to grow certain drug plants in the presence of radioactive carbon dioxide. After the radioactive carbon (carbon 14) is incorporated into all materials manufactured by the plant, it is harvested, dried, finely pulverized, and the labeled drug extracted and refined. Some drugs synthesized by this method, and studies with these drugs that have contributed to a better understanding of how they act within the bodies of normal and diseased human beings, are described below.

Digitoxin, a drug that is supportive in cardiac function, obtained from the foxglove plant, persists in the body at least 80 days after initial administration and is changed by the liver into other compounds, one of which is digoxin, itself an active heart drug. Digitoxin does not accumulate in the heart as previously supposed but primarily in the liver and kidney. It passes from a pregnant mother to her child only in minute nontoxic amounts.

Colchicine, an antigout and antimitotic agent, obtained from the autumn crocus plant, prolongs the sleep and sedation caused by hypnotics and anesthetics. The effect of colchicine on the action of thiopental, an anesthetic, is to prolong the sedation by inhibiting the breakdown of thiopental in the body and by decreasing urinary output.

Morphine, obtained from an opium poppy, was found either to interfere with the utilization of glucose by the brain, or with the transport of glucose into brain, and this effect may in part explain the depression of the central nervous system by morphine and related compounds. Compounds have been studied also which counteract the depressant properties of morphine and morphine-like substances, and these studies show that the antagonists reverse the urine-suppressing effects of the narcotic and thereby assist more rapid urinary excretion of the narcotic.

Studies with antituberculosis drugs indicate that *para-aminosalicylic acid* (*PAS*), and *isoniazid* penetrate readily into the tuberculous caseous material (the site of the tuberculosis infection). Isoniazid actually shows an affinity for the site of tuberculosis infection while PAS is not retained. This may explain why isoniazid is the more effective of the two drugs ln the treatment of tuberculosis. A study into the relationship of PAS to connective tissue disease showed that the salicylate localizes in the cartilage.

Central nervous system drugs are being studied in order to gain fundamental information about action of drugs on the brain. Isoniazid has been shown to concentrate in gray matter, especially in the hippocampus. Carbon bisulfide, an industrial solvent, concentrates

in the white matter and appears to be correlated with myelin formation. Acetazolamide (Diamox) differs from both of these and concentrates at the meningeal surface of the central nervous system. Urea gains access to the brain but is not metabolized by the tissues of the central nervous system.

Reserpine, which occurs in the root of *Rauwolfia*, is of medical importance because of its tension-reducing and tranquilizing action. Its metabolism has been studied using a reserpine with a carbon 14-labeled methoxy group. In order to investigate more fully the metabolic fate of reserpine, a form uniformly labeled with carbon 14 was produced by biosynthesis. Four different species of the plant were grown in an atmosphere enriched with radioactive carbon dioxide. The two most efficient species were selected and grown, and the reserpine isolated from the roots for use in animal metabolism studies.

In addition to the projects described above, *other studies* which have been carried out are: the effect of SKF–525A and quinine on the excretion of carbon 14 pentobarbital; role of various tissues on the metabolism of carbon 14-priscoline in rats; uptake of potassium 32 into various phosphorus-containing fractions in the brain of normal, hypophysectomized, and ACTH-treated hypophysectomized rats; site of synthesis of atropine in belladonna plants; laboratory synthesis of diamox-1-sulfur 35 and effect of hydrocortisone in $C^{14}OOH$-P-aminosalicylic acid distribution in the cartilage of rats.

Bibliography of carbon systheses. Methods of synthesizing most biologically important substances have been known for a long time, but new methods had to be devised to place a radioactive tracer atom in a specific position in a molecule needed for a research project, and to do this efficiently. Because developing new synthetic methods is time consuming, ready access to details of methods already devised for "labeling" or "tagging" compounds with radioactive carbon is of great value.

In the hope of making somewhat easier the job of searching literature on these techniques, organic chemists at the University of California at Los Angeles Atomic Energy Project have compiled a "Bibliography of Syntheses with Carbon Isotopes," abstracting some 750 individual publications issued through 1952. A supplement, reviewing some 600 additional publications in 1953–54, has been completed.[7]

Vitamin B12. Crystalline cyanocobalamin, commonly known as vitamin B12, is essential for human nutrition. Therefore, it has been important to study the metabolic function, means of increasing

[7] *Bibliography of Synthesis with Carbon Isotopes*, through 1952, UCLA Atomic Energy Project, UCLA-316; Office of Technical Services, Department of Commerce, Washington 25, D. C.; December 17, 1954; $1.05. *Bibliography of Synthesis with Carbon Isotopes, 1953—54*, UCLA Atomic Energy Project, UCLA-395; Office of Technical Services, Department of Commerce, Washington 25, D. C.; July 25, 1957; $1.

absorption, and the role of vitamin B12 in disease and in nutrition. The absorption of orally fed vitamin B12 is poor, but can be improved by the coadministration of an intrinsic factor obtainable from hog stomach or duodenum. (Intrinsic factor is an unidentified, unspecified, material produced in the mucosal cells of the stomach and upper duodenum which has the function of assisting in the absorption of vitamins.) The highlights of recent studies on vitamin B12 facilitated or made possible by the availability of this vitamin with a radioisotopic label may be divided into three parts:

In studying the *mechanism of B12 absorption,* researchers found that certain preparations of intrinsic factor contained substances which enhanced absorption and that other preparations inhibited absorption. Prolonged feeding of the latter type of preparation caused B12 deficiency.

The intrinsic factor is a large mucoprotein molecule. However, it has been found that a common food additive of small molecule weight, sorbitol, can improve B12 absorption by healthy people, in a manner similar to the intrinsic factor preparations that do not inhibit B12 absorption. This compound may be found to assist also in the absorption of nutrients.

Vitamin B12 as a therapeutic is effective in treating pernicious anemia, sprue, and macrocytic anemia. Studies have been extended to possible use of this vitamin (*a*) in managing such metabolic diseases as diabetes, and (*b*) in supplementing the diets of pregnant women and the aged.

In diabetes, a metabolic derangement results in oversecretion of adrenal hormones and causes deleterious effects, such as hyperglycemia (excess of blood sugar). Adequate dosages of vitamin B12 will correct this condition.

The serum vitamin B12 level of older people is lower than that of the young. This phenomenon and other studies indicate low reserves of this nutrient among the aged.

Likewise, adequate supply of vitamin B12 should be provided to pregnant women since the embryonic child has a great parasitic demand for vitamin B12 which could enlarge a deficiency in the mother.

Intelligent use of vitamin B12 can be made only if its *metabolic role* is fully understood and if biochemical means are available to correlate with clinical manifestations of B12 deficiency. It has been found that B12 deficiency modifies the glutathione content of the red cells, decreases the enzymes capable of degrading glucose to ribose, and causes an increase both in blood sugar and cholesterol. All these data indicate the importance of vitamin B12 in utilizing sugars and fats.

Cell Metabolism

A clearer understanding of normal cellular physiology must precede determination of the fundamental disturbance which produces cancer. Radioisotopes have provided a powerful new tool for tracing complex interrelationships which govern the life and activities of the cell.

A key metabolite in the energy-yielding reactions of all cells is a derivative of the pellagra-preventing vitamin, niacin (nicotinic acid), known as diphosphopyridine nucleotide (DPN). The amount of this material within cells is crucial to their ability to obtain useful energy, either in the presence or absence of free oxygen. Fifteen years ago the enzymatic reactions which destroy or inactivate this compound were demonstrated, but the process of its manufacture never had been learned. With the aid of nicotinic acid labeled with carbon 14, it has been possible to trace the series of reactions by which niacin is converted to DPN in human red cells, rat liver, and baker's yeast.

Since the intermediate substances exist only in trace amounts, compatible with the vitamin status of nicotinic acid, the studies might have been utterly impossible without the sensitivity of detection provided by radioisotopic carbon. Three enzymes responsible for the reactions have been isolated and their properties are currently under investigation. The significance of this information is that, according to some investigators, the basic difference between tumor and normal cells is the extent of their aerobic glycolysis (handling of sugars in the presence of oxygen), and DPN is absolutely essential to this process.

Another aspect of these studies lies in the area of the actual enzymatic mechanism of biological oxidations. The operation of xanthine oxidase, an enzyme obtained from milk and liver, has been studied. Using six different radioisotopes and radioisotope-labeled substances—potassium 32, hypoxanthine-carbon 14, iron 59, sulfite-sulfur 35, cyanide-carbon 14, and acetaldehyde-carbon 14—researchers succeeded in assigning a structure to the "active site" of this enzyme, which has proved to be even more complex than had been supposed.

Liver and Kidney Techniques

Some medical uses of radiomanganese. Manganese has interested the biochemist for some time because of its catalytic properties in various enzyme systems. Nutritionists recently also began to study the metal which has been shown to be important as a nutrient and to be present in all living matter. Its concentration in animal tissues is very low, but it is constantly present and stable. When it is diminished because of nutritional deficit, disease sets in: Perosis

occurs in the chick; bone defects, sterility, and brain damage in other animals. Conversely, marked increases in concentration of manganese result in manganism, associated with an incurable palsy occurring principally in some miners of ferrous ores.

The dual role of this metal, as regulator in health and as a cause of disease, still is obscure. Studies with radioisotopes tend to elucidate this problem.

In early experiments with short-lived manganese 56, the isotope was found to disappear very rapidly from the blood stream after injection, having been taken up mostly by the liver and the pancreas. The cells of these two organs are very rich in mitochondria, intracellular structures primarily active in cell respiration. The theory that these bodies were instrumental in uptake of radiomanganese was confirmed by direct experiments with cats and rats.

The fact that the mitochondria accumulate radiomanganese led to a hypothesis that the disappearance rate of the isotope from the blood stream would be proportional to the body's mitochondrial population. Confirmation of this was desirable, because of the critical role of mitochondria in the phenomenon of life. Work on man showed that the early disappearance rate of manganese 56 from the blood correlated very well with its appearance in the liver, in which the cellular distribution pattern has already been studied. The quantitative relationships between blood and mitochondria must be known, however, before this technique can be used for clinical purposes.

The impressive efficiency of liver and pancreas in taking up manganese from the blood lead to another hypothesis, namely, that malignant tumors of these organs might be controlled by administration of the isotope. This was attempted in a small number of patients suffering from cancer of the liver, and they responded well enough to the injections to justify further effort.

Later, a depression of blood formation appeared in these patients, and this made mandatory the search for a means of accomplishing a more exclusive retention of the isotope by the liver. Best results were obtained from injecting radiomanganese into the portal vein, which transports blood directly from the intestines and spleen into the liver. Injection of animals via this route resulted in sudden enrichment of the liver with radioactivity with minimal destruction and exposure of the rest of the body. The recirculation out of the liver was so slow that it was considered of no consequence to the rest of the body when the short-lived manganese 56 was used.

The results of this animal study justify the resumption of therapeutic trials in man.

Tracers in testing kidney and liver functions. Diodrast has been used extensively in its stable form to measure specific functions of the kidneys, and rose bengal, a dye, has been used similarly in liver tests. Diodrast also has been employed in X-ray and fluoroscopy of the urinary tract and is known to be secreted actively by the tubular cells of the kidneys.

Rose bengal (tetraiodo-tetrachlor-fluorescein) has been known to be removed from the blood stream exclusively by the polygonal cells of the liver as is bromsulfalein, and both have been used to test liver function indirectly. In normal subjects each of these dyes is removed from the blood stream almost completely within 45 minutes after intravenous injection of a test dose, whereas in individuals having liver disease the dyes are retained in the blood for longer periods.

Employment of tracer quantities of rose bengal or diodrast labeled with iodine permits measurement of functioning of the kidneys and liver with gamma ray scintillation probes and radiation counting equipment. Use of minute doses has such additional advantages as absence of untoward drug reactions and rapid removal from the body, thus permitting subsequent repetition of test procedures without danger from either chemical reactions or radiation overexposure.

The techniques for performing these external tracer tests were first developed in animal studies and subsequently modified for application in clinical medicine after their feasibility and safety had been established.

Radiogram of liver. The original procedure for conducting a liver uptake-excretion test using rose bengal labeled with iodine 131 consisted of placing over the upper anterior surface of the liver a lead-collimated sodium-iodide scintillation probe, or instrument for detecting and measuring radiation. After intravenous injection of the tracer material, levels of radioactivity were measured continuously and registered graphically with an Esterline-Angus recorder. Later the technique was modified and a second recorder with a probe placed over the patient's head simultaneously registered the rate at which the blood cleared of the tagged dye.

A recent technique employs a single crystal detector and a scaler. From repeated (1 minute) measurements of radioactivity levels over the head, liver, and midabdomen, it is possible to determine the rates of blood clearance, liver uptake and excretion, and delivery of bile into the upper intestinal tract. When these values are plotted, it is possible to estimate liver vascularity, polygonal-cell function, and possible obstruction of the bile passages or other interference with the flow of bile.

This modified tracer technique, called the *rose bengal I 131-hepatogram*, has been employed in studying many patients with diseases of the liver and biliary tract. The original procedure has now been used to study liver function and bile-flow interference as influenced by carbon tetrachloride poisoning, X-ray exposure, and partial and complete bile-duct obstruction on a large number of test animals. On the basis of laboratory and clinical experience, this type of hepatogram is presently considered one of the more sensitive specific tests for polygonal cell function of the liver. When the procedure is used repeatedly in jaundiced patients, results correlate well with clinical findings and indicate the underlying physiological disturbances more quickly than do biochemical liver tests. Since the hepatogram also provides data on interference with the flow of bile, it has distinct value as a tool in distinguishing between diseases of the liver and biliary tract calling for medical treatment and those requiring surgery.

Radiogram of kidney. The technique of using diodrast labeled with iodine 131 for a radiogram of the kidney is similar to the rose bengal hepatogram and permits external measurement of three similar functions of each kidney individually: renal vascularity, tubular cell function, and possible obstruction of the upper urinary passages.

The test can be performed in a doctor's office: The patient is seated and a scintillation detector directed from above downward at the upper pole of each kidney. After intravenous injection of a tracer amount of test material there is an initial, rapid increase in radioactivity, the height of which provides an estimate of renal vascularity. During the next 3 to 5 minutes radioactivity levels rise abruptly and reach peak levels. Coinciding with this rapid rise in kidney radioactivity there is a reciprocal decline in blood concentration, indicating that this second segment of the renal uptake-excretion curve represents an active secretory process.

In normal individuals, kidney radioactivity levels then fall rapidly from their peak levels to near background values within 15 to 20 minutes. In patients or animals having upper urinary tract obstruction, this declining segment of the renogram is absent and replaced by a continued rise of radioactivity.

Renograms of this type have been studied thoroughly in several hundred animals and in 450 patients with a variety of renal and upper urinary tract disorders. Of 200 urological patients who produced normal renograms, no more than 3 percent was demonstrated by standard diagnostic methods to have significant renal diseases.

In urological practice, the major application of the diodrast renogram is in postoperative management of patients having obstructive disorders of the upper urinary passages. From a medical standpoint,

the renogram has considerable value as a rapid screening procedure to detect unilateral and renal disorders in children and young adults with hypertension. Since renal hypertension occurs in only 5 to 10 percent of hypertensive patients, individuals having normal renograms may by this process be spared extensive urological diagnostic examinations.

These investigations demonstrate the usefulness in research, and the clinical applicability, of dynamic, external radioisotope tracer techniques which permit the simultaneous measurement of multiple physiological events and the rapid clinical evaluation of specific renal-hepatic disorders. The same techniques may be adapted for investigation of other organs and organ systems.

Studies of Metabolism

Fat metabolism and artery disease. The deposition of fatty materials or lipids in the walls of the arteries of the body leads to a condition described under the general term of atherosclerosis, a variety of arteriosclerosis. The deposition of fatty materials in the arteries that supply blood to the heart muscles leads to coronary occlusion, coronary thrombosis, and myocardial infarction. Investigations with radioactive isotopes into the nature of this disease have been directed toward three fundamental problems: (*a*) the manner by which these fatty materials enter the arterial walls, (*b*) the rate at which they enter the walls, and (*c*) the underlying metabolic defect which determines the rate.

To test the theory that the macrophages (reticuloendothelial cells) are concerned in the transport of lipids, and hence are important in the production of atherosclerosis, these cells were labeled by means of radioactive thorium. The resulting data were interpreted as evidence against the macrophage theory of genesis of atherosclerosis.

Using tritium-labeled cholesterol (a fatty material) in studies of rabbits, it was found that the higher the level of this fatty material in the blood, the more rapidly it was incorporated into arteriosclerotic tissue.

The rabbits were caused to have a high cholesterol level by overfeeding with fats. However, again using tritium-labeled cholesterol, it was demonstrated that defects can exist in lipid metabolism which are independent of diet. The same conclusion was reached by using tritium-labeled fatty acids in humans. Further experiments using cholesterol labeled with carbon 14 as well as tritium are being conducted on the absorption, transport, and excretion of cholesterol in an effort to uncover these underlying metabolic defects.

Another study has been made of the means of transport of various types of fatty acids. Fatty acids of the three main types were labeled

by replacing their carboxyl groups with groups labeled with carbon 14. The fatty acids chosen were stearic (a saturated acid), oleic (a mono-unsaturated acid), and linoleic (a poly-unsaturated acid). These were fed to rats, and, at various periods following administration, the lipids of the rats' blood were isolated and separated by a chromatographic method. Results of these experiments indicated a theoretical basis for the different effects of these classes of lipids when present in the diet. It was shown that the saturated fatty acids in the diet promoted high levels of blood cholesterol, supposedly associated with increased incidence of atherosclerosis, and that the poly-unsaturated fatty acids tend to lower blood cholesterol values. Increasing the amounts of dietary poly-unsaturated fatty acids increased the amount of circulating phospholipid and lowered the blood cholesterol.

In these same experiments, it was shown that about 20 percent of the circulating carbon 14 was present in two lipid fractions not suspected previously: monoglycerides and diglycerides. The finding of this high proportion of recently ingested fatty acid in these partially degraded glycerides may indicate that this type of degradation proceeds in the blood during transport. The importance of this finding in consideration of lipids as sources of energy will be investigated.

Sugar metabolism and diabetes. Radioactive glucose labeled with carbon 14 is being used to measure the degree of impairment of carbohydrate metabolism in diabetic patients and to test the efficacy of new oral compounds as replacements for injected insulin.

Protein metabolism in the liver. On the biochemical level, nonspecific trauma, degenerative diseases such as arteriosclerosis, and the development and growth of cancer, are associated with extreme abnormalities in protein metabolism. Through the use of amino acids labeled with radioactive carbon 14, the pathways traveled by the amino acids in their buildup into the proteins of normal tissue and into the proteins of experimental cancer tissues have been followed.

In the adult animal where there is no net increase in tissue or blood proteins since full growth has been attained, the presence of the radioactive carbon in amino acids permits a quantitative estimate of the rate of protein buildup (synthesis) and breakdown (catabolism).

In these studies the role of the liver in metabolism of amino acids and proteins has been closely examined by devising and using a simple system for surgically removing a liver and pumping blood through it to keep it alive. This technique, with the aid of carbon 14-labeled amino acids, has revealed that the liver plays a dominant role in regulating the amounts of amino acids available for growth (protein

synthesis). The liver also is the major site not only of the production but also of the breakdown of the blood-plasma proteins.

The liver's function in supplying amino acids and other essential structural components for the abnormal growth of cancer is being currently investigated.

Radioactive uric acid labeled with carbon 14 is being used to measure disturbances in protein metabolism in patients with leukemia, polycythemia, and gout.

Radioisotopes and Livestock

In the animal science field, radioisotopes in the hands of scientists have provided information useful to producers of livestock. By labeling feed constituents with radioisotopes, investigators measured the extent to which these constituents went directly into the milk or were incorporated in body tissues. For example, it was found that some short-chain fatty acids are absorbed from the digestive tract and used for the formation of the milk sugar lactose, while other fatty acids are used mainly to form butter fat.

The pathways of metabolism of feed constituents for meat animals, and the complex changes that occur before their incorporation into body proteins and fats, have been partially elucidated by the use of radioisotopes.

In ruminants it was found that a lack of cobalt in the diet inhibited formation of vitamin B12. It was also found, by using cobalt 60 as a tracer, that the synthesis of vitamin B12 was inhibited by high levels of molybdenum, known to occur in natural feeds in some regions of the country.

Some breeds of cattle, especially those of European origin, have less tolerance for high temperatures than do some Asian breeds. The ability to withstand heat is closely related to the activity of the thyroid gland. Thus, thyroid activity is an excellent index of the way an animal is affected by temperature and the result in food consumption, milk production, and growth. Thyroid activity can be measured by using radioiodine which permits prediction of the potential capacity of a calf for milk or meat production, and assists in selecting and breeding cattle.

Until recently it has been thought that chickens could not utilize inorganic sulfur for building such organic molecules as the amino acids cystine and methionine. Recently it has been shown, using radioactive sulfur 35, that the chicken can use inorganic sulfur to form cystine, and that the addition of sulfate to some poultry rations increases the rate of growth.

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It has also been found that when low-protein diets are fed cattle and sheep, there is a definite requirement for sulfur.

Studies of Animal Nutrition

Much of the knowledge about animal nutrition is derived from studies of laboratory animals. Animals of economic importance, particularly large farm animals, are not widely used in rigorous experiments because of the prohibitive expense of highly purified diets. Isotopes such as carbon 14 and nitrogen 15 used to trace dietary materials have made it possible to conduct some experiments of this kind, which have heretofore been practical only in poultry and small laboratory animals.

Since the advent of radioisotopes, lactating farm animals have proved very useful laboratory animals because the milk provides sufficient quantities of rapidly synthesized protein and fat to facilitate useful tracer work.

Experiments showed that the pig metabolizes nicotinic acid in the same manner as the rat. This determination would have been a laborious and costly procedure by purely chemical methods, but by use of carbon 14-labeled nicotinic acid the problem was much more easily solved. In like manner studies have been conducted with vitamin A, the lack of which occasionally causes impaired vision in cattle.

The understanding of interrelations of vitamin B12 and the amino acids, methionine, choline, betaine, histidine, glycine and serine has been advanced appreciably by the use of isotope tracer techniques. A rationale has been derived for the correction of methionine deficiencies in dry plant livestock feeds by such additives as choline and betaine.

Fowls excrete most of their nitrogen in the form of uric acid. The manner in which the uric acid is formed has been largely determined in birds by means of isotopic tracers. In turn, this advance has provided a basis for understanding much of the mechanisms for synthesis of nucleic acids which are fundamental constituents of all living cells.

Among minerals of nutritional significance to farm animals, calcium is one of the most important. Studies of the absorption and excretion of calcium as affected by vitamin D have shown how to improve dairy cattle feeding so as to reduce the incidence of milk fever.

Other studies using calcium and phosphorus tracers have provided information which will enable livestock feeders to get maximum efficiency from feed by more careful control of the calcium-phosphorus

ratio of the diet and by eliminating high concentrations of elements which affect adversely the absorption of these elements.

Extension of the basic fact that the ability to concentrate iodine 131 in the thyroid glands of animals is an indicator of thyroid function has allowed research workers to study (*a*) the rate of thyroxine production under varying environmental conditions, (*b*) the effect of various drugs and natural feedstuffs upon thyroid function, and (*c*) to formulate means of increasing the rate as well as the efficiency of milk production.

Another discovery that shows much promise concerns the use of iodine 131 labeled 4-iodo-antipyrine for the measurement of total body water in farm animals. This discovery will allow research workers to evaluate more critically the effect of dietary additives upon body composition as well as rate of gain in weight.

Work during this period also showed that the volume of red cells, plasma, and total blood volume of farm animals could be determined by the use of radioisotopes such as phosphorus, chromium, iron, potassium, radioiodine- or radiochromium-labeled plasma protein. It has also been observed that in swine the total blood volume, expressed as a percentage of live weight, decreases with age, probably reflecting the increase in fat.

Other Studies

Milk formation. A great deal of research has been carried out with the dairy cow because of its importance as a provider of food. Much of this research has been done to evaluate feed effects on milk formation.

In the rumen of the cow, carbohydrates in the form of both starch and cellulose, as well as proteins, are acted upon by micro-organisms and broken down into small molecules. Radioisotopes show the principal end products to be acetic acid, propionic acid, and butyric acid. These are absorbed in the body for metabolic processes. Acetic acid is built into body fats and other substances, used for energy, and converted into milk fats. Propionic acid is converted into liver glycogen, and butyric acid appears to be converted primarily into beta-hydroxybutyric acid. Knowledge of such processes is extremely important in improving milk production.

When acetic, propionic, and butyric acids containing radioactive carbon were injected into cows, it was noted that 17 percent of the radioactivity from the acetic acid, 11 percent from propionic acid, and 6 percent from butyric acid appeared in the milk, thus giving their efficiency of transformation into milk. When glucose containing radioactive carbon was injected into the cow, 56 percent of the radioactive carbon appeared in the milk. By analyses of the milk and

study of the amount of activity found in each milk component, it was shown which milk substances arise from acetic acid, propionic acid, glucose, and butyric acid. These studies suggest the pathways by which biochemical transformations take place.

In a similar study, radioactive glucose pumped through an udder by an artificial heart-lung apparatus showed that all the radioactivity goes into milk sugar and practically none to other milk components. When injected into the cow, the glucose is converted into substances such as fat and protein, which then are carried to the udder by blood and converted into milk components. A considerable amount of the glucose also passes directly to the udder and is converted into milk sugar. By use of an artificial cow and radioactive glucose, it has been possible to show that the udder itself utilizes glucose only for milk sugar production.

This kind of information helps to improve milk production in individual animals, leads to the choice of economic feeds and better management practices, and assists in choice of better stock for breeding.

Agricultural Studies

Research on Insecticide Action

By incorporating a radioactive label into insecticidal compounds, research workers have accurately determined the nature and extent of possible toxic residues in or on raw agricultural commodities. To assure safe usage of the increasing numbers of organophosphate insecticides now commercially available, investigators defined the small differences in the mechanisms by which they poison insects and characterized the precise chemical nature of traces of their residues in food. The tracers also help provide a more complete understanding of the nature of the poison's toxic action on plants and animals.

Phosphorus 32 has been used to study the metabolic pathway of such organophosphorus insecticides as Parathion, Schradan, Dimefox, Thimet, Phosdrin, Delnav DDVP, Dipterex, Viozene, Malathion, and many others. Metabolism studies included insects, rats, dogs, cattle, and other large animals, agricultural crops and cocoa-producing trees.

Studies with radioactive Thimet assisted the U. S. Food and Drug Administration in making its determination that this substance could be used for seed treatment of cotton. Studies with radioactive Phosdrin led to FDA approval for its use on vegetable crops and on forage fed to cattle. Studies with radioactive Viozene led to an understanding of the residues associated with cattle ingesting this antimyiatic agent (protection against diseases caused by fly larvae in or on the

body). Studies with Parathion led to a demonstration of an unexpected metabolite appearing in the milk and meat of cows ingesting this chemical.

Recent studies have been initiated on the effect of one organophosphate on the metabolism and residues of a second phosphate insecticide; sometimes when mixed, the two organophosphates are more toxic than the sum of the individual toxicities. The individuals of such pairs of insecticides are being investigated by using one of the pair radiolabeled and the other nonradioactive, and then reversing the labeling.

Radiotracer Studies on Insect Biochemistry

Radiotracers have been used in insect biochemistry studies on the metabolism of cholesterol and iodine. Although insects do not require dietary iodine or a regulatory thyroxine hormone, they metabolize iodine in a manner very similar to mammals where iodine and thyroxine are essential. The insect sterols and the enzymes acting on them were found to be like those in mammals. Yet insects require dietary sterols and mammals do not. Differences in sterol biosynthesis may serve as a partial explanation.

Other Applications

Radioisotopes and radiation have provided many other possibilities for the eradication of harmful insects and livestock pests. Their migration has been measured by following the movement of insects made radioactive. Very encouraging results were first obtained in 1954 in the use of radiation to eliminate destructive insects.

Eradication of screwworm flies. It had been estimated that screwworm damage causes livestock producers of the southeast an annual loss of $10 million. The female fly of the species mates only once. It was found in the laboratory that about 3,000 roentgens of radiation would cause sterility in the male. By irradiating males with cobalt 60 gammas and releasing them among the natural population, researchers succeeded in eliminating screwworm flies in one season (1954) from the island of Curacao in the West Indies.

Since this study pointed to the definite possibility of controlling certain insect pests by radiation, the Department of Agriculture is conducting experiments to determine what techniques might be used in eradicating the screwworm from Florida. Techniques must be worked out for the release of sterile males. The optimum intervals at which drops might be made, and the number of insects required.

Weed Control-Plant Growth Regulators

A number of chemical compounds that, in very low concentrations, affect the growth or behavior of plants are commonly referred to as plant growth regulators, or weedkillers. Some of these such as 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) when applied to broad-leafed plants will cause the death of many varieties and are used in control of weeds in croplands.

The first recognition of selective herbicidal properties of plant-growth regulator occurred in England only a decade ago. Since then, millions of dollars have been saved yearly in crop production. Although these compounds have been widely studied and a great deal learned about their gross effects on plants, very little is known concerning their uptake and distribution, the way they operate within the cells, or their effects on metabolism.

For herbicides to be effective in killing plants, the materials must first enter the plant, then be translocated through the plant, and finally, carry out the toxic reaction. An understanding of the basic mechanisms affected by plant-growth regulators would contribute to understanding the growth process itself, and could well lead to improvement of weedkillers. More satisfactory use of this group of compounds might be achieved in such practices as inducing fruit set, and controlling fruit drop.

Studies of uptake and distribution. In one phase of work, a number of carbon 14-labeled herbicidal chemicals, such as 2,4-D and 2,4,5-T, was applied to the leaves of plants to study their rates of absorption and their subsequent translocation in both susceptible and resistant plants. The persistence and the fate of the chemicals in plants also were investigated.

Both susceptible and resistant plants readily absorbed certain herbicides. Their subsequent translocations differed among the chemicals tested. Early work provided convincing evidence that labeled 2,4-D was readily absorbed through the plant leaf and carried to remote parts of the plant along with food materials. Because these materials apparently moved from organs carrying on active food synthesis such as leaves to regions of active food utilization such as roots, growing shoots, cambium, and storage organs, knowledge of plant physiology permitted a prediction of the ultimate location of applied, 2,4-D molecules. Testing proved the prediction accurate and has permitted the interpretation of a large mass of field data on the use of 2,4-D.

In case of 2,4-D, other evidence indicated that the translocation of this chemical was much more rapid in susceptible plants than in

the resistant ones. On the other hand, the movement of 2,2-dichloropropionic acid (Dalapon) and 2,2,3-trichloropropionic acid (TPA) in birdfoot trefoil which is resistant, and corn and bean plants which are susceptible, was the same. Following the absorption of labeled herbicides (2,4-D, 2,4,5-T, Dalapon, and TPA), the radioactivity apparently was translocated from the treated area primarily toward the rapidly developing plant tissue. The transport of 2,4-D or Dalapon in plants appeared to be more rapid than that of their trichloroanaloges.

Increasing the amount of radioactive herbicides applied to the leaves resulted in a decrease in percentage of cabon 14 translocated from the treated area to other plant parts. This may, in part at least, explain why high rates of application of plant growth-regulator herbicides sometimes result in less efficient weed control than do moderate rates of application. In general, the absorption of radioactive herbicides by the leaves was somewhat less as the plant grew older and the leaves became more mature. This is why older plants may be more tolerant to herbicides than are younger plants.

More recently comparative studies using labeled molecules of 2,4-D, 2,4,5-T, maleic hydrazide, amino triazole, urea, parachlorophenyl dimethyl urea (Monuron) and 2,2-dichloropropionic acid (Dalapon) have provided new and interesting facts concerning herbicide absorption and movement. These may be summarized as follows:

Of the above compounds, maleic hydrazide is the most mobile within the plant. It apparently is not accumulated by living cells and hence is free to move by diffusion or in the stream of assimilates.

Urea also appears to move freely, but there is evidence indicating that it is split to ammonia and carbon dioxide upon absorption into the living mesophyll. Apparently the carbon dioxide is rapidly synthesized to sugar and moved in this form in the assimilate stream. Extraction and chromatography of the labeled material in roots of oak seedlings that absorbed urea through the leaves proved the label to be carried in sugar.

Amino triazole also moves freely in plants and is rapidly distributed to growing regions following application to active leaves.

Labeled 2,4-D and amino triazole applied to chlorotic leaves of variegated Tradescantia plants failed to move from the area of treatment.

Labeled 2,4-D and Dalapon molecules may be accumulated by living plant cells and held near the point of applications. Because of this, the compounds move extensively in plants only when phloem transport is very active. In midsummer and fall, these compounds may be held in living parenchyma of leaves and stem, and hence fail

to reach the roots. Amino triazole under the same conditions may reach the roots in lethal quantities.

Monuron appears to move freely in the cell walls of plants, and it enters roots and moves upward in the transpiration stream. However, applied to leaves, it fails to enter the phloem and hence is not translocated to the roots.

Under certain conditions, maleic hydrazide and amino triazole may enter leaves, move to the roots, and then migrate from phloem to xylem and move up in the transpiration stream. Phosphorus is known to circulate in this way and attain a truly systemic distribution.

Parallel studies with these compounds, both labeled and unlabeled, in the field have permitted many valuable interpretations concerning the function of herbicides. They prove the value of comparative work. They aid in the understanding of the physiology of herbicide action. And they are proving invaluable in the application of physiological principles in the efficient use of herbicides.

Effects of plant growth regulators on metabolism. Carbon 14 also has been used as a tracer in trying to learn how plant metabolism may be affected by growth regulators.

2,4-D, 2,4,5-T, indolebutyric acid, and naphtahleneacetic acid were used, and apparently caused increases and decreases of various amino acids in different plants. When it has been established how increases or decreases in these amino acids affect the nutrition of the plant, more will be known about the action of herbicides. The changes produced in plant physiology may provide a clue as to how the herbicide works. At present, results of these studies cannot be interpreted fully.

Fertilizer Studies

The use of radioisotope tracers has demonstrated that leaves, stems, and fruits take up nutrients from sprays and use them in growth. Conversely, nutrients previously absorbed through the roots may be leached from leaves, stems, and fruits by rainfall.

Absorption of labeled phosphoric acids by leaves of beans and tomatoes grown on three types of soils—sand, loam, organic—was far more efficient than absorption by roots. Radioisotopes studies demonstrated that foliar applications of nutrients may be an efficient means of quickly supplying deficient nutrients, as well as aiding the roots in satisfying the fertilizer needs of a rapidly growing plant.

Elements easily taken up by leaves and transported to other parts of the plant included potassium, sodium, rubidium, phosphorus, chlorine, sulfur, zinc, copper, and manganese. Minerals that were

absorbed by leaves but moved very slowly, if at all, to other plant parts were calcium, strontium, barium, iron, ruthenium, and molybdenum. Direct absorption through the skin of fruits also was demonstrated. The radioactive isotopes—strontium 90 and ruthenium 103—were readily absorbed by plants from sprays or dusts and accumulated as contaminants in developing tomato fruit. With many horticultural plants where the tops are grafted onto roots of another variety or species, the upward movement of radioactive elements was not restricted by the union. If two young shoots were grafted not end-to-end, but tip-to-tip so that the natural direction of sap flow was reversed, the calcium 45 did not cross the graft union against this flow. On the other hand, phosphorus 32 moved across this same graft union easily. There was no accumulation of radioactivity either above or below the graft. Absorption of calcium 45 and phosphorus 32 by a dwarfing apple rootstock was less than by a nondwarfing stock.

While it was demonstrated by means of radioisotopes that leaves take up fertilizer from sprays, many factors influenced the rate. Absorption was greatest during daylight hours when temperatures were between 60° and 85° Fahrenheit. Slightly acid solutions were more easily absorbed than alkaline. Wetting agents (soaps) either enhanced or depressed absorption, depending on the nutrient and the plant. High levels of a nutrient in the soil decreased absorption of that mineral by leaves.

While all elements were absorbed by leaves, stems, and fruits, they also were leached out by rain. Sodium and manganese were most readily lost, followed by calcium, magnesium, sulfur, potassium, and strontium. Very little iron, zinc, phosphorus, and chlorine was removed. Losses of minerals from mature leaves were greater than from immature leaves. Soluble carbohydrates (sugars) were leached in great quantities from leaves and fruits, especially during daylight hours, and percentage losses exceeded those for elements.

Studies of Plant-Growth Substances

The way in which plants make the growth regulator, indoleacetic acid (IAA), and the manner in which this substance controls growth of plants, have been questions of paramount importance to plant scientists since this hormone was isolated in the early thirties.

In 1935 it was proposed that IAA arises from the amino acid, tryptophan, through a series of biochemical reactions, although no compelling direct evidence had been presented. During the past 3 years it has been possible, with the aid of radioactive-labeled

tryptophan, to show that not only IAA but similar compounds arise from this amino acid.

Among the most important compounds are: the plant hormone, indoleacetonitrile, found in quite high concentrations in plants of the mustard family; 5-hydroxytryptophan, which in the animal body is converted to serotonin (5-hydroxytryptamine) and is active in regulating animal metabolism.

In an attempt to gain some insight into the mechanism of action of plant-growth substances, particularly those of the auxin group, it has been proposed that "without auxin there is no growth." It has been impossible to demonstrate this response in the expansion of dark-grown leaves.

Several past attempts to show a need for auxin in leaf expansion apparently failed because of the large amount of auxin which occurs naturally in a young leaf. This was overcome by exposing the young leaves to X-irradiation for some 60 hours which inactivated the enzyme system responsible for converting indoleacetaldehyde to the acid auxin, IAA. By then treating the leaves with auxin, it was possible to demonstrate a definite need for this substance. These results then appeared to show that the "no auxin-no growth" hypothesis extended even further than previously suspected.

In understanding the mechanisms of ionizing radiation effects, a primary problem is the efficiency of the effect; i. e., the amount of damage from a given quantity of radiation. In the absolute sense, relatively little energy is absorbed by the organism irradiated with low radiation doses. Yet these doses engender profound physiological and morphological disturbances, even though ionizations initially produced are 1 million to 10 million less in number than the molecules in any tissue. One of the simplest interpretations of this phenomenon was that agents in the plant responsible for the turnover of many molecules were affected by radiation; i. e., that regulatory mechanisms of the cell were primary loci of radiation damage. This interpretation was substantiated by the effect of ionizing radiation on auxin.

Work has shown that the auxin molecule itself in the plant is not sensitive to radiation damage. Yet the concentration of auxin in the plant drops sharply immediately after irradiation. The biochemical locus of radiation damage then was shown to be a specific enzymatic reaction in auxin formation. Both in sensitivity and in pattern of inhibition and recovery, the enzyme inhibition could be experimentally integrated with phenomena in the plant: auxin production itself and morphological responses that depend on auxin production.

A kinetic study of auxin turnover found that in tissues of young grass, 50 percent of the auxin molecules are replaced each hour.

Most enzymes in living systems resist immediate damage by ionizing radiation, unless the radiation doses are very high. The process of auxin formation is unusually radiosensitive. It appears that the radiosensitive step involves an enzyme at a terminal stage in the process.

Cooperative Radiation Mutations Program

In 5 years of formal operation of the Brookhaven Cooperative Radiation Mutations Program, irradiations on more than 70 different crop plants have been performed for some 125 scientists in the United States, and projects begun in cooperation with more than 50 foreign scientists in 22 different nations. Research in the 1930's, especially in Sweden, had indicated radiation could induce mutations in crop plants, some of which might be beneficial. After the war of 1939–45, with the Commission encouraging exploitation of peaceful uses, studies at Brookhaven National Laboratory, and in cooperation with Oak Ridge National Laboratory, and elsewhere, on the interaction of radiation with the genetic material of living organisms led to establishing an extensive program at Brookhaven in 1952. Scientists throughout the United States were invited to send seed, cuttings, or entire plants to Brookhaven, for exposure to a variety of radiations. Growing plants are irradiated by gamma rays from a cobalt 60 source in crop area; seed and cuttings are exposed to X-rays from a large 250-kilovolt peak therapy unit or to neutrons from the nuclear reactor.

Several years usually are required after radiations are performed to select and test mutations beside proved varieties before material is turned over to commercial plant breeders. Reports submitted in the cooperative program indicate that beneficial mutations are being found in sufficiently high numbers to justify continuing efforts. Disease-resistant strains have been reported in wheat, oats, and flax. High-yield dwarf forms have been observed which should suffer less wind damage than customary strains. Encouraging results are reported by scientists attempting by mutation to eliminate from certain otherwise useful forage plants a principal toxic to livestock.

Fruit trees grown in the gamma field for 1 to 3 years, then permitted to return to normal growth, now are being analyzed for possible mutations. Two beneficial mutations have been reported on peach trees placed in the gamma field. One branch on a Fairhaven peach tree being tested at Rutgers University bears fruit that ripens approximately 10 days earlier than the rest. A branch on a different tree ripens its fruit some 3 weeks later than normal. These mutations were first observed in 1956 and were confirmed in 1957. These

two radiation-induced mutations may lead to increasing by more than a month the season over which the fruit can be available. The mutations resulted from the first experiments with fruit trees after this program was initiated in 1952.

Buds from these mutations now will be grafted on other trees, and when a large enough population of these new types is established they will be critically tested to see if they are of satisfactory quality for general commercial use.

Plant and Seed Irradiation

In the relatively young field of radiation breeding, close cooperation is needed between scientists performing basic research on radiation biology at Oak Ridge and elsewhere, and those applying the findings of such research. Based on the foregoing, the University of Tennessee-Atomic Energy Commission Agricultural Laboratory was authorized in February of 1956 to (*a*) provide a central source of radiation for public-service plant breeders in the Southeastern States, and (*b*) conduct research on more effective uses of radiations in plant genetics.

During 1956, a gamma-ray source powerful enough and versatile enough to irradiate seeds, pollen, or entire plants was designed, built, and calibrated. Access to neutrons from a nuclear reactor was provided by Oak Ridge National Laboratory. In the first year of operation, 134 separate samples were irradiated for 38 plant breeders in 14 States. In 1957, the laboratory irradiated 78 samples for 36 breeders in 14 States.

It is too soon to report on mutations induced in this program. Since the birth of this program, only four varieties containing genes altered by radiation have been released to growers. Each of these was 10 to 15 years in the making.

Other Biological Studies

Studies in Aquatic Biology

Recent isotopic techniques developed in the laboratory are being utilized in the field to determine the nutrients essential to the growth of aquatic organisms and rates of growth at various nutritional levels. Production of aquatic life in an environment depends upon the production of one-celled plants. This can be reliably estimated from the absorption of radioactive carbon dioxide by one-celled plants. This quantitative, fundamental information can be used to measure the economic productivity of the rivers, lakes, and seas during different seasons.

Quantitative evaluation of factors influencing production in the seas is a part of a marine survey program being conducted in an area of the Continental Shelf directly off the Hudson River. The species composition, volume, and chlorophyll content of the samples of plankton collected during the surveys have been determined. The chemical constituents of the water essential to plant growth were determined, especially organic and inorganic phosphorus compounds, nitrate, nitrite, ammonia, and dissolved organic nitrogen compounds. Researchers also evaluated the photosynthesis of the natural marine phytoplankton populations, and the relationship of the rate of photosynthesis to light intensity and to the chemical constituents of the water. Continuing surveys will be made to determine the relationship between the nutrients in the water and the photosynthesis rate of the phytoplankton populations. The chemical composition of both the phytoplankton and the zooplankton will be determined, together with their ability to accumulate trace elements from the sea water.

Isotopes are also being used in field studies to determine how the large reservoir of inorganic nutrients in lake and river bottoms and the sea can be made available to algae and plankton, and subsequently to economically important food products, and to determine what happens to nutrients added to lakes. An effort is being made to increase the productivity of the bog lakes of Wisconsin. The nutrient content of these lakes is low because of the slow decomposition of organic matter in lake mud and inhibition of the release of phosphorus to the water, and because light penetration is cut down due to the high colloidal organic content in the water. These factors sharply limit fish production. One approach to increased productivity has been an effort to make available the phosphorus from the mud of the lake bottom. Aeration, addition of chemicals, tilling the bottom, and methods of accelerating the decomposition of the mud have been tried in the laboratory with some success; efforts will be transferred to a bog lake and experiments carried out under natural conditions.

Studies of Photosynthesis

The mechanism by which a green plant converts solar energy to bound chemical energy by photosynthesis has been under active investigation for 10 years. The way in which this trapped solar energy is used by the plant to make sugars from atmospheric carbon dioxide has been rather completely worked out, thanks to radioisotope techniques. Very little has been done in studying in the cell how the energy is converted or determining the relationships between these processes. Studies over the past 2 years on the comparative bio-

chemistry of photosynthesis, using isotopes of carbon, sulfur, phosphorus, and hydrogen, have yielded some information on the mechansism of both the energy-converting and the sugar-synthesis mechanisms of photosynthesis.

Much must be learned concerning the parts of the cell responsible for various aspects of photosynthesis, before photosynthesis can be controlled or carried on outside a living cell. A study has been completed on the distribution and structural association of several enzymes concerned with fixation and reduction of carbon dioxide. A direct investigation of isolated chloroplasts containing the pigment chlorophyll which captures light showed that the enzyme responsible for the primary fixation of carbon dioxide by plants was bound physically to the chloroplast. A series of experiments removed the chloroplasts of both algae and higher plants by the action of chemicals or radiation. In all cases it was shown that the first two enzymes concerned with sugar synthesis from carbon dioxide were removed with the chloroplast. A survey of plant, animal, and microbial organisms was undertaken to study the distribution of the photosynthetic carbon dioxide-fixing systems in nature. This system was found primarily associated with plants, and in turn with the chloroplasts of plants.

One exception to the general rule was found in a photosynthetic bacterium, one of the most primitive photosynthetic organisms studied, which contains a plastid-bound chlorophyll and energy-producing system, but does not contain a plastid-bound carbon dioxide-fixing system. Thus for the first time in nature an intracellular separation of the energy-conversion steps and the sugar-synthesizing steps of photosynthesis has been demonstrated, and a new light-dependent, carbon-fixing mechanism discovered. The classical photosynthetic carbon-fixing system involves the addition of carbon dioxide to a 5-carbon sugar to give two 3-carbon acid precursors of sugar. This new system involves the carboxylation of a 3-carbon acid phosphate to give a 4-carbon acid which is rapidly transformed to an amino acid, or ptorein. This reaction was previously known only as a dark reaction in other organisms.

A study of the production of high-energy phosphate by light, which is the plant's way of trapping solar energy, was carried out in another photosynthetic bacteria *Chromatium*. Cellular particulates that have been isolated and purified contain all the photochemical pigments, and these structures can produce high-energy phosphate from light. This process must be a simpler one than has previously been envisaged, as the size (125 angstrom units) and composition of these structures limit the amount of protein available for enzymatic activity. Studies underway using isotopes of both phosphorus and sulfur should help

to clarify the actual mechanism of conversion of solar to chemical energy.

Mechanism of phosphorus transport. Phosphate is so firmly bound to soil particles and to the protein surfaces in plant cells that it was difficult to explain its rapid transport with the sap. Radioactive phosphate absorbed by barley or spinach roots appeared in the sap of cut stems within a few moments. Paper chromatographic analysis of the sap exudate showed that it was not all free phosphate but was bound to a simple molecule, choline, which served to neutralize the negative charge of the phosphate and reduce its tendency to absorb on cell surfaces. The fastest moving radioactivity in the stem contained six times more of this compound, phosphoryl choline, than of free phosphate. Thus the tracer method provided an answer to another problem in plant physiology.

Identification of new class of phospholipids. An unknown compound in green algae wh ch becomes strongly labeled with radiophosphorus has provided a cilue to the widespread existence of a new class of phosphorylated lipids (fats), the phosphatidyl glycerols. The labeled unknown was identified by its chromatographic properties and found to contain two molecules of glycerine, the usual skeletons of fats, held together by one molecule of phosphate, another common component in the fats.

The long chain fatty acids (soaps) were carefully removed from the phospholipids of algae and 45 percent of the phosphorus was observed in the new compound, diglycerophosphate. These lipids, then, contain twice as much glycerine as science had recorded for the past 30 years.

These results indicate some revision of current concepts of composition of these substances may be necessary. The phospholipids play such a prominent role in nerve fibers, enzymatic particles, photosynthetic chloroplasts, blood cells, and other actively metabolizing structures. The symmetry, simplicity, and ease of cleavage of the diglycerophosphate molecule to give the same products as normally obtained from fats had delayed its recognition as an important metabolite of plants and animals.

BASIC RESEARCH IN PHYSICS AND CHEMISTRY

Research scientists have found isotopes to be very important tools in a multitude of fundamental problems, and as tracers for chemical and physical processes involving individual atoms and molecules.

Both radioactive and stable isotopes are widely used. Radioisotopes

are easily detected and measured with simple and inexpensive equipment. Stable isotopes do not lose their value through decay, but are comparatively expensive, and require complex equipment and techniques for measurement.

Physical Chemistry

Physical chemists find isotope tracers especially useful in fundamental studies of such natural phenomena as atom exchange, aging of precipitates, surface reactions, diffusion, vapor pressures, and thermodynamic properties.

Isotope exchange. Exchange of like atoms, between two different chemicals species in solution, occurs spontaneously and can be detected and measured only with isotopic tracers. Observations on the rate of exchange can shed much light upon the strength of various chemical bonds. Strong bonds would prevent substantial exchange.

Aging of precipitate. Alteration of chemical precipitates with time has been studied with radioactive tracers. When a solid is precipitated from solution, a definite number of molecules remain dissolved, depending upon the solubility of the precipitate. But a newly formed precipitate may differ in character from an "aged" precipitate and the solubility often varies with aging. Tracer studies have clearly demonstrated what was long suspected; namely, that the precipitate simultaneously redissolves and reprecipitates (recrystallizes) to form a new and more stable surface during aging. The use of radioisotopes to measure quantitatively the very small solubilities of many solids has proved valuable to analytical chemistry.

Surface reactions. Radioisotopes are useful in studies of surface reactions—corrosion, for example—which are frequently encountered in industrial processes. The surface area of solids, powders, or colloids cannot be determined by ordinary measuring techniques, but many methods have been devised for estimating these areas. The method using radioisotopes is generally in agreement with others and is usually faster and more convenient. It involves selective transfer (adsorption) of radioactive atoms from a solution onto a surface and determination of the area from the number of atoms on the surface.

Water flotation of mineral ores for separations in the mining industry is based on adsorption of certain organic chemicals on the mineral particle surfaces. Since the chemicals coat one type of particles more readily than another, it is possible to make the uncoated kind sink while the coated substance floats in a froth on the surface so

that it can be skimmed off. Through use of a radioactively tagged chemical and a counter, it is possible to determine the conditions for, and extent of, adsorption on any particular mineral.

Many tracer techniques with radioisotopes have been devised for evaluating the efficiency of cleaning agents, producing information of importance both to the manufacturer and to the user of detergents and laundry equipment. Radioisotopes measure the ability of detergents to combat adsorption on cloth fiber of soiling substances. Automatic washing machines are routinely tested in this way by many firms.

Many important chemical reactions can be made to proceed on a commercial scale only by means of catalysts, substances which promote chemical reactions without entering into them. Adsorption and exchange on the catalyst surface are important factors in surface reactions. Information regarding these factors can be obtained with tracer isotopes and often is of vital importance to an industry.

Diffusion. Isotopic tracers are particularly useful for identifying and following particular atoms or molecules in a chemical or physical system. In studies of gaseous, liquid, or solid self-diffusion, there is virtually no other way to distinguish the diffusing atoms or molecules from chemically identical neighbors in the surrounding materials. Such studies not only are of fundamental value in the understanding of molecular dynamics but also are of potential use in many metallurgical and chemical processes.

Diffusion studies are valuable in determining what happens in the alloying of metals. In alloying, the strength, corrosion resistance, heat resistance, etc., depend on the distribution of unlike atoms.

In chemical processes, diffusion influences reaction rates and is thus important to know.

Diffusion in solids can be readily studied by bringing radioactive and stable atoms of the same element into contact, and then subjecting them to conditions calculated to cause diffusion. Self-diffusion in gases and liquids is usually studied by introducing a tracer at the end of a long, thin tube containing the material and measuring the movement of radioactivity along the tube.

Diffusion between dissimilar materials can be investigated in the same way. Such studies are particularly valuable in the case of metal alloys, where the strength and other characteristics depend on the distribution of the unlike atoms.

Vapor pressure. Measurement of vapor pressure over solid or liquid metals is difficult and time consuming. With metals of high melting point, it takes hours or days to collect enough condensed vapor to

allow accurate weighing. If a radioactive tracer is added to the metal, the determination may be made much more quickly. The superior sensitivity of radioisotope measurement is clearly demonstrated in this analytical technique.

Thermodynamic properties. The great sensitivity obtainable in radioisotope tracing allows chemists to use extremely small quantities of material when this is desirable. The thermodynamic properties of a solution, for example, usually are extrapolated to their values at "infinite dilutions" since they change significantly with concentration. The researcher can verify or study thermodynamic behavior in a quantitative manner at extreme dilutions by using radioactive solutes.

Organic Chemistry

The chemistry of carbon compounds has benefited greatly from studies with isotope-labeled organic compounds now available. Formerly, many different mechanisms and theories were proposed for a single chemical reaction; now investigators can resolve the differences between various mechanisms and theories by using some among the hundreds of compounds labeled with radioactive carbon 14.

Once the mechanism of the reaction was known, determination of the kinetics, primarily the rate of the reaction, required study. In many industrial chemical reactions it would be desirable to speed up these rates and cause them to go with a minimum of energy added to the system. Measuring these rates makes it possible to determine the effects of different reaction conditions.

Prior to the use of isotopically labeled compounds, it was not possible to study the kinetics of a reaction under equilibrium conditions. Data on the progress of a reaction had to be obtained by a chemical analysis, requiring that a reaction proceed a substantial degree in one direction so that changes in concentration of reactants and products were great enough to be measured. Reaction rates so far from being in balance, however, may not be the same at equilibrium. Isotopically labeled reactants allow kinetic studies under equilibrium conditions and provide the kineticist with an extremely sensitive means of measuring rates and determining the reversibility of a reaction step.

Although radioisotopes are extremely valuable in kinetics, their use interposes an additional factor, the isotope effect, in rate studies. This additional complication can be turned to advantage. Two factors are involved in changes in reaction rate resulting from isotopic substitution. One is the lower frequency of rupture of the critical bonds in the activated intermediate complex containing the heavier isotope. The other is the higher activation energy for disassociation

of the heavier molecule. In hydrolysis of an ester, for example, substituting radioactive carbon 14 for normal carbon 14 in the carbonyl-carbon causes the molecule to react somewhat more slowly. This indicates that the rate-determining step involves breaking a bond to the isotopic label.

Physics

Work in nuclear physics in particular has benefited by ready availability of a large variety of stable and radioactive isotopes.

Stable isotopes are particularly useful as "purified" species with which to perform nuclear reactions and to determine spin, magnetic moment, and other nuclear properties of interest to the physicist.

Concentrated stable isotopes have proved useful in fundamental studies of energy states, or levels, or atoms and molecules. These particles, when excited, emit visible light, infrared and ultraviolet light, microwaves, or X-rays. All are electromagnetic radiations, differing in energy range, which are released when the energy content of an atom or molecule shifts to a lower, more stable level. The spectroscopist can determine the energy state from the emitted spectrum.

Formerly, much of this work was complicated by the fact that normal undifferentiated materials, no matter how chemically pure, usually contain a number of isotopes of the element. Ordinary mercury, for example, has seven isotopes, each with a different number of neutrons in its nucleus, and gives slightly different spectra which blur together. By using mercury in which the isotope Hg 202 has been electromagnetically enriched from its natural relative abundance of 30 percent to 98 percent or better, the researcher obtains results that are overwhelmingly those from one isotope of mercury and are quite definite.

The wavelength of the red line in the spectrum of cadmium was long ago set as the international standard of length. Although quite precise for most purposes, this standard suffers in being a combination of slightly different lines from cadmium isotopes. Therefore, for still greater precision in laboratory wavelength comparisons, separated isotopes such as cadmium 114, and mercury 198 and 202 are used as spectrographic sources. Because mercury is so easily used in a light source, its enriched form is useful as a primary standard.

Peculiar characteristics are found among the hundreds of stable isotopes and some have proved particularly valuable in pure form. Boron 10, for example, has an especially high probability of capturing a slow neutron. When capture occurs, boron 10 converts into an alpha particle and a lithium nucleus, both with high velocity.

This special property makes boron 10 useful for measuring or counting neutrons. Slow neutrons usually pass through a Geiger counter without being counted, but a coating of boron 10 in the counter absorbs a large portion of them. The resulting particles from the boron 10 trip the counter.

The physicist frequently employs radioisotopes as tracer atoms. Thicknesses down to a trillionth of an inch are measured in a method for calibrating the shadow-casting technique. Specimens to be viewed in an electron microscope are frequently sprayed at an angle with chromium or other metal atoms so that "shadows" are formed which reveal varying depths of the surface. Atoms are evaporated in vacuum from a heated metal. The resulting film must be thick enough to produce good shadows but not so thick as to blur details of the specimen. Thickness of film laid down at a given time at a particular place is determined by a test run with radioactive metal. A standard area of this film is measured for radioactivity with a counter. Solutions containing known weight of the same labeled starting material are dried on identical areas and are counted. Comparison of activities then gives the weight of film for conversion to film thickness.

The variety of uses to which stable and radioactive isotopes are put in fundamental research, in medical and diagnostic studies and treatment, and in industrial processes depends, of course, upon the problems that arise in different fields. The wide application that isotopes already have achieved is an indication of their efficiency and utility. In fact, the greatest contribution of isotopes does not lie in their specific uses, no matter what knowledge or saving they contribute at any particular time, but in the fact that they provide a tool which, like the wheel of prehistoric invention, may be applied throughout the future to mankind's current problems.

III

PROGRESS WITH POWER REACTORS

The year 1957 saw major advances in the Nation's development of reactors to produce economic nuclear power for use in the United States and in other countries.

At the end of the year, the Commission had in operation seven experimental civilian power reactors of six different types, plus an Army reactor that has direct civilian uses.

Another experimental power reactor, the first in this country financed exclusively with private capital, was supplying electricity to company lines.

Construction was underway on four full-scale power reactors in which private enterprise is the sole or primary investor.

Contracts had been signed for the first nuclear-powered merchant ship and for its propulsion reactor.

The reactors in operation at the end of 1957 were—

PRESSURIZED WATER REACTOR, AEC and Duquesne Light Co., at Shippingport, Pa., 60,000 electric kilowatts, which achieved criticality December 2, 1957.

EXPERIMENTAL BOILING WATER REACTOR, AEC, at Lemont, Ill., 5,000 electric kilowatts, critical December 1956.

BOILING REACTOR EXPERIMENT No. 4, AEC, at National Reactor Testing Station, Idaho, 2,400 electric kilowatts, critical December 1956.

SODIUM REACTOR EXPERIMENT, AEC and North American Aviation, Inc., at Santa Susana, Calif., 6,500 electric kilowatts, critical April 1957.

EXPERIMENTAL BREEDER REACTOR, No. 1 (Mark III core), at NRTS, 200 electric kilowatts, critical November 1957.

ORGANIC-MODERATED REACTOR EXPERIMENT, AEC, at NRTS, no electrical power, critical September 1957.

HOMOGENEOUS REACTOR EXPERIMENT No. 2, AEC, at Oak Ridge, Tenn., 300 electric kilowatts, critical December 27, 1957.

ARMY PACKAGE POWER REACTOR, AEC, at Fort Belvoir, Va., 1,855 electric kilowatts, critical April 1957.

VALLECITOS BOILING WATER REACTOR, General Electric Co. with associated turbine-generator owned and operated by Pacific Gas & Electric Co., at GE Vallecitos Laboratory, Calif., 5,000 electric kilowatts, critical October 1957.

The full-scale reactors under construction were—

COMMONWEALTH EDISON Co. Dresden plant, near Joliet, Ill., 180,000 electric kilowatts.

CONSOLIDATED EDISON Co., of N. Y., Indian Point, N. Y., 163,000 electric kilowatts nuclear, 112,000 superheat conventional.

POWER REACTOR DEVELOPMENT Co. Enrico Fermi plant, Monroe, Mich., 100,000 electric kilowatts.

YANKEE ATOMIC ELECTRIC Co., Rowe, Mass., 134,000 electric kilowatts.

In addition to these plants under construction, nine more are projected under the Commission's Power Demonstration Reactor Program in which the Federal Government and a non-Federal industrial organization share costs. On two of these, the Commission has signed contracts—with the Consumers Public Power District, for a 75,000-electric-kilowatt reactor at Hallam, Nebr., and the Northern States Power Co., for a 66,000-electric-kilowatt reactor near Sioux City, S. Dak. Three other proposals have been accepted as basis for negotiation: a joint proposal by Chugach Electric Association and Nuclear Development Corp. of America for a 10,000-electric-kilowatt reactor at Anchorage, Alaska; a proposal by the city of Piqua, Ohio, for a 12,500-electric-kilowatt plant; and a proposal by Rural Cooperative Power Association for a 22,000-electric-kilowatt plant at Elk River, Minn. Three proposals are under study; negotiations on a fourth have been deferred.

In the following pages, the Commission reports highlights of its civilian reactor development program since 1954, then describes some key technical problems of economic reactors, and summarizes progress and programs for the various types of civilian power reactors. Progress in military reactors during the last 6 months is reported in Part Two of this report.

SUMMARY OF PROGRESS, 1954–57

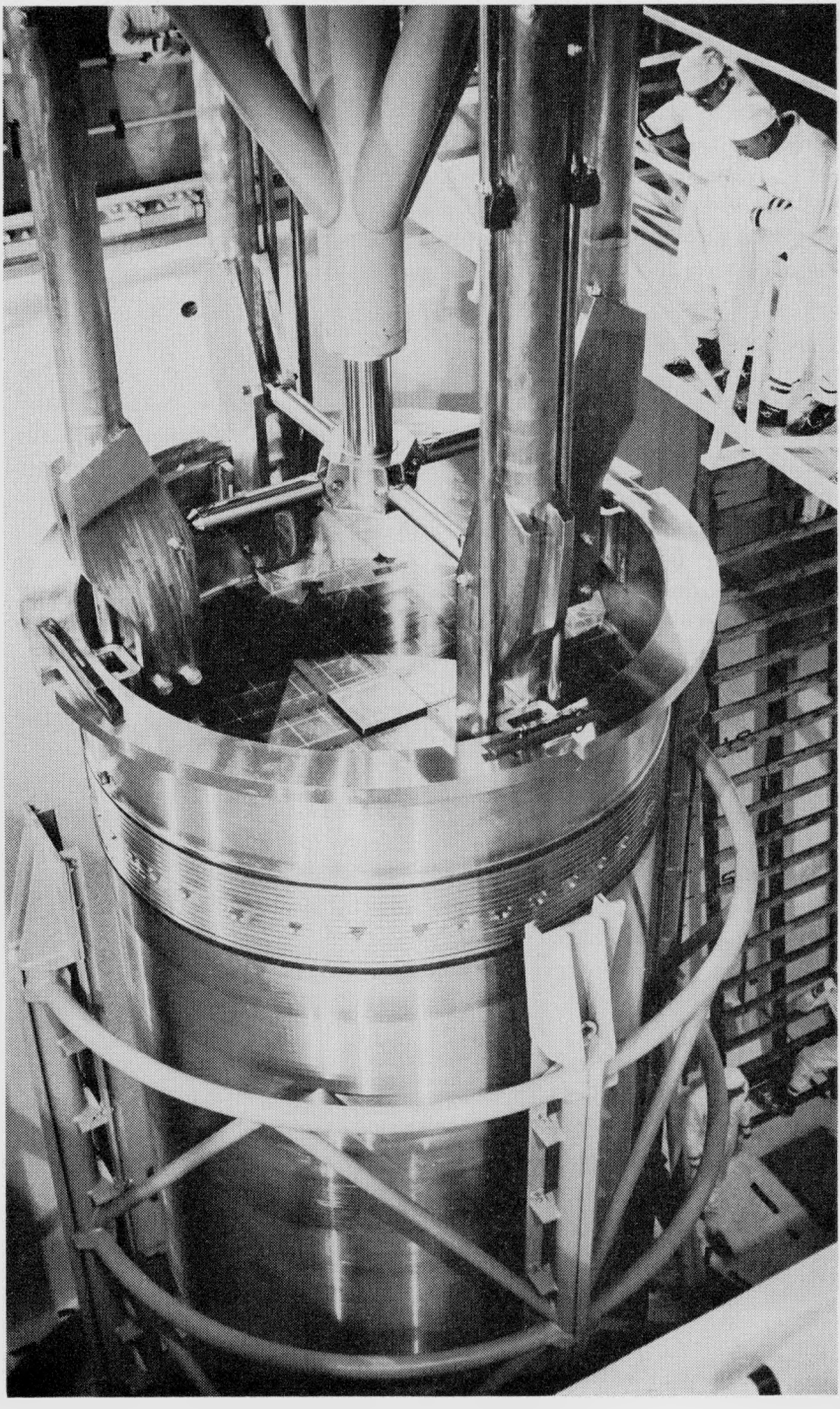
Highlights of 1954

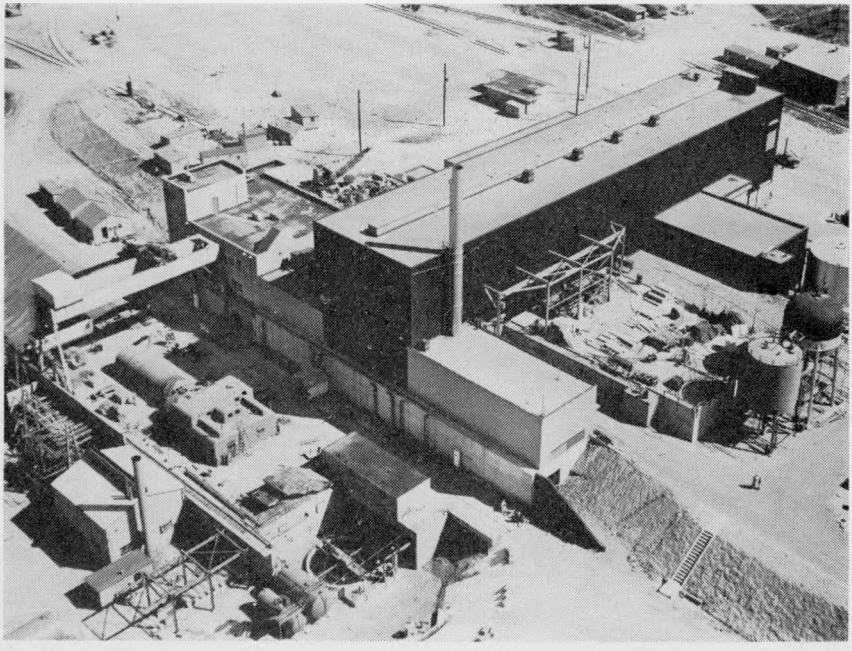
- Program sent to the Joint Committee on Atomic Energy proposing providing for development over a 5-year period of five distinct technological approaches believed to be the most likely to lead to economic nuclear power.
- Facilities of the Materials Testing Reactor made available to the public, providing a higher neutron intensity for experiments than available in other reactors.
- Ground was broken for construction of the Nation's first full scale civilian nuclear powerplant, the Pressurized Water Reactor, at Shippingport, Pa.
- Construction began on the first sodium-cooled, graphite-moderated reactor, the Sodium Reactor Experiment, near Santa Susana, Calif., one of the reactor types selected for development under the 5-year program.

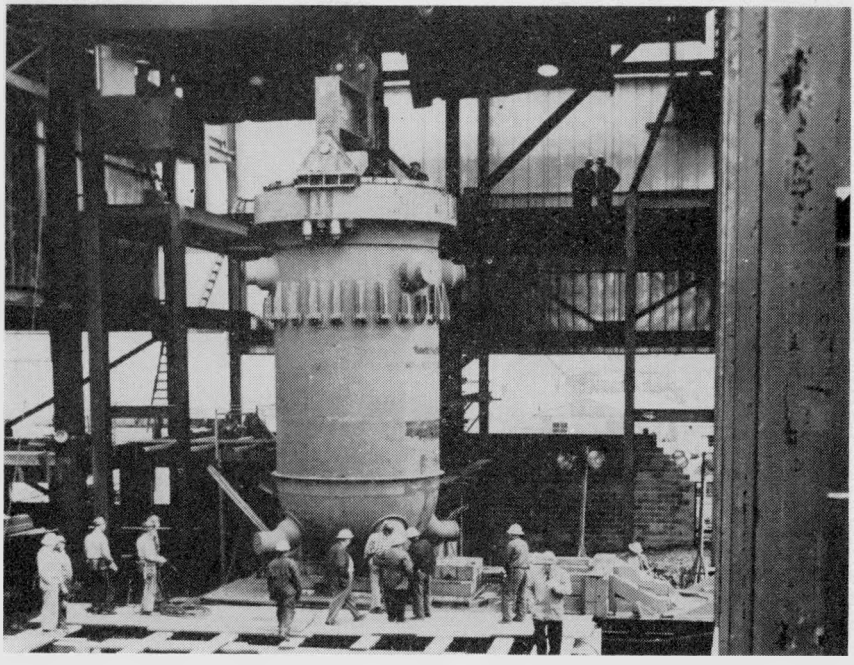
- Construction started on the Homogeneous Reactor Experiment No. 2 at the Oak Ridge National Laboratory, another of the reactor types selected for development under the 5-year program.
- Boiling Reactor Experiment No. 1 (BORAX–1) was destroyed in a deliberate test at the National Reactor Testing Station by allowing power to rise well over a million kilowatts in a tenth of a second.
- A second boiling reactor experiment (BORAX–2) was placed in operation at the National Reactor Testing Station to demonstrate the operational reliability of a boiling water system.

Highlights of 1955

- The schedule was set for basic charges on available materials and services needed by private atomic energy developers and users in the United States, and for prices that the Commission will pay for certain products from privately operated American atomic reactors.
- Industry was invited to build and operate with private funds an Engineering Test Reactor needed for military and civilian nuclear power development programs. Later, lacking an acceptable proposal, the Commission decided to construct the reactor with its own funds, and a contract for construction was awarded to Kaiser Engineers.
- Proposals were invited by public, cooperative, or private organizations to purchase the heat produced in experimental operation of the Sodium Reactor Experiment.
- Boiling Reactor Experiment No. 3 (BORAX–3) was placed in operation at the National Reactor Testing Station, Idaho, and supplied the town of Arco, Idaho, with electricity for 1 hour on an experimental basis, the first time in history for such an event.
- Construction began on the Experimental Boiling Water Reactor at Argonne National Laboratory.
- First lump-sum contract was awarded for the fabrication of reactor fuel elements in a privately owned facility to the Babcock & Wilcox Co., New York.
- Construction was completed on Special Power Excursion Reactor Test facility (SPERT–1) for a series of tests to study the effects of sudden or extreme increases in power in heterogeneous reactors.
- The Commission issued its first and second invitations under Power Demonstration Reactor Program designed to open the way for industry to develop, fabricate, construct, and operate experimental nuclear power reactors. Three proposals were received by closing date in response to first invitation.



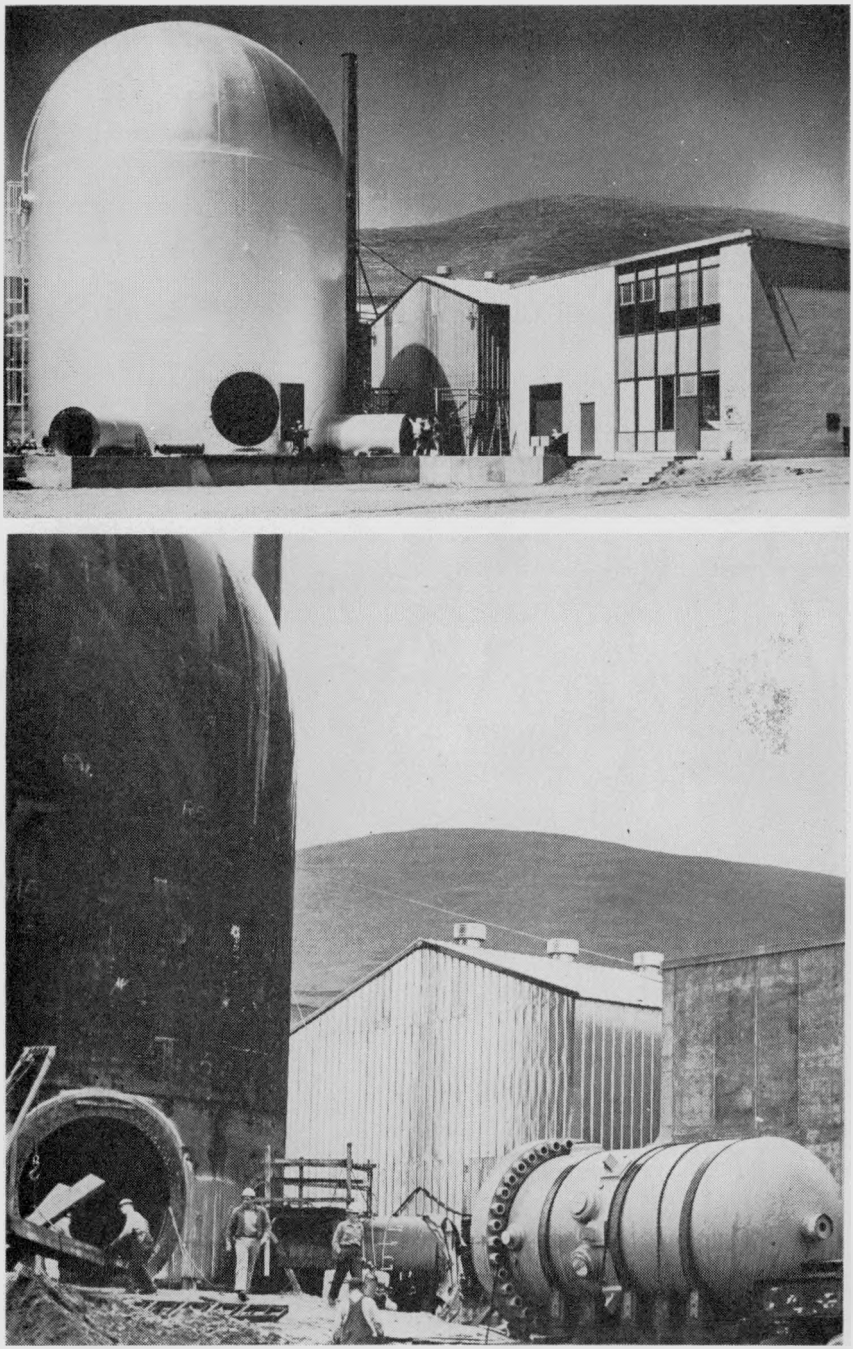




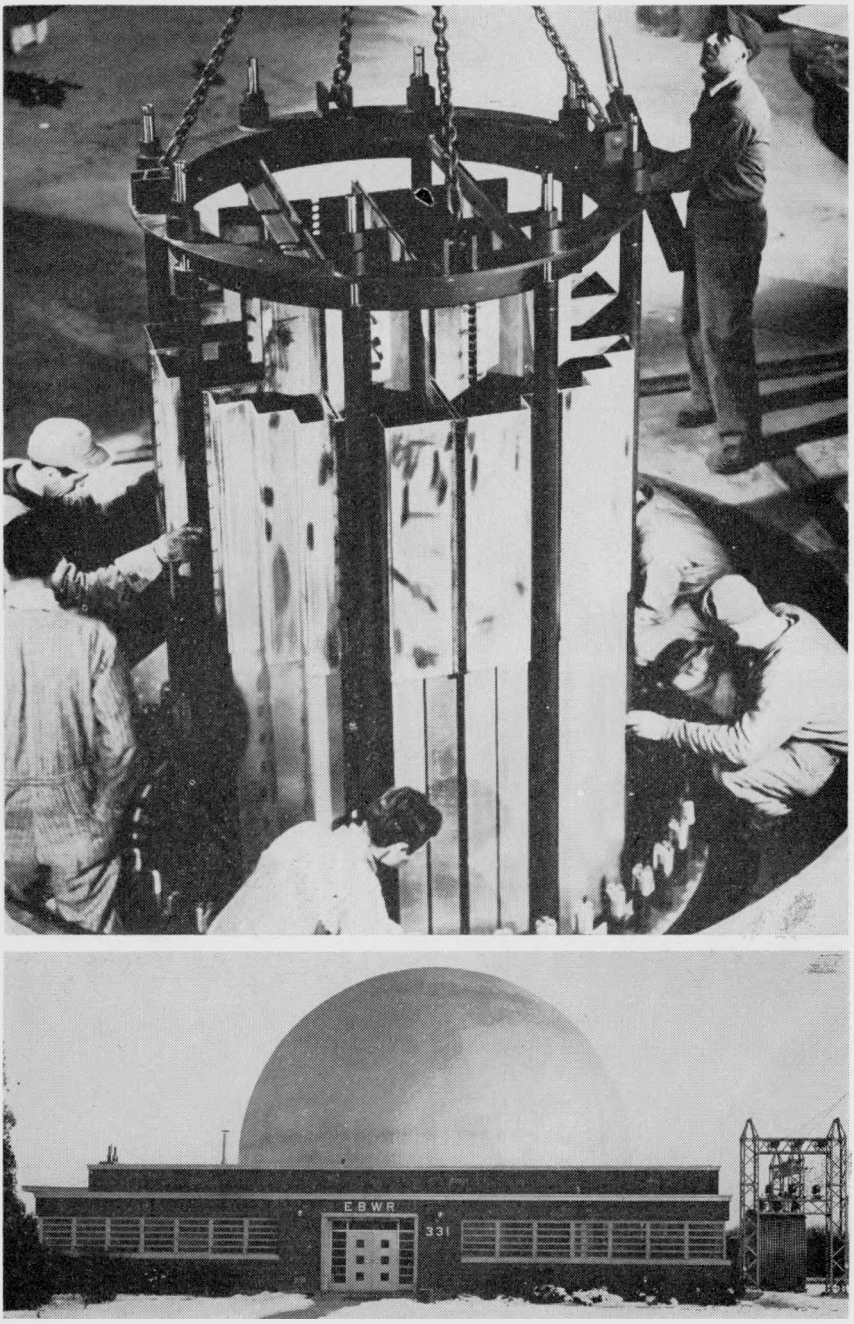
PWR. An external view of the Pressurized Water Reactor installation at Shippingport, Pa., the first full-scale power reactor in this country. Below, the pressure vessel; opposite, the reactor core.

Enrico Fermi Plant. Lowering into place the cap of the container structure for the Power Reactor Demonstration Co., Inc., 100,000 electric kilowatt reactor at Monroe, Mich.

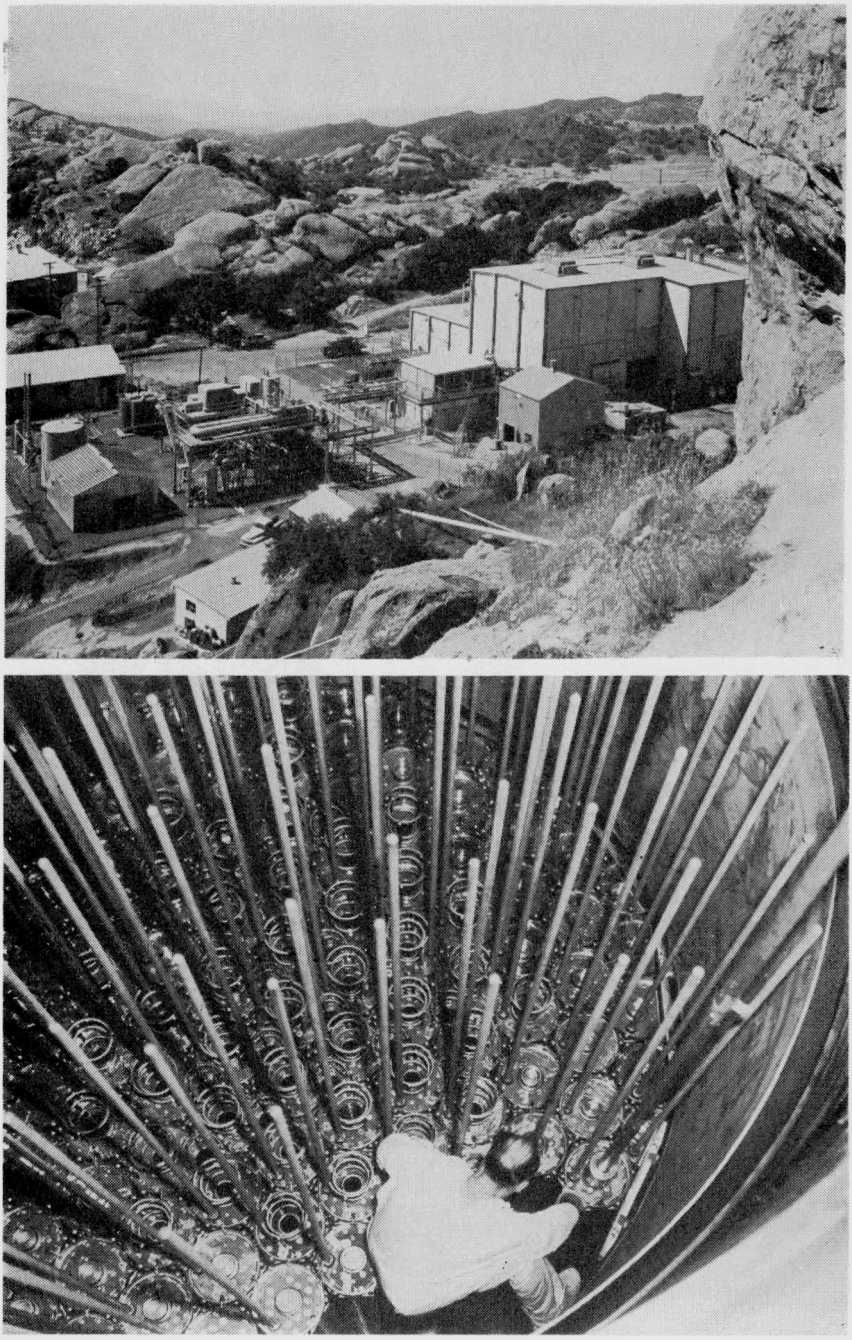
Dresden Plant. Construction underway for the 180,000 electric kilowatt reactor of the Commonwealth Edison Co., near Joliet, Ill.



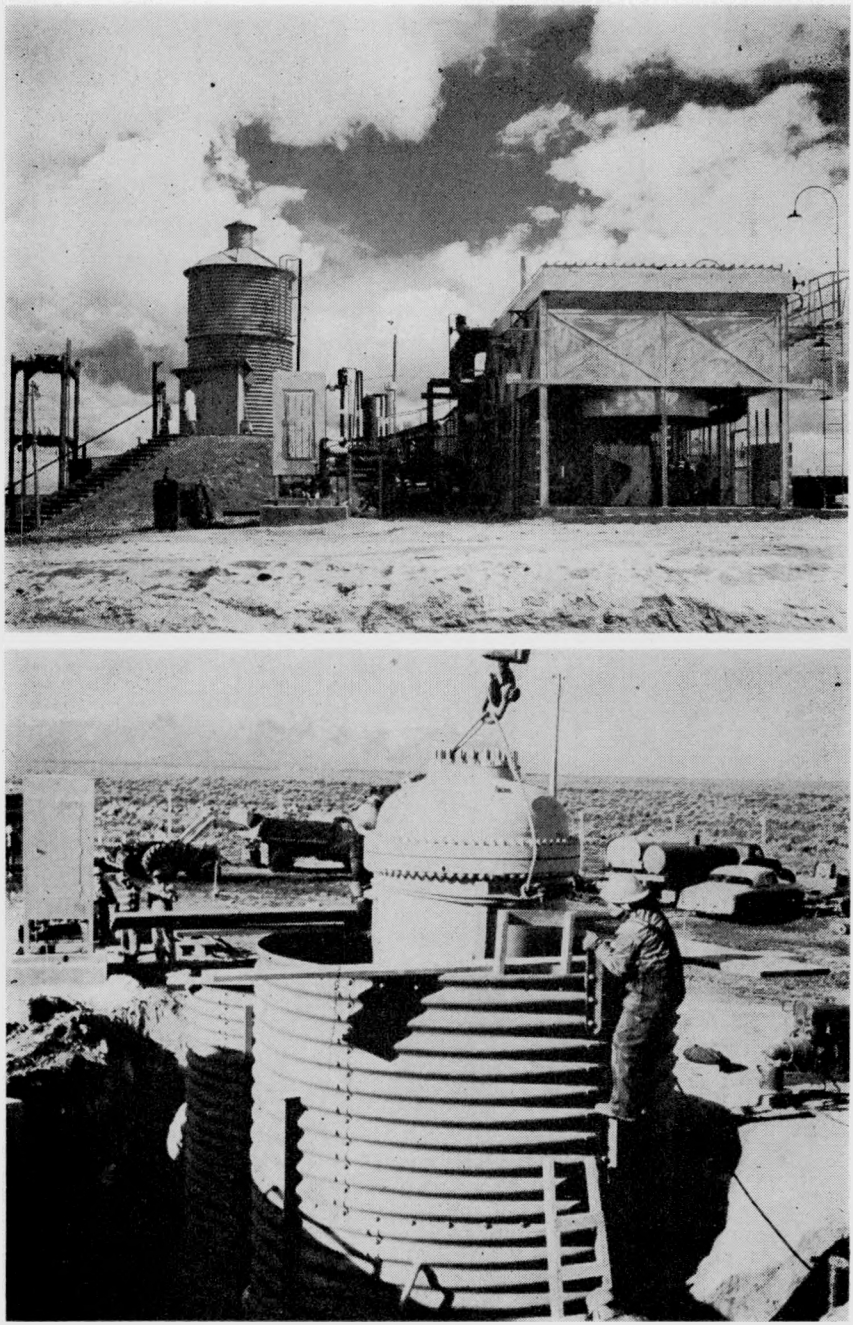
Vallecitos. The first commercial power reactor to operate in the United States, the 100-foot container and installation at General Electric Co. Vallecitos Laboratory in California; below, core being moved into position.



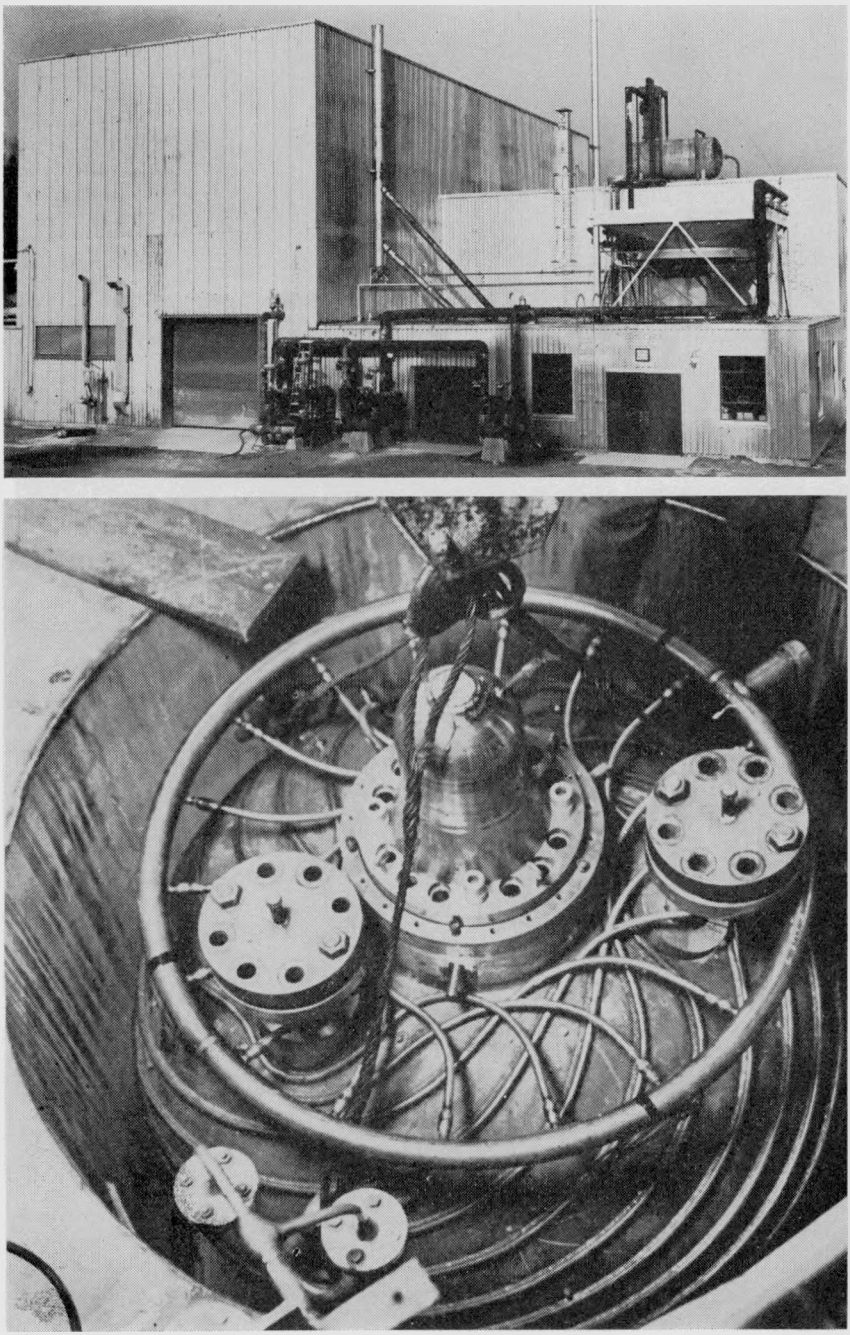
EBWR. The Experimental Boiling Water Reactor which supplies the electricity for Argonne National Laboratory; above, the reactor core being lowered into position.



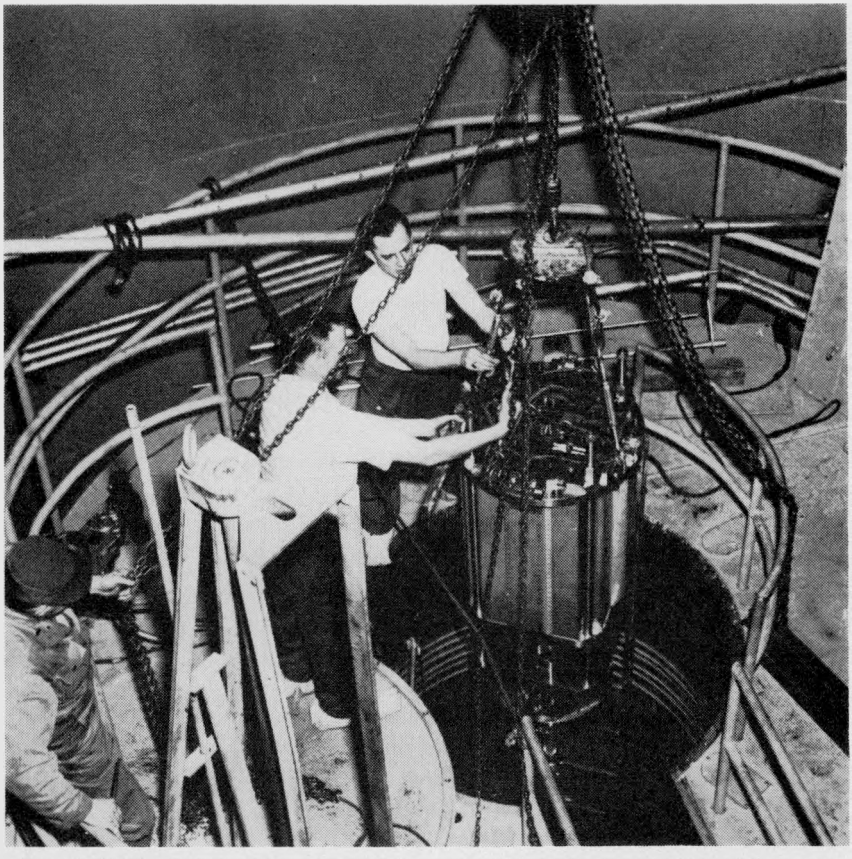
SRE. The Sodium Reactor Experiment installation in the Santa Susana mountains, California, and a view down into the reactor core. The round containers are zirconium cans containing the graphite moderator.

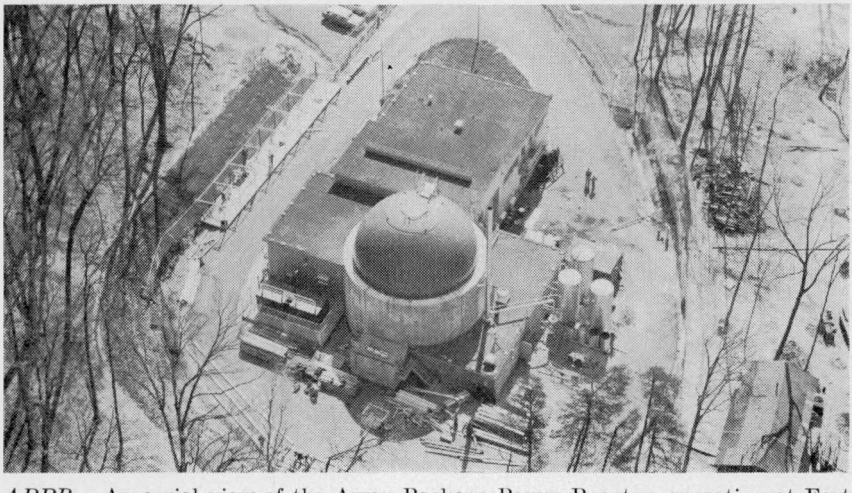


OMRE. A general view of the installation of the Organic Moderated Reactor Experiment now operating at the National Reactor Testing Station; below, lowering the 28-foot reactor tank into place.



HRE–2. The second Homogeneous Reactor Experiment at Oak Ridge National Laboratory, a general view of the installation and, below, the core and pressure vessel assembly of the reactor.





APPR. An aerial view of the Army Package Power Reactor, operating at Fort Belvoir, Va., and, above, lowering the reactor core into place.

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Highlights of 1956

- A contract was signed with Atomics International, a division of North American Aviation Inc., to construct and operate the Organic Moderated Reactor Experiment.
- Construction was completed on Homogeneous Reactor Experiment No. 2 at Oak Ridge National Laboratory.
- The Babcock & Wilcox Co. was selected to design, fabricate, and operate a liquid metal-fueled reactor experiment (LMFRE), a new type chosen for research and development aimed at the achievement of economic electrical power.
- Proposals invited for a Gas-Cooled Reactor Experiment at the National Reactor Testing Station, a type chosen for possible civilian application as well as military applications.
- The Commission announced that it would construct and operate an experimental facility to be known as the Argonne Boiling Reactor Facility (ARBOR), to be operated by the Argonne National Laboratory, as an extension of the work on boiling water reactors.
- A design study and development work were initiated to determine the feasibility and economics of heavy water-moderated power reactors using natural uranium as fuel by E. I. du Pont de Nemours & Co. for the Commission.
- Procurement of zirconium and hafnium was expanded to meet the growing needs of the Commission's reactor programs.
- First permits were issued for private construction of large-scale nuclear powerplants to Consolidated Edison Co. of New York and Commonwealth Edison Co., Chicago.
- Permit issued to General Electric Co., Schenectady, N. Y., for construction of a developmental nuclear power reactor in Alameda County, Calif.
- The Commission approved a program to encourage private industry to build and operate plants for the chemical processing of irradiated fuel elements from research and power reactors.
- The Experimental Boiling Water Reactor was completed and operated at Argonne National Laboratory, the first of the Commission's original five reactor experiments to be operated successfully.
- A contract was signed with the Yankee Atomic Electric Co., Boston, Mass., under which the company would receive assistance in the development and operation of a large-scale nuclear powerplant at Rowe, Mass. This was the first contract under the Power Demonstration Reactor Program.
- Negotiations authorized with Rural Cooperative Power Association, Elk River, Minn., and the Wolverine Electric Cooperative, Big Rapids, Mich., on nuclear powerplant proposals made in response

to the Commission's second invitation, calling for development, design, construction, and operation of plants with capacities within the 5,000- to 40,000-electric-kilowatt range.

● Negotiation was approved on a contract for limited initial design and development work on a nuclear power reactor system as a result of a joint proposal by the Chugach Electric Association of Anchorage, Alaska, and the Nuclear Development Corp. of America, White Plains, N. Y., in response to the second invitation.

● Negotiation was begun on contract provisions for initial design and development work related to the nuclear powerplant project proposed by the city of Piqua, Ohio, in response to the second invitation.

● A construction permit was granted to the Power Reactor Development Co., Detroit, Mich., for building of a nuclear powerplant near Monroe, Mich., proposed under the first invitation.

● The fourth in a series of boiling reactor experiments (BORAX–4), operated at National Reactor Testing Station.

Highlights of 1957

● The Pressurized Water Reactor, at Shippingport, Pa., went into operation, the Nation's first full-scale nuclear powerplant, and the first full-scale plant in the world designed exclusively for production of civilian electric power.

● The Experimental Boiling Water Reactor at Argonne National Laboratory operated successfully throughout the year and was tested at 2½ times its design capacity of 20 thermal megawatts.

● The Sodium Reactor Experiment was operated, the first nonmilitary reactor to produce heat for the generation of power by a private utility.

● The Organic Moderated Reactor Experiment was operated at the National Reactor Testing Station.

● The Homogeneous Reactor Experiment No. 2 was operated at the Oak Ridge National Laboratory.

● Vallecitos Boiling Water Reactor, the world's first privately financed atomic electric powerplant, received power reactor license No. 1 to operate at General Electric Co.'s Vallecitos Atomic Laboratory near Pleasanton, Calif. The plant is producing 5,000 kilowatts of electricity for distribution over the Pacific Gas & Electric System, but will be used primarily to develop operational data for application to the design of the 180,000-electric-kilowatt Dresden nuclear power station which GE is building near Chicago for the Commonwealth Edison Co.

● Consolidated Edison Co. of New York began construction at Indian Point, N. Y., of its 275,000-electric-kilowatt combined nu-

clear and conventional powerplant being built entirely with its own funds to furnish power for New York City and environs.

- Commonwealth Edison Co. began construction of its Dresden station near Joliet, Ill., financed entirely with private funds.
- A contract was signed with United Engineers & Constructors, Inc., for architect-engineer work in connection with the Argonne Boiling Reactor Facility (ARBOR), to be located at the National Reactor Testing Station.
- Experimental Breeder Reactor No. 1 operated at the National Reactor Testing Station with its third core. EBR–1, which in 1951 produced the world's first electricity from nuclear energy, was damaged in 1955 during a series of transient experiments. It is being used to investigate safety aspects of fast breeder reactors.
- Site preparation began and components were ordered for the Experimental Breeder Reactor No. 2 at the National Reactor Testing Station.
- Kaiser Engineers was selected to submit a preliminary engineering design of a natural uranium, gas-cooled, graphite-moderated nuclear electric powerplant of 40,000-electric-kilowatt capacity.
- A construction permit was issued following public hearings to the Yankee Atomic Electric Co. to build its 134,000-electric-kilowatt, pressurized water powerplant near Rowe, Mass., under a Power Demonstration Reactor Program contract. Ground was broken for start of construction and components ordered.
- Agreement was reached with Consumers Public Power District on contract terms covering the construction and operation of a 75,000-electric-kilowatt, sodium-cooled, graphite moderated nuclear powerplant at Hallam, Nebr., the final contract under the first invitation issued by the Commission.
- A contract was signed with the Power Reactor Development Co. under which the Commission will grant the company assistance in developing of its 100,000-electric-kilowatt, sodium-cooled, fast-breeder reactor being built near Monroe, Mich.
- A general invitation was extended for proposals to design, develop, construct, and test-operate a boiling water powerplant with a design capacity of 22,000 net kilowatts of electricity to be installed in the system of the Rural Cooperative Power Association, Elk River, Minn. Six firms which indicated interest have been allowed until February 3 to make firm proposals.
- Plans were canceled for negotiation of a contract with the Foster Wheeler Corp. for the development and construction of a 10,000-electric-kilowatt, aqueous homogeneous nuclear powerplant for operation by the Wolverine Electric Cooperative, Big Rapids, Mich.

- A contract was signed with the Nuclear Development Corp. of America for research, development, and preliminary design work to demonstrate the feasibility of a 10,000-electric-kilowatt, liquid sodium-cooled, heavy water-moderated reactor system under a proposal made jointly by the Chugach Electric Association and the Nuclear Development Corp.
- A third invitation was issued for nuclear powerplant proposals under the Power Demonstration Reactor program.
- A formal proposal was received from the Carolinas Virginia Nuclear Power Associates, Inc., Charlotte, N. C., for the development, design, construction, and operation of a 17,000-electric-kilowatt, heavy-water-cooled and heavy water-moderated reactor fueled with slightly enriched uranium.
- A contract was signed with the Northern States Power Co., Minneapolis, Minn., for development, design, construction, and operation of a 66,000-electric-kilowatt advanced boiling water reactor fueled with slightly enriched uranium.
- A proposal was made under the Power Demonstration Reactor program by Pennsylvania Power & Light Co. for a 150,000-electric-kilowatt aqueous slurry homogeneous plant which the company had earlier planned to build without Government financial assistance.
- A development program was conducted to investigate recycling of plutonium in thermal reactors. Construction is to begin early in 1958 on a Plutonium Recycle Test Reactor at the Commission's Hanford, Wash., Works.
- Development work continued on gas-cooled, liquid metal fuel, pressurized heavy water, and fused salt reactor types of reactors.
- The Engineering Test Reactor was operated at the National Reactor Testing Station. It is the Nation's largest and most advanced nuclear test facility.
- Westinghouse Electric Corp. received a permit authorizing construction of the first privately owned generalized testing reactor.
- A joint Commission-Maritime Administration program was announced for developing nuclear-powered merchant ships. A contract was awarded to the New York Shipbuilding Corp., Camden, N. J., for construction of the first nuclear-powered merchant ship, the NS. *Savannah*, and to The Babcock & Wilcox Co. for a nuclear propulsion plant for the ship.
- A proposal was received from the East Central Nuclear Group and the Florida West Coast Nuclear Group for the development, design, construction, and operation of a 50,000-electric-kilowatt, gas-cooled, heavy water-moderated powerplant.

TECHNICAL PROBLEMS OF ECONOMIC REACTORS

Progress in the civilian atomic power effort requires extensive operating experience. Time is the necessary ingredient to provide this experience. The program is just a little over 3 years old and the initial experimental reactors have just been completed.

Nevertheless, there has now been sufficient experience to identify basic problems which must be solved before economic nuclear power will be achieved.

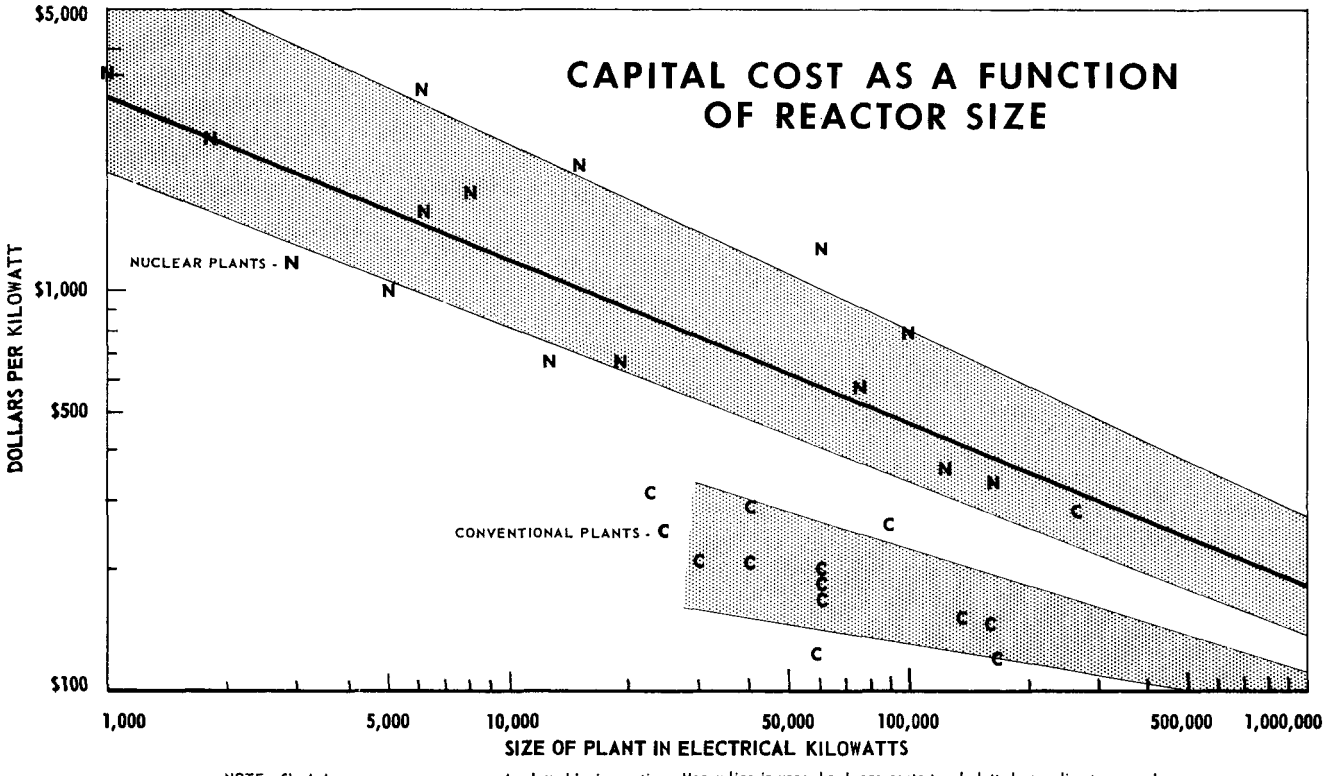
Reduction In Capital Costs

It is expected that capital costs will be reduced by simplification of design, by increased use of standardized components, by adoption of commercial specifications and fabrication techniques and by multiple production of components. Unit capital costs will be reduced when performance is improved and larger plants are built.

Improved plant performance. Construction costs commonly are measured in terms of dollars per installed electrical kilowatt. Hence the plant performance (kilowatts produced) is a factor of great importance. Improvements in technology will permit reactors to run at higher temperatures, and hence higher efficiencies for converting the heat into electricity. Another potential improvement is attainment of higher specific power; that is, higher reactivity per unit of fuel, which may result in severalfold increases in net output. This is being evidenced even at this early stage of civilian reactor development. The Experimental Boiling Water Reactor, for example, originally designed for 5,000 electric kilowatts, has demonstrated a capability of operation at from 2 to 3 times this design level.

Building larger plants. Nuclear power reactor plants built to date have been small compared to conventional powerplants—60,000 electrical kilowatts is the largest single reactor unit, and most are far smaller, compared to the 100,000 to 450,000 kw per generating unit range in conventional plants. Unit costs of conventional plants tend to become lower as size of plant is increased and experience with nuclear plants is expected to parallel this pattern. (See chart, Capital Cost as a Function of Reactor Size.)

Simplification of design. The Commission-sponsored reactor experiments are conservatively designed as a protection against uncertainties in technology and inadequate experience with the specific



NOTE: Shaded areas represent cost trends plotted by inspection. Heavy line in upper band represents trend plotted according to general industry formula relating unit cost to size: Unit cost ($/KW) = 47,500 (Electrical rating of plant in kilowatts)$^{-0.4}$

systems. Designers of full-scale prototype plants will have the benefit of experience gained in construction and operation of the reactor experiments. They will be able to substitute for the initial understandably excessive conservatism a confidence based on knowledge and experience. In addition, they will need to place significantly less emphasis on experimental flexibility in the reactors and the complications in design this requires. Major design simplification can accordingly be expected even in some of the earliest full-scale plants.

Some of these effects already are evident and are being incorporated, for example, in the plant designs for the Yankee, Commonwealth, Consolidated, and Consumers Public Power District projects. These factors should continue to contribute to design simplification in later generations of power reactors.

Increased use of conventional components. Another factor tending to reduce construction costs will be the increased standardization in nuclear plants of pumps, heat exchangers, valves, and other components. This has been attempted in several experimental reactors, including, for example, the Vallecitos Boiling Water Reactor and the Organic Moderated Reactor Experiment. Experience is indicating that in a number of areas standard equipment can replace the specially designed components used initially. This again is a reflection of increased knowledge and confidence which can result only from actual operating experience.

Adoption of commercial specifications and fabrication techniques. At this early stage in the development of power reactors, it is necessary to impose very stringent specifications on the reactor and much of the ancillary equipment in order to reduce to an absolute minimum the possibilities of breakdown or failure. To the extent that these conditions bear on public safety, there can be no relaxation of specifications. However, in many cases the stringent requirements are merely an attempt to avoid shutdown for replacement or routine maintenance, or are a hedge against anticipated problems which actual experience subsequently may indicate do not exist.

As experience is gained and more becomes known about the reliability of reactors and their components, it will be possible to have less stringent specifications, leading to substantial reductions in the costs of fabricating these parts. Use of standard melts of steel, gasket closures, and reduced fabrication tolerances on pressure vessels are examples. Large containment structures which now contribute so importantly to costs may prove unnecessary.

Reduction In Fuel Costs

A central problem in the attempt to reduce fuel costs is the need to increase the useful life of fuel elements. Longer life would mean fewer replacements, consequently less frequent incurrence of fabrication and processing costs, which are at present major factors in total full cycle costs. It is difficult to estimate in advance the life of any given fuel element. Its life can be limited by irradiation damage, by corrosion, by decreases in reactivity, and by accumulation of poison products. Reliable operating data on fuel life will be available only after several power reactors have been in operation for several years.

In the absence of full information, the search for fuel elements which will give the best results nevertheless goes on.

Metallic uranium fuel elements have been given extensive consideration. A factor which limits their useful life is the tendency of metallic uranium to swell substantially at high burnups and at high temperatures as a result of the buildup of fission product gases. Solutions are being attempted or considered along various lines, each of which seems to have both advantages and disadvantages. One of these is the use of alloying materials to strengthen the metal at high temperature and thereby resist swelling. This may be an acceptable solution in fast reactors. In thermal reactors use of large amounts of alloying materials would impair neutron economy and decrease the conversion ratio.

Use of oxides and carbides also shows promise. For example, uranium oxide or mixed uranium-thorium oxides seem able to give very good fuel element life, perhaps 25,000 megawatt-days a ton or more at moderately high temperatures. Their use, however, tends to reduce reactor specific power because it involves use of a material which has low density and poor thermal conductivity.

Many current designs for fuel elements for water-cooled reactors are based on use of compacted and fired uranium dioxide pellets in stainless steel or zirconium tubes. Uranium oxide is chemically compatible with water and appears to have sufficient stability to permit long burnups.

Processing of used fuel elements to extract fissionable materials, or to remove reactor "poisons" is a part of fuel costs, as is handling and disposal of radioactive industrial wastes. Pyrometallurgical processing may offer a shortcut process for recycling of fuels, and other methods are being investigated, as are various approaches to reducing waste handling costs. These and other investigations are described later in this report.

An essential point in evaluating whether a new plant should be nuclear fueled or fossil fueled would be the cost performance of the

plant over its entire useful life. Thus, a decision might be made to build a nuclear plant even though it would not be competitive at first, because nuclear fuel costs would be expected to decrease over the next 30 years while conventional fuel costs increased. Even if over the life of the plant the comparison favored conventional fuels on the basis of cost projections, a nuclear plant might be selected as a hedge against the possibility of unusually large future increases in conventional fuel costs.

Reduction in Operating and Maintenance Costs

Because of lack of operating experience for civil nuclear powerplants, estimates of operating and maintenance costs are particularly uncertain. Present plants or plants about to be placed in operation may require relatively large operating and maintenance staffs to meet contingencies. Operation and maintenance will also be complicated and relatively costly due to the necessity for controlling radiation. Experience is expected to reduce these costs to the range of those for conventional plants.

Accounting for Power Reactors

The Commission gathers and distributes technical information on all reactors which it builds or helps to finance. All these data are made available through the normal channels of technical information as reported in the following chapter. The Commission has access to all economic data equally on the reactors it builds and those on which it shares costs with a publicly or privately owned organization.

Ascertaining costs for nuclear electric plants has required new applications of accounting principles. The items of capital costs of conventional plants are specified by the Federal Power Commission, for example, but as yet there is no agreement on the components of capital costs for nuclear reactors. During the past year the Commission has studied the accounting problems inherent in power reactor construction and operations, and has developed an accounting basis for use in determining the operating economics of these new plants.

The major emphasis in the Commission study was on accounting for operations of the Shippingport Pressurized Water Reactor. Most of the basic accounting system developed for this plant, however, will apply to all power reactor operations, although varying physical operating characteristics of reactors must be taken into account.

As a result of the first study of this kind, the Commission outlined the preliminary operating statements and statistics to be submitted by the companies concerned, and defined the accounts generally

affected by the production of electricity from power reactors. The financial and statistical data available under the system are comparable, in many respects, to those required by the Federal Power Commission for conventional utilities. The knowledge gained from early reactors will provide a basis for estimating the cost of constructing and operating future plants of the same type, and for more accurately estimating the cost of producing electricity.

The Commission has been working with the Federal Power Commission and the National Association of Railroad and Utility Commissioners on revising uniform classification of accounts to cover production of power through the use of reactors.

PROGRESS IN REACTOR DEVELOPMENT

Hundreds of reactor types capable of producing heat for conversion to electric power are possible, considering all the alternative materials available for use as fuels, moderators and coolants, the range of possibilities from a completely heterogeneous system to a completely homogeneous system, and the variation of neutron energies possible.

Research and development work on any reactor concept which seems promising goes through several phases. At the outset, conceptual ideas are studied in a theoretical and preliminary way, assisted in some cases by work on fuels and other materials. Well over 100 variations on reactor concepts have been considered in such exploratory work, centered in Commission laboratories with assistance from industrial contractors.

A considerably smaller number of concepts has survived this first test and passed into a second phase of research and development work in which concepts are tried out on an expanded experimental basis. At this stage, more detailed studies are made of such matters as fuel element design, control of the reactor, ways of transferring heat, and fluid mechanics. This work also is done primarily in Commission laboratories and by private contractors.

Reactor concepts which continue to look promising after passing this second developmental phase have been proposed for reactor experiments. In this stage, design and construction of one or more operating reactors of a concept are undertaken to provide the most definitive answers possible to remaining technological questions, including, for example, performance of fuel elements, behavior of control systems, safety of the reactor, and its general physics and engineering characteristics.

For the most part reactor experiments worked on thus far in the program have been financed by the Commission and have been built at Commission-owned sites.

The fundamental scientific and many of the engineering problems of a reactor concept have been largely solved after a successful reactor experiment. Operation of these relatively small experiments, however, usually cannot demonstrate everything it is desirable to know about full-scale reactor operation. Concepts which seem promising after a reactor experiment, therefore, are carried through a further phase in which a full-scale prototype powerplant is built.

Full-scale reactor powerplants have been and are being built under a variety of administrative arrangements. The Pressurized Water Reactor has been built as part of the Commission's experimental program. Its reactor portion was primarily Government financed but with a contribution by Duquesne Light Co., builder of the turbine-generator portion of the plant.

Two plants, those being built for the Commonwealth Edison Co. and the Consolidated Edison Co. of New York, are financed entirely with private funds.

Most of the remaining full-scale plants now included in the United States program are included in the Power Demonstration Reactor Program in which the Commission and industry groups cooperate to build plants under negotiated contracts which involve varying degrees of Government financial participation.

In the Power Demonstration Reactor program, the Commission and utility groups cooperate under negotiated contracts to assure development, construction, and operation of full-scale reactor power prototype plants of types whose further development may lead to economic nuclear power. (See Table I, Active Power Demonstration Reactor Program Projects.) The program is directed toward obtaining as much industrial participation as possible in the construction of complete prototype power reactors so as to enlist cost-cutting incentives at a stage in development when economies are of major importance, and to help provide manufacturers and utilities with experience in constructing and operating nuclear powerplants.

The various ways of developing and financing reactors are often reported, for reasons of convenience, as if each constituted a discrete effort; in fact, the United States program as a whole has an essential unity in that reactors built at any time depend on technology developed up to that time in other civilian plants regardless of administrative arrangements. Technological contributions are made also by a cross-flow of unclassified data from military reactors.

TABLE I.—ACTIVE POWER DEMONSTRATION REACTOR PROGRAM PROJECTS

Builder and plant location	*Type and electrical capacity—(kilowatt)*	*Status*
	First Invitation	
Yankee Atomic Electric Co., Rowe, Mass.	Pressurized water, 134,000.	Contract signed June 6, 1956.
Consumers Public Power District, Hallam, Nebr.	Sodium graphite, 75,000.	Contract signed Sept. 20, 1957.
Power Reactor Development Co., Monroe, Mich.	Fast breeder, 100,000	Contract signed Mar. 26, 1957.
	Second Invitation	
Wolverine Electric Cooperative, Hersey, Mich.	Homogeneous, 10,000	Negotiations deferred.
Chugach Electric Association, Anchorage, Alaska.	Sodium-heavy water, 10,000.	Under negotiation.
Rural Cooperative Power Association, Elk River, Minn.	Boiling water, 22,000	Bids due Feb. 3, 1958.
City of Piqua, Ohio	Organic moderated, 12,500.	Under negotiation.
	Third Invitation	
Carolinas Virginia Nuclear Power Associates, Inc., Parr Shoals, S. C.	Pressurized heavy water, 17,000.	Under study.
Northern States Power Co., Sioux Falls, S. Dak.	Boiling water, 66,000	Contract signed Nov. 19, 1957.
East Central and Florida West Coast Nuclear Groups.	Gas cooled, 50,000	Under study.
Pennsylvania Power & Light Co.	Aqueous homogeneous, 70–150,000.	Under study.

THE DEVELOPING FAMILIES OF REACTORS

Major families of reactors, the state of development in each, and the units being operated, built or planned under each, are described in this section.

The water-cooled group includes pressurized light water, pressurized heavy water, and boiling water reactors. A closely related group is the organic moderated reactors.

Sodium-cooled reactors have been developed in both thermal and intermediate energy ranges.

Fast-breeder reactors may also be sodium cooled.

Homogeneous reactors are discussed along with the advanced molten-salt type.

Remaining types discussed are gas-cooled and liquid metal fuel reactors.

Water-Cooled Reactors

The water-cooled reactors planned, building, and operated, are listed in Table II, Water-Cooled Reactors.

Pressurized light water reactors. This type has a strong lead in the power reactor program of the United States. More of them have been built, and more hours of successful operation have been logged for them than for any other type of power reactor. These reactors will undoubtedly constitute a major fraction of the first group of large-scale power reactors built in this country.

In pressurized water reactors the fuel rods containing fissionable material are surrounded by water under high pressure. The water serves both as a moderator and coolant to transfer heat. The water is heated by the fuel elements and is pumped through a heat exchanger at about 500° Fahrenheit. In the heat exchanger the water gives up heat to generate steam which operates a turbogenerator to produce electricity. The high pressure prevents water from boiling in the reactor and the primary circuit.

The technical feasibility and reliability of this concept have been established beyond doubt. The problem of making it economically competitive remains to be solved. The ultimate position of pressurized water reactors in the nuclear power industry will depend upon the success achieved in reducing costs of power from these systems—success which can only come from operating experience.

TABLE II.—WATER-COOLED REACTORS

Reactor and location	Electric kilowatts	Status	Startup
Civilian Reactor Experiments			
Boiling Reactor Experiment No. 4 (BORAX–4), NRTS, Idaho.[1]	2, 400	Operated	1956.
Experimental Boiling Water Reactor (EBWR), Lemont, Ill.	5, 000	Operated	1956.
Argonne Boiling Reactor (ARBOR), NRTS, Idaho.	(2)	Being built	1960.
Full-Scale Civilian Reactors			
Pressurized Water Reactor (PWR), Shippingport, Pa.	60, 000	Operated	December 1957.
Vallecitos Boiling Water Reactor, Pleasanton, Calif.	5, 000	Operated	October 1957.
Commonwealth Edison Co., Dresden Station, near Joliet, Ill.	180, 000	Being built	1960.
Consolidated Edison Co. of N. Y., Indian Point, N. Y.	[3]275,000	Being built	1960.
Yankee Atomic Electric Co., Rowe, Mass.	134, 000	Being built	1960.
Northern States Power Co., Sioux Falls, S. Dak.	66, 000	Contract let	1962.

See footnotes at end of table.

TABLE II.—WATER-COOLED REACTORS—Continued

Reactor and location	Electric kilowatts	Status	Startup
Full-Scale Civilian Reactors—Con.			
Rural Cooperative Power Association, Elk River, Minn.	22, 000	Bids invited	
Carolinas Virginia Nuclear Power Associates, Parr Shoals, S. C.	17, 000	Under study	
Nuclear Ship *Savannah*	16, 400	Being built	1960.
Belgium (Syndicat d'Etude l'Engergie Nucleaire—SEEN), Mol.	11, 500	Being built	1959.
Italy (Edisonvolta), Milan	134, 000	Announced	1961.
Italy (Societa Italiana Meridionale Energia Atomica—SIMEA), Rome.	134, 000	Announced	1962.
Brazil (American & Foreign Power Co.), Sao Paulo.	12, 500	Announced	1960.
Cuba (American & Foreign Power Co.).	12, 500	Announced	1960.
Full-Scale, Prototype, and Experimental Military Reactors			
Submarine USS *Nautilus* (SSN571)		Operated	1955.
Submarine USS *Skate* (SSN578)		Operated	October 1957.
Nautilus Land-Based Prototype (S1W), NRTS, Idaho.		Operated	1953.
16 submarines (1 of which has 2 reactors).		Being built	
Guided Missile Cruiser (CG(N)160), Long Beach (2 reactors).		Being built	
Aircraft carrier, 8 reactors (CVA(N) 65).		Being built	
Destroyer reactor prototype (D1G), Schenectady.		Authorization requested.	
Large ship reactor prototype, (2 reactors) (A1W).		Being built	
Submarine advanced reactor prototype (S3G), West Milton, N. Y.		Being built	
Small submarine reactor prototype (S1C), Windsor, Conn.		Being built	
Army Package Power Reactor No. 1, (APPR–1) Fort Belvoir, Va.	1, 855	Operated	April 1957.
Argonne Low Power Reactor, (ALPR) NRTS, Idaho.	200	Being built	1958.
Army Package Power Reactor No. 1, (APPR–1a) Alaska.	1, 689	Being built	1959.

[1] BORAX–1, –2, and –3 were predecessor experiments in this series at the same location using some of the same equipment.

[2] No electricity.

[3] 163,000 kw nuclear plus 112,000 kw oil-fired.

Development of the technology of pressurized water power reactors began in 1951 with construction of the S1W, the land-based prototype of the USS *Nautilus* powerplant, at the National Reactor Testing Station. It first produced substantial amounts of power on May 31, 1953. This plant is now being operated as a flexible test facility where new developments in technology, design, and operation of improved naval water-cooled nuclear powerplants can be investigated and improved design cores can be tested. The plant also is used to train naval personnel.

The plant was designed by Westinghouse Electric Corp. as prime contractor to the Commission. The Duquesne Light Co., Pittsburgh, Pa., in addition to contributing $5 million toward the cost of the nuclear portion of the plant, built the nonnuclear portion and will operate the entire plant. Total plant cost is estimated at $72.5 million, including the first core.

In spite of extensive technical background available from other pressurized water projects, the Commission found it necessary to undertake a considerable amount of research and development for PWR, and this work has made major contributions to reactor technology. For example, fabrication of the core required the first large-scale production of uranium oxide, zircalloy-clad fuel elements. The pressure vessel is the largest of its kind ever constructed in the United States.

The prospects for making pressurized water technology economically competitive in the United States are being aided by several additional large-scale reactor projects in which design variations in the basic concept are being explored. These variations deal with fuel material, core arrangement, cladding material, control system, and the use of fossil fuel-fired superheaters.

The Consolidated Edison Co. of New York began construction in February 1957 at Indian Point, N. Y., on a pressurized water reactor being built entirely with its own funds to furnish power for New York City and environs. The plant received a construction permit from the Commission in May 1956. It will have a total generating capacity of 275,000 electrical kilowatts, of which 163,000 kilowatts will be supplied by nuclear energy and 112,000 kilowatts by an oil-fired superheater. Completion of plant is scheduled for 1960.

The company estimates that the plant will cost about $90 million, of which approximately $20 million had been spent at the end of October. The company reported at that time that all major equipment for the conventional portion of the plant had been purchased. The Babcock & Wilcox Co., contractor, has begun fabrication of the reactor vessel and boilers. Critical experiments and other research supporting the project are underway.

The Yankee Atomic Electric Co. pressurized water plant at Rowe, Mass., also is scheduled for completion in 1960. Yankee Atomic Electric Co., composed of 11 major utilities supplying about five-sixths of the power needs of New England, proposed the plant in response to the first invitation under the Power Demonstration Reactor Program. In February 1956 the Commission accepted the Yankee proposal as a basis for contract negotiations, and on June 6 of that year signed the contract—the first under the Power Demonstration Reactor Program.

The contract calls for the company to bear all construction costs and all research and development costs over $5 million. The Commission will bear research and development costs below that figure, and will waive its normal charge for use of nuclear fuel for the first 5 years of operation. All technical and economic data developed will be available to the Commission for public distribution.

The Yankee plant will have electric generating capacity of 134,000 kilowatts. Westinghouse Electric Corp. and Stone & Webster Engineering Corp. of Boston will construct the plant as joint contractors. Conceptual design has been completed and many major items of equipment have been ordered. The Commission conducted public hearings before issuing a construction permit on November 4. Construction was begun immediately thereafter.

This project represents an effort to make advances toward economic power by using a simplified core, by substituting stainless steel for more costly zirconium cladding, and by designing the reactor to produce more power for its size than previous pressurized water plants. The company believes it can achieve a power cost per kilowatt-hour of about 12–15 mills compared to costs from nearby conventional plants of 9 to 10 mills.

The Army Package Power Reactor was the first effort to apply the pressurized water system to a small powerplant. In April 1957, it was placed in operation at Fort Belvoir, Va. This 1,855-electric-kilowatt pressurized water powerplant has demonstrated the feasibility of building small units for assembly and operation in remote locations. While designed primarily for military purposes, the powerplant is completely unclassified and its technology is available for civilian uses.

This plant was built for the Commission and the Department of Defense by Alco Products, Inc. It is the first reactor to have been built on a competitive fixed-price basis. Current progress in operation of this reactor is described under Military Reactor Development, Part Two of this report.

In addition to the reactor plant of USS *Nautilus* and the USS *Skate*, the propulsion plants for 18 naval ships, including an aircraft

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carrier, a guided-missile cruiser, and 16 submarines, as well as the first nuclear-powered merchant ship, described later, also will be powered by pressurized water reactors. Progress in the naval reactor program also is described under Military Reactor Development.

Boiling water reactors. Boiling water reactors are similar to pressurized water reactors in fuel technology and in their use of water as moderator and coolant. The basic difference is that in boiling water reactors the coolant moderator is permitted to boil in the reactor core, and steam can pass directly to the turbine. The entire primary system can operate at lower pressures, and various pieces of equipment, notably the intermediate heat exchanger and possibly a separate boiler as used in many types of reactors, may be eliminated.

The quantity and completeness of boiling water technology is a close second to that on pressurized water reactors. The doubt that such reactors could achieve stability of operation now has been replaced by a state of confidence that the remaining uncertainties will be resolved favorably. A large-scale plant based on this technology is being constructed and another has been contracted for. Operating experience seems likely to lead the way to lower costs.

The BORAX family ushered in intensive work on boiling water reactors. Experiments with Boiling Reactor Experiment No. 1 (BORAX–1), constructed by Argonne National Laboratory at the Idaho Testing Station in 1953, demonstrated the stability and inherent safety characteristics of this reactor system. BORAX–1 was deliberately destroyed in July 1954 in a test to determine its reaction to extreme conditions.

There have been three further BORAX experiments at Idaho. BORAX–2, constructed in 1954, was utilized for further transient tests and various new core combinations using enrichments of uranium 235 in the metal fuel plates.

BORAX–3, first operated in 1955, was a modification of BORAX–2. It was operated with a turbine generator rated at 2,500 electrical kilowatts to investigate problems arising from steam radioactivity in the turbine generator. On July 17, 1955, this reactor served as the exclusive source of electricity for the town of Arco, Idaho, for a period of about an hour, the first such event in history.

A further modification, designated BORAX–4, went critical late in 1956. Its principal purpose was to test fuel elements made from mixed oxides of uranium and thorium. The BORAX facility late in 1957 was approaching the end of its useful life. A series of tests on fuel element failures and other terminal experiments are planned for early 1958.

The Experimental Boiling Water Reactor achieved criticality a little over a year ago on December 1, 1956, at Argonne National Laboratory. A month later, the reactor reached its rated power of 20,000 thermal kilowatts and 5,000 electrical kilowatts. Electricity produced by the EBWR is used to supply the needs of the laboratory.

This reactor is a direct outgrowth of the BORAX experiments, but is still an experimental plant intended to provide as much information as possible for use in designing large central station units. The plant was completed on schedule.

Performance of the EBWR to date has been spectacularly successful. Although this plant was designed to have a thermal capacity of 20 megawatts, it has successfully operated at powers up to 50 megawatts—more than twice the design capacity. This power level was obtained with the original core loading (114 elements) and with natural circulation of the coolant within the reactor core.

EBWR experiments to date have revealed no unstable characteristics. Preliminary analysis of transfer function measurements indicate that the ability of the system to remove heat from the fuel elements rather than nuclear stability is the theoretical limitation on the power from this type reactor. This is a finding of major importance in the effort to achieve economic nuclear power. Practically, the output of this plant is presently limited by the availability of equipment to dissipate the heat generated. Installation of additional heat dissipation equipment is planned.

Conversion to forced circulation of the water moderator-coolant is scheduled for early 1958. This will result in the recirculation rate being independent of power level and will permit a more extensive analysis of the plant's performance. Other future plans under consideration are conversion to heavy water operation and the substitution of plutonium for uranium as the reactor fuel.

The Argonne Boiling Reactor is the most ambitious boiling water reactor yet projected for the Commission's reactor program. This experiment, titled ARBOR, to be built at the National Reactor Testing Station, will have a thermal capacity of about 200 megawatts, will operate at pressures up to 2,000 pounds per square inch, and will have sufficient flexibility to simulate experimentally a wide range of operating conditions. Data from ARBOR experiments should contribute substantially to design of future boiling water central station nuclear powerplants and should provide practical operational experience under a variety of reactor conditions.

In June 1957, Argonne National Laboratory entered into a cost-plus, fixed-fee contract with United Engineers & Constructors, Inc., for architect-engineer work on this reactor. Preliminary design study was nearly complete in late 1957, and detailed design is scheduled for

completion to permit start of site construction in the summer of 1958. Initial operation of the plant is expected in 1960.

The Vallecitos Boiling Water Reactor, built by the General Electric Co. at its Vallecitos Laboratory near San Francisco, is a 5,000-electric-kilowatt experimental reactor. It went critical in August 1957 and is currently operating under Power Reactor License No. 1 from the Commission. The reactor is linked to a turbine generator owned and operated by the Pacific Gas & Electric Co. Electricity produced is being fed into the utility's transmission system. Principal purpose of the plant is to develop information to be used in design and construction of Commonwealth Edison Co.'s Dresden plant.

Direct construction cost of the reactor alone was $2.5 million, and the turbine generator cost $572,000, according to company statements. The reactor was dedicated November 25 as the first privately financed reactor to produce power. Lewis L. Strauss, Commission Chairman, in an address at the ceremony, emphasized that "This is the first atomic powerplant financed and built entirely by private capital to come into operation in the United States—or, to the best of my knowledge, anywhere in the world.

"It is distinguished, however, in other aspects as well. This plant and the electricity flowing from it to the homes and industries in 47 California counties is a symbol of the atomic future—and a not far-distant future—when larger and more advanced nuclear powerplants will be in operation up and down and across our Nation, patterned after this and other promising reactor concepts."

Commonwealth Edison Co.'s 180,000-electric-kilowatt Dresden Station is being built near Joliet, Ill., by General Electric Co. and the Nuclear Power Group, Inc. The Commission issued a construction permit for the Dresden plant in May 1956. The contract price is $45 million. Almost all major components have been ordered. The manufacturer reported at the end of October that $16 million had been spent on the project and an additional $23 million committed. The project was on schedule at that time, with construction 10 percent complete and operation scheduled for 1960.

The Commonwealth plant attempts to reduce nuclear power costs through a high-temperature, high-performance reactor design. Proposed operation at 1,000 pounds per square inch pressure and 541° Fahrenheit temperature will require high temperature fuel cladding, and enriched uranium oxide rod-type zircalloy-2 clad fuel elements will be used to provide prolonged fuel life along with good neutron economy. The plant will also utilize dual-cycle operation in which a portion of the water circulating through the core will be drawn off to generate steam. The purpose of dual-cycle operation is to increase the stability of the reactor and its response to rapid load changes.

The Rural Cooperative Power Association of Elk River, Minn., proposed construction of a 22,000-electric-kilowatt boiling water reactor plant in response to the second invitation issued under the Commission's Power Demonstration Reactor program. This proposal was accepted as a basis for contract negotiations in April 1956.

On September 17, 1957, the selected reactor manufacturer, American Machine & Foundry Co., notified the Commission that its price for building the reactor, and for accompanying research and development work, would be $10.75 million rather than the $7.93 million ceiling price previously agreed upon. During subsequent negotiations this became an estimated price with no firm upper limit; the Commission therefore discontinued negotiations with AMF. Since the Cooperative maintained its offer to furnish plant site and electric generating equipment on previously agreed terms, the Commission on October 9 extended a general invitation to manufacturers for new proposals to supply the reactor portion of the plant along with a conventionally fueled superheater. Six firms which indicated interest have been allowed until February 3 to make firm proposals, an extension of time from the first established date, January 13.

The Northern States Power Co. of Minneapolis, Minn. on November 22, 1957, signed a contract with the Commission under the third invitation of the Power Demonstration Reactor Program. Northern States agreed to construct by June 30, 1962, near Sioux City, S. Dak. a nuclear reactor of an advanced boiling water type. It will have a capacity of 66,000 electric kilowatts.

The Northern States project incorporates several features designed to reduce nuclear power costs. The reactor will be operated at rather modest temperatures and pressures, thereby permitting the use of a relatively inexpensive pressure vessel and low-cost, easily fabricated aluminum-nickel cladding for fuel elements. The reactor will employ high-volume controlled recirculation of the coolant-moderator, a procedure which significantly increases the output of a given sized reactor. Finally, it will employ either a conventionally fired or a nuclear superheater to raise the temperature of steam produced in the reactor to a level approaching that used in more efficient modern steam power stations, permitting the use of a smaller and less costly steam turbine.

The Commission will furnish assistance in research and development up to a maximum value of $6 million and will waive an estimated $1 million charge for nuclear fuel. The cost of the plant, estimated at $21.6 million, and any further research and development costs, will be borne by Northern States, which undertakes also to operate the plant for 5 years.

Northern States has engaged Allis-Chalmers Manufacturing Co. to undertake reactor development, design, and plant construction.

The Argonne Low Power Reactor (ALPR) is being constru ted under the Commission's Army reactors program at the Idaho Testing Station. The ALPR will have an output of about 200 kilowatts of electricity and 1.3 million Btu per hour for space heating. It represents one of several types of reactors under consideration as power sources for remote locations. Completion is expected in 1958. Current progress is described under Military Reactor Development in Part Two of this report.

Pressurized heavy water reactors. Pressurized heavy water reactors are similar to light water reactors except that heavy water is used as the coolant-moderator. Heavy water has the advantage of absorbing fewer neutrons than light water and this makes it possible to use natural uranium as fuel. Heavy water has the disadvantage of being quite expensive and the cost of the heavy water inventory is significant. In addition, it takes more heavy water than light water to slow down neutrons to the energies needed for thermal fission operation. Cores of heavy water reactors consequently are usually quite large and require more expensive pressure vessels or pressure tube construction.

The pressurized heavy water development at Savannah River is the main Commission effort in this field. Research and development is being conducted on fuel elements, components, and pressure vessels and pressure tube systems. Savannah River has had extensive experience with heavy water systems through development and operation of the heavy water production reactors.

The Commission has under consideration a proposal of the *Carolinas Virginia Nuclear Power Associates, Inc.*, Charlotte, N. C., made in response to the Commission's third invitation to industry under the Power Demonstration Reactor Program. The proposal calls for constructing at Parr Shoals, S. C., a pressurized heavy water-cooled and heavy water-moderated reactor fueled with slightly enriched uranium, with a capacity of 17,000 net electric kilowatts.

Organic Moderated Reactors

One technical problem in pressurized water reactors has been the need for thick, expensive pressure vessels to maintain the high pressures necessary to prevent boiling. A modification which eases these requirements involves the use as a moderator of hydrogen atoms in an organic substance instead of in water. Organic-moderated reactors produce fairly high steam temperatures at modest reactor pressures.

Other advantages include the fact that the organic material does not cause corrosion problems, and does not become highly radioactive in the reactor. These factors may reduce capital costs. A major problem is the tendency of organic coolants to decompose under irradiation.

The Organic Moderated Reactor Experiment, which embodies this concept, was placed in operation on September 17, 1957, at the National Reactor Testing Station. It utilizes the organic material terphenyl as both moderator and coolant. A variety of low-power experiments is being performed prior to bringing the reactor to full power. At present there are no plans to use the heat from the OMRE to generate electricity. This reactor was developed by Atomics International, a division of North American Aviation, Inc., under contract with the Commission.

Contract negotiations with the *City of Piqua, Ohio,* for a 12,500-electric-kilowatt, organic-moderated reactor plant were renewed under the changed arrangements of Public Law 85–162. Piqua made a proposal in response to the second invitation issued under the Power Demonstration Reactor Program.

Sodium-Cooled Thermal and Intermediate Reactors

Considerable work has been done on reactor systems using liquid sodium as a coolant.

Sodium remains a liquid at powerplant temperatures and at normal atmospheric pressures. Its melting point is 208° F.; it boils at 1,620° F. This range permits high temperatures for transfer of heat energy without the problem of boiling even at atmospheric pressure. Sodium also is an excellent heat transfer medium.

The use of sodium is, however, not without certain disadvantages. It reacts strongly with oxygen and water and must therefore be isolated from them. Further, when exposed to neutrons, as in a reactor, it becomes a highly radioactive gamma-ray emitter with a half-life of about 15 hours, which creates a serious problem of radiation control. For these reasons, present designs use a double circuit to transfer the heat, a primary circuit through the reactor in which the sodium becomes radioactive, and a secondary nonradioactive circuit parallelling the first outside the reactor to transfer heat from the primary circuit to the boiler. Table III lists Sodium-Cooled Thermal and Intermediate Reactors.

Sodium-graphite reactors. One group of reactors combines use of sodium as coolant and graphite as moderator. Graphite is inexpensive, absorbs few neutrons, and can withstand very high temperatures.

Experience in its use dates to 1942. Graphite moderator sections are canned in zirconium, thus preventing absorption of sodium into the graphite.

The Sodium Reactor Experiment (*SRE*) was an important step forward in developing the sodium graphite concept. Built for the Commission by Atomics International, a division of North American Aviation, Inc., the reactor is designed to produce 20,000 kilowatts of heat, from which equipment installed by the Southern California Edison Co. will generate approximately 6,000 kilowatts of electricity.

TABLE III.—SODIUM-COOLED THERMAL AND INTERMEDIATE REACTORS

Reactor and Location	Electrical kilowatts	Status	Startup
Civilian Reactor Experiments			
Sodium Reactor Experiment (SRE) near Los Angeles.	6,000	Operated	April 1957.
Full-Scale Civilian Reactors			
Consumers Public Power District, Hallam, Nebr.	75,000	Under development.	1962.
Chugach Electric Association, Anchorage, Alaska.	10,000	Design study	1962.
Military Reactors			
Submarine Intermediate Reactor, Mark A (S1G), West Milton, N. Y.	----------	Dismantled	1955.
Submarine USS *Seawolf* (SSN 575)	----------	Operated	1956.

The SRE was brought to criticality on April 25, 1957. On July 12 it became the second in the five-reactor program established in 1954 to produce electricity.

At the SRE dedication, Lewis L. Strauss, Chairman of the Commission, pointed out that "This nuclear powerplant which we dedicate today—experiment though it may be—is distinguished by the fact that it is the first nonmilitary nuclear reactor, designed and built exclusively for civilian use, to produce electric power for distribution on a commercial basis.

"In generations to come, when those who follow us look back to these primitive years of the nuclear age, I feel sure that they will find today's event duly recorded as a benchmark along the trail of achievement that began in 1951 when the world's first usable amounts of nu-

clear electricity were produced by another United States experimental reactor at Arco, Idaho."

During the dedication the SRE produced 2,000 kilowatts of electricity which entirely supplied the electrical needs of Moor Park, Calif.

Design studies and development work already have begun on a second core for the SRE. Fabrication and installation of the core are planned for the spring or summer of 1958.

The Consumers Public Power District, of Columbus, Nebr., signed a contract with the Commission on September 20 covering construction and operation of a large-scale nuclear powerplant at Hallam, Nebr. The Joint Committee on Atomic Energy had waived the 45-day waiting period which must elapse while Congress is in session before contracts of this type can be signed.[8] This was the final contract signed on a proposal responsive to the first invitation issued under the Power Demonstration Reactor Program.

Under the contract, the Commission will construct a sodium-cooled, graphite-moderated reactor designed to produce 75,000 kilowatts of electricity. Consumers will provide the site and a 100,000-kilowatt turbine generator, will contribute $5.2 million toward the cost of construction of the nuclear portion of the plant, and will operate the entire plant for 5 years.

It is estimated that the reactor portion of the plant will cost about $29 million to construct. Consumers will finance turbine generator and conventional facilities for an estimated $11 million.

The Commission, in addition to financing the bulk of construction costs for the nuclear portion of the plant, has agreed also to bear preconstruction research and development costs estimated at $18 million. A major portion of this work, which has recently been initiated, will be done by Atomics International under its existing contract with the Commission. The Commission also has agreed to bear postconstruction costs, estimated at $8 million, covering some fuel costs and extraordinary maintenance. Architect-engineer and construction contractors for the nuclear portion of the plant are to be selected by the Commission.

Work on the first phase of the project, covering the conventional facilities, is expected to get underway early in 1958. Construction of the reactor is expected to start in mid-1959, with testing and operation scheduled for 1961.

The completed reactor should embody many improvements over the SRE. Two major improvements now planned are use of oxide fuel elements and zircalloy-2 or stainless-steel moderator cans. Oxide fuel elements will enable the reactor to achieve high burnup, which cannot be achieved, due to radiation damage, in the present SRE fuel. The

[8] As required by Public Law 85-162.

use of zircalloy-2 or stainless-steel moderator cans will reduce thermal stress and oxidation control problems.

Other sodium cooled reactors. A proposal by the *Chugach Electric Association,* Anchorage, Alaska, and the Nuclear Development Corp. of America (NDA), White Plains, N. Y., has been the subject of contract negotiations with the Commission since August 1956. The two organizations proposed a sodium-cooled, heavy-water-moderated reactor plant at Anchorage in response to the Commission's second invitation under the Power Demonstration Reactor Program.

The Commission already has contracted with NDA for research, development, and preliminary design work at an estimated cost of $2.2 million to demonstrate the feasibility of the proposed reactor system.

The Commission also has given Chugach representatives a general outline which the Commission expects to follow in drafting the definitive contract on the basis of Public Law 85–162.

The Submarine Intermediate Reactor (S1G) at West Milton, N. Y., was the land-based prototype for the USS *Seawolf's* propulsion plant. In February 1950 the research and development program at the Knolls Atomic Power Laboratory was reshaped to give priority to this reactor and construction was authorized in February 1952. It began operating on March 20, 1955.

In July 1955 the S1G plant developed leaks in both superheaters and in one steam generator. The superheaters were isolated, the generators repaired, and operations continued. In March 1957 the Commission shut down the S1G after the Navy's decision against using sodium-cooled reactor propulsion systems in additional naval vessels.

In July 1956 the Commission signed a contract with the Niagara Mohawk Power Corp. for sale of byproduct electrical power produced by the S1G at a dump-power price of 3 mills per kilowatt-hour. At termination of the contract on March 21, 1957, the Commission had sold 765,160 kilowatt-hours for a total of $2,295.48.

The Submarine "Seawolf" Reactor (S2G) was assigned for construction in July 1952 by the Navy to the Electric Boat Division of General Dynamics Corp. Construction began in 1955, and the submarine began sea trials January 21, 1957.

Leaks developed in the starboard superheater and the starboard steam generator during dockside tests of the *Seawolf* in the summer of 1956. The propulsion plant was shut down to investigate and make necessary repairs. When operation was resumed with the superheaters isolated from the system, another leak developed, which also was repaired. No difficulty was experienced with the nuclear reactor itself and the safety of the plant was not impaired. As a result of

builder's trials and Board of Inspection and Survey trials, the Board recommended that the *Seawolf* be accepted for restricted service and that the sodium plant ultimately be replaced with a pressurized water reactor.

The *Seawolf* has been operating satisfactorily in routine naval operations. As of December 31, she had steamed over 29,000 miles, of which 20,000 were while submerged.

Fast-Breeder Reactors

Fast-breeder reactors commonly employ sodium as coolant because it is an efficient coolant, and fits well with the requirements that the core of breeder reactors must be small in size and unmoderated. A reactor is said to "breed" when its operation produces a greater quantity of fissionable material than is consumed.

In one type of fast-breeder reactor most of the neutrons not necessary to sustain the fission chain reaction are captured in the more abundant isotope, uranium 238. When this happens, uranium 238 is converted to plutonium (Pu 239) which may be used as fuel in reactors. This is the same nuclear transmutation which produces plutonium in the large thermal reactors at Hanford and Savannah River. However, in the production reactors breeding does not take place—plutonium is produced less rapidly than uranium 235 is consumed. When plutonium is used as fuel in a fast-breeder reactor, it should be possible to produce as much as 1.5 atoms of plutonium for each atom of plutonium burned up as fuel. Breeders may eventually be very important to a large-scale atomic power economy.

Table IV lists the fast breeder reactors.

Early work on fast reactors was initiated in 1945 at Argonne National Laboratory (then called the Argonne Laboratory) and the Los Alamos Scientific Laboratory when both submitted proposals to the Manhattan Engineer District to design and construct fast reactors.

The Los Alamos fast reactor, called Clementine, was primarily composed of plutonium rods cooled by mercury. No power was produced, and its breeding characteristics were not tested. It operated successfully as a research reactor until 1953, when it was dismantled. The proposal submitted by Argonne culminated in construction of the *Experimental Breeder Reactor No. 1* at the National Reactor Testing Station. It was designed primarily to study the physics and breeding characteristics of fast reactors, and secondly to study the technology of liquid metals as coolants.

Construction of EBR–1 was approved in November 1947. The reactor went critical in August 1951. On December 22, 1951, it produced the world's first electricity from atomic energy. Subsequently

TABLE IV.—FAST BREEDER REACTORS

Reactor and location	Electric kilowatts	Status	Startup
Civilian Reactor Experiments			
Experimental Breeder Reactor No. 1 (EBR–1), NRTS, Idaho.	200	Operated	1951
Experimental Breeder Reactor No. 2 (EBR–2), NRTS, Idaho.	20, 000	Being built	1960
Los Alamos Molten Plutonium Reactor Experiment No. 1 (LAMPRE–1), Los Alamos, N. Mex.	(1)	Being designed	1960
Full-Scale Civilian Reactors			
Power Reactor Development Co., Enrico Fermi Plant, Monroe, Mich.	100, 000	Being built	1960

[1] No electricity.

it provided electricity for self-contained operation of the plant and associated laboratory facilities.

Operation of EBR–1 on its first core from 1951 to 1954 demonstrated that breeding was feasible. Additional experiments were carried on with the second core until November 29, 1955, when this core became overheated and partially melted down during a fast excursion experiment.[9]

The EBR–1 went critical with its third core on November 11, 1957. This core will be used for detailed studies of the effect upon the stability of the reactor of bowing of fuel elements. It is believed that excessive bowing of the fuel elements in the previous core caused the power excursion that disabled it. The Mark III core is designed so that inward bowing of the fuel elements can be controlled and coolant flow altered at need.

The Experimental Breeder Reactor No. 2, like EBR–1, will be unmoderated and liquid metal cooled. It will have a thermal output of 62,500 kilowatts and an electrical capacity of 20,000 kilowatts. EBR–2 will employ full-size components in its sodium system; for example, pumps and piping of 5,000 to 6,500 gallons per minute capacity. It is expected to yield much practical power operating information.

The EBR–2 was authorized for construction by Public Law 85–162, and preliminary construction began in October at the Idaho testing station. Major construction will begin in 1958, with completion expected by early 1960, and full power operation scheduled for 1960.

[9] See pp. 45–46, Twentieth Semiannual Report to Congress (January–June 1956).

The EBR–2 is to be fueled initially with uranium 235, but will later operate on plutonium. The facility will include an integrated fuel processing and fabrication plant. Pyrometallurgical processing will be employed to remove only objectionable fission products from irradiated fuel elements, and to extract plutonium and objectionable fission products from the blanket elements. The resulting partially decontaminated fuel material will then be recast into fuel elements by remote control techniques. The fuel will remain in metallic form throughout, and the usual chemical processing will be avoided.

Los Alamos Molten Plutonium Reactor Experiment No. 1, which will use molten plutonium as a fuel, is a small-scale fast reactor. It is not designed to produce electricity. It will be employed as a short-term experiment primarily to develop methods of containing molten plutonium, which is highly active metallurgically. The containing material must be amenable to fabrication, inert to molten plutonium and the sodium-potassium coolant, and have a high melting point. Further work on the reactor experiment is contingent on results of materials development work now underway.

The Enrico Fermi Reactor plant is being constructed near Monroe, Mich., by a group of electric utility and industrial companies forming the Power Reactor Development Co., Inc. It will include a solid-fuel fast-breeder reactor. The Commission signed a contract for this project under its Power Demonstration Reactor Program on March 26, 1957. Under this contract the Commission will provide research and development assistance up to a total of $4.45 million, and waive fuel-use charges for a period of 5 years. Detroit Edison Co. will supply, own, and operate the electrical generation portion of the station, buying steam from the reactor company and selling auxiliary power, water, and sewer facilities.

The design of this reactor provides for an initial output of 100,000 electrical kilowatts and a possible later capacity of 140,000 kilowatts. The expected breeding ratio is 1.2. Fuel elements will be of an enriched uranium-molybdenum alloy clad with zirconium, and liquid sodium will be used in both primary and secondary circuits as the heat transfer material.

Ground was broken on August 8, 1956, after the Commission issued a construction permit on August 4. The reactor containment vessel was pressure tested in October 1957. It is gas tight, 120 feet in height, and 72 feet in diameter, and will house the test facility and reactor. Preliminary construction has begun on sodium-handling facilities.

Detroit Edison Co. has finished most site preparation work and will begin construction of the turbogenerator building next April. Completion of the nuclear powerplant is scheduled for late 1960.

The record of Commission hearings conducted on the Power Reactor Demonstration Co. matter has been completed, all briefs of the parties have been filed, and the matter was pending in December before the Commission for intermediate decision.

Homogeneous Reactors

Aqueous homogeneous reactors utilize solutions or suspensions of fuel in light or heavy water which serves as moderator-coolant. By combining fuel, moderator, and coolant in a single fluid medium, the homogeneous reactor avoids problems of fuel-element fabrication and stability, and makes possible high-power density and low-fuel inventory. It has good control characteristics from the standpoint of both safety and power demand, and does not require control rods. Continuous chemical processing can be carried on, and new fuel added and fission products drawn off without shutting down the reactor.

Major problems associated with the homogeneous reactor concept stem from the need to handle and contain the radioactive and corrosive or erosive fuel solution or slurry circulating through an extensive system of pressure vessels and piping. This system must possess high integrity to insure leaktightness. In addition, provision must be made for recombination, either internally or in external equipment, of the hydrogen and oxygen produced by radiolytic decomposition of the light or heavy water.

Table V lists Aqueous Homogeneous Reactors.

TABLE V.—AQUEOUS HOMOGENEOUS REACTORS

Reactor and location	Electric kilowatts	Status	Startup
Reactor Experiments			
Homogeneous Reactor Experiment No. 1 (HRE–1), Oak Ridge.	150	Dismantled	1952
Homogeneous Reactor Experiment No. 2 (HRE–2), Oak Ridge.	300	Operated	December 1957
Los Alamos Power Reactor Experiment No. 1 (LAPRE–1).	None	Dismantled	1956
Los Alamos Power Reactor Experiment No. 2 (LAPRE–2).	None	Being built	1958
Wolverine Electric Cooperative, Hersey, Mich.	10,000	Cost study	----
Pennsylvania Power & Light Co. (Pennsylvania Advanced Reactor), northeastern Pennsylvania.	70,000 to 150,000.	Under study	1963

The Homogeneous Reactor Experiment No. 1 (HRE–1) was authorized for construction at Oak Ridge, Tenn., in April 1950. Criticality was first achieved on April 15, 1952. Electricity was generated on February 24, 1953, and the reactor was dismantled in the spring of 1954.

HRE–1 was designed to explore the nuclear characteristics of a reactor containing a circulating uranyl sulfate fuel solution surrounded by a heavy water moderator. In this reactor the fuel solution circulated at nearly 500° Fahrenheit under a pressure of 1,000 pounds per square inch and at a power density of 30 kilowatts per liter. HRE–1 had a thermal capacity of 1,000 megawatts, and utilized a small turbogenerator to produce 140 kilowatts of electrical power during the course of its operation.

The Homogeneous Reactor Experiment No. 2 (HRE–2), approved in January 1954, is a two-region, forced circulation reactor operating on a heavy water solution of uranyl sulfate and will be operated initially with heavy water in the blanket. Construction began in August 1954, and the reactor was essentially completed in May 1956. Nuclear operation was initiated December 27, 1957.

Located on the same site as the dismantled HRE–1, HRE–2 has a designed thermal output of 5,000 kilowatts, and will furnish steam for a small turbogenerator; excess steam will be dissipated to the atmosphere. The plant includes chemical processing equipment for purifying irradiated uranyl sulfate fuel solution through the removal of solid corrosion and fission products.

During preoperational testing during the summer of 1956, chloride ion contamination damaged the stainless-steel leak detection tubing and associated flanges. Repairs delayed operation of the reactor. In the interim, the reactor underwent fairly extensive nonnuclear operation at design temperature, pressure, and uranium concentration with generally successful results. It also has been possible to try out maintenance techniques, which are a major concern in operation of powerplants based upon the aqueous homogeneous reactor concept.

Work on the *Los Alamos Power Reactor Experiment*, an aqueous homogeneous power reactor using phosphoric acid instead of sulfuric acid as the fuel solvent, is continuing at the Los Alamos Scientific Laboratory.

Contract negotiations with *Wolverine Electric Cooperative* have been underway since April 1956 on Wolverine's proposal in response to the second invitation under the Power Demonstration Reactor Program for a single-region aqueous homogeneous reactor plant of 10,000 electric kilowatts capacity at Hersey, Mich. On August 21, 1957, Wolverine informed the Commission that Foster Wheeler Corp. had withdrawn its offer to develop and construct a reactor for the Wolverine system at a ceiling price of $5.5 million, and made an alternate

offer to undertake the work on a cost basis, at an estimated $14.4 million. The Commission announced on October 3 that plans to negotiate a contract with Foster Wheeler had been canceled.

The Commission believes that with a minimum extension of existing technology, a low-power aqueous homogeneous reactor on a commercial system would make an important contribution to the field of nuclear power development. The Oak Ridge Operations Office has accordingly been requested to undertake a detailed cost analysis of an aqueous homogeneous reactor of 10,000-electric-kilowatt capacity including conventional superheating, and suitable for installation on the Wolverine system. Decision on whether or not to ask bids and proceed with construction will depend on this analysis and on technological and cost information gained through operation of HRE–2.

The Pennsylvania Power & Light Co., in a joint effort with Westinghouse Electric Corp., initiated research and development work in July 1955 to investigate the technical and economic feasibility of a large-scale, single-region, aqueous slurry homogeneous reactor for central station use. To date the two organizations have invested $5.5 million in this development program. The projected nuclear powerplant, called the Pennsylvania Advanced Reactor (PAR), would have a capacity of 70,000 to 150,000 electric kilowatts. It was announced on December 11 that a proposal for this reactor had been submitted in response to the third invitation issued by the Commission in January 1957 under its Power Demonstration Reactor Program.

A molten salt reactor program has been initiated at the Oak Ridge National Laboratory to use technology developed in aircraft reactor experiments. Molten salts as a reactor fuel could provide the benefits of a fluid fuel in an unpressurized reactor operating at temperatures high enough to generate 1,000° Fahrenheit steam, a desirable temperature for efficient production of power. The wide range of solubility of uranium, plutonium, and thorium fluorides in fluoride salts allows a variety of reactor types to be considered. The program in its present stage is directed toward the study and determination of rates of corrosion of various materials under contemplated operating temperatures and flow velocities, as well as design studies of powerplants employing molten fluoride reactors.

Gas-Cooled Reactors

Gas-cooled power reactors can be designed to generate steam in a secondary loop, or to use the primary gas coolant directly to operate a gas turbine. Temperatures on the order of 1,200° Fahrenheit are required to operate a gas turbine efficiently, and therefore this type

of reactor requires special materials of construction. Somewhat lower temperatures are required for generating steam to operate a turbine, and thus the materials problems are less severe. The Calder Hall reactors in the United Kingdom are of this latter type of power reactor.

High-temperature approach. A substantial amount of high-temperature work utilizing gas coolants has been done in the military Aircraft Nuclear Propulsion Program, which is contributing technology for civilian gas-cooled reactors. For example, the Heat Transfer Reactor Experiment No. 1 (HTRE–1), which went into operation at the National Reactor Testing Station in 1956 and was dismantled in 1957, employed this technology.

The Gas-Cooled Reactor Experiment (GCRE) being constructed as part of the Army Reactors Program at NRTS also involves high-temperature technology. Criticality is expected to be achieved in 1959. The GCRE is intended to develop engineering data for design and construction of gas-cooled military package powerplants and small civilian central stations. Current progress is reported under Military Reactor Development, in Part Two of this report.

The Maritime Gas-Cooled Reactor (MGCR) would be a high-temperature, high-pressure gas-cooled reactor coupled with a closed-cycle gas turbine for ship propulsion and central station power. Investigation of the MGCR is a cooperative undertaking by the Commission and the Maritime Administration, Department of Commerce.

On August 1, the two agencies extended an invitation to industry for proposals of research and development programs which would lead to development of a reactor prototype. Proposals were received from 18 firms and selection of a contractor was to be made early in 1958.

Although design feasibility studies indicated that this system possesses definite promise of economic propulsion power and useful safety and weight characteristics, its successful development is dependent upon advancing both reactor and gas-turbine technology beyond their present status. While high-temperature operation is a major technical problem, its solution will permit high system efficiency in generating power.

The initial phase of the MGCR project will include development of high-temperature fuel elements, reactor controls, selection of the proper coolant and moderator, and compatible turbine machinery. If research and development is successful and if funds are available, design, fabrication, erection, and test operation of a prototype plant will follow.

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Complete construction of the prototype plant is anticipated from 5 to 7 years after awarding of the initial contract.

The prototype MGCR will advance the eventual development of an economic nuclear fleet. The first nuclear merchant ship, the NS. *Savannah*, a 21,000-ton, cargo-passenger vessel, now is under construction with completion scheduled for early 1960. (See later section on Maritime Reactors.)

Low-temperature approach. Low-temperature, gas-cooled reactors are necessarily large and involve high capital costs. Although this application has received considerable study in the United States, the utility industry has shown little interest in it and there was no large-scale project involving this technology in the United States program until August 1957, when Congress authorized a study leading toward a gas-cooled, graphite-moderated reactor, fueled with natural uranium, to have an electrical capacity of 40,000 kilowatts. Construction of a reactor has not been authorized.

Kaiser Engineers was selected from among 31 firms which submitted bids on this study which is to be submitted to the Joint Committee on Atomic Energy no later than April 1, 1958.

ACF Industries, Inc., has been designated by Kaiser as nuclear design subcontractor. Certain information will be available under the United States agreement for cooperation with the United Kingdom, whose Calder Hall dual-purpose, plutonium-and-power reactors are gas-cooled reactors of this general type.

Liquid-Metal Fuel Reactor

In the type of liquid-metal fuel reactor now under study, the core is a graphite moderator structure with liquid-metal fuel of uranium-bismuth flowing through it. The fuel solution then gives up its heat to an intermediate system, which in turn generates steam. The advantages and disadvantages of this system are similar to those of homogeneous reactors, but by using liquid metal it is possible to generate higher temperature steam.

The Liquid Metal Fuel Reactor Experiment (*LMFRE*) is currently the only project of this type. It is the outgrowth of extensive research and development studies by Brookhaven National Laboratory. These studies show that liquid-metal fuel systems are feasible and have possibilities of achieving low-cost power. The Babcock & Wilcox Co. has contracted to design, fabricate, assemble, and operate the LMFRE. Extensive development work in the areas of materials, components, and remote maintenance systems is being carried out. Evaluation of alternate reactor designs is underway.

Plutonium Recycle Program

Work is proceeding in an effort to demonstrate the feasibility of recycling plutonium as fuel in thermal heterogeneous reactor systems. If successful, a system recycling plutonium generated in its own operation will be able to produce 3 to 4 times as much power from a given quantity of natural uranium, or even of a somewhat depleted uranium, as would be possible without recycling. By this method, thermal reactors with auxiliary chemical separations and fuel fabrication facilities could be designed to operate continuously without dependence on a virgin supply of enriched uranium. A reactor system of this type might be useful also for nations with raw uranium resources but without gaseous diffusion plants.

Construction of an experimental *Plutonium Recycle Test Reactor* at the Commission's Hanford Works was authorized in 1957. Construction is scheduled to begin early in 1958 on a facility to develop plutonium-bearing fuel elements for the plutonium recycle program.

Further data on plutonium as fuel will be obtained from the Materials Testing Reactor by using a full charge of plutonium-aluminum alloy fuel elements currently being fabricated at Hanford.

Maritime Propulsion Reactors

Public Law 848 passed by Congress in July 1956 authorized construction of the first nuclear-powered merchant ship. The President, on October 15, 1956, directed the Commission and the Maritime Administration, U. S. Department of Commerce, to proceed as rapidly as possible. He made the Commission responsible for providing the powerplant, and the Maritime Administration for providing the ship and other equipment, for training crews, for providing fuel-handling facilities, and for future operation of the ship.

Application of nuclear power to merchant ships is one of the more economically promising uses of nuclear energy. As compared with conventionally powered bulk cargo or oil carriers, for example, nuclear-powered ships would have substantially greater cruising radius, lower per ton mile cost at high speeds, and ability to carry larger cargoes.

President Eisenhower has determined that the first merchant ship should bear the name NS. *Savannah*, "NS." for nuclear ship, and "Savannah" in commemoration of the SS. *Savannah*, the first American flag ship to cross the ocean employing steam power.

The *Savannah* will be powered by an advanced pressurized water reactor, the same general system used in the first nuclear-powered submarine, USS *Nautilus*.

A contract was executed on April 8, 1957, with the Babcock & Wilcox Co., of New York, for design and construction of the *Savannah*'s propulsion plant. The contract stipulated that for a fixed price of $9.87 million, Babcock & Wilcox would furnish the basic propulsion system, including the reactor and components of the steam plant and auxiliary systems.

Substantial progress has been made by Babcock & Wilcox on the nuclear propulsion plant. Fabrication of the pressure vessel started in December; fabrication of boilers and primary piping is expected to start early in 1958. Installation of equipment for criticality experiments at Lynchburg, Va. was completed, fuel fabrication techniques were established, and manufacturing of fuel rods for the criticality experiments was well underway. The criticality experiments will start in February, and it is expected that design for the fuel elements to be manufactured for the ship itself will be frozen by June 1958. Review and approval of the nuclear propulsion plant was started.

The Maritime Administration awarded a contract to George G. Sharp, Inc., New York, on April 4, 1957, to act as design agent for the ship itself. By the year's end, the company had essentially completed preliminary design and specifications for the ship. The company engaged Walter Kidde Nuclear Laboratories, Inc., as consultant on nuclear phases of ship design.

On November 19, 1957, the Maritime Administration and the Commission jointly awarded a fixed price contract for construction of the *Savannah* to the New York Shipbuilding Corp. Sea trials are scheduled for 1960.

The ship will be of all-welded construction and will have the following approximate characteristics:

Length	587 feet.
Beam	78 feet.
Full load displacement	21,800 tons.
Cargo deadweight	9,600 tons.
Normal shaft horsepower	20,000.
Design sea speed	20 knots.
Passenger capacity	60.

Work started during the first 6 months of 1957 on resolving many unique operating requirements associated with entry of nuclear-powered ships into foreign and domestic commerce. Cooperative efforts were begun with the Public Health Service, Department of Health, Education, and Welfare, to develop appropriate health and safety regulations. Marine insurance underwriters were studying anticipated insurance needs. Arthur D. Little, Inc., Cambridge, Mass., undertook to survey literature on the health physics and safety

aspects of operating nuclear-powered merchant ships, and the Ralph M. Parsons Co., Los Angeles, made a preliminary investigation of shore- and fuel-handling facilities.

Programs are planned to provide for the training of crews for safe operation of nuclear ships, and for the establishment of international operating codes and practices.

Study of environmental hazards which might result from merchant ship operations was started with a survey of the New York Harbor by the Coast and Geodetic Survey. Armour Research Foundation is concurrently developing procedures for limiting possible contamination. The U. S. Salvage Association is analyzing conventional ship accidents as a basis for long-range nuclear ship design.

A symposium with representatives of shipping lines on the application of nuclear power to the propulsion of merchant ships was held July 30 in Washington, D. C., by the Maritime Administration and the Commission.[10]

Six design feasibility studies involving three promising approaches toward the objective of economic maritime propulsion have been underway. The approaches being studied are the gas-cooled reactor with closed-cycle turbine, the organic-moderated-and-cooled reactor, and the boiling water reactor.

On the gas-cooled approach, as discussed above under Gas-Cooled Reactors, the Commission and Maritime Administration expect early in 1958 to award a contract for work leading to the development of a prototype powerplant.

GENERAL ENGINEERING AND DEVELOPMENT

Reactor Safety Research

The basic goal of the Commission's reactor safety program is to assure the safety of power reactors at as low a cost as possible. The program includes general studies and work done on individual reactors. As much as possible of the work is kept unclassified.

The program includes operation of 5 thermal reactors and 1 fast reactor devoted entirely to safety and transient testing; i. e., testing the dynamic behavior of the reactor when subjected to both sudden and slow changes in reactivity. Three of these reactors have been built, two are under construction, and one is being designed.

SPERT I (Special Power Excursion Reactor Test) is an unpressurized water-moderated reactor specifically designed to yield basic

[10] Nuclear-Powered Ships for American Ship Operators, September 1957. TISE, Oak Ridge, Tenn. TID 7539, $5.50.

safety information and understanding of reactor behavior through transient testing. It began operation in July 1955. Some SPERT I operations have been devoted to aiding other research programs because of its value as an experimental machine capable of producing bursts of high-energy neutrons for very short time periods. Like all the SPERT series, this reactor is located at the National Reactor Testing Station, Idaho, and is operated under contract for the Commission by Phillips Petroleum Co.

SPERT II is a pressurized water reactor of medium pressure and temperature—300 pounds per square inch, 400° Fahrenheit—designed to supply test technology in the intermediate zone between SPERT I, which is unpressurized, and SPERT III, which will be a high pressure machine. A construction contract for SPERT II totaling approximately $1.5 million was awarded to Paul Hardeman, Inc., of Los Angeles, in June 1957. Construction is scheduled for completion in October 1958. SPERT II will supply basic kinetic and transient information applicable to both light- and heavy-water pressurized reactor systems.

SPERT III is designed to operate at high temperature and high pressure—2,500 pounds per square inch and 668° Fahrenheit. The core vessel is designed for 3,500 pounds per square inch pressure. Construction has been underway since November 1956, with operation scheduled to begin in 1958. Paul Hardeman, of Los Angeles, is construction contractor. The overall estimated cost is $3.0 million. SPERT III will provide basic information on surges in highly pressurized reactors. The data will have specific application to many military and power reactors currently in use or under construction.

KEWB (Kinetic Experiment on Water Boilers), a water boiler reactor rated at 50 thermal kilowatts, was designed to obtain experimental data to make possible safer designs of homogeneous reactors. KEWB, in operation since July 1956, is located in the Santa Susana Mountains near Los Angeles and is operated by Atomics International. One important finding to date is that radiolytic formation of gases during an excursion is an effective shutdown mechanism.

A planned KEWB–2 reactor project has been dropped. It was determined that the core configurations intended for KEWB–2 could be studied at a somewhat slower pace in KEWB without detriment to program needs.

EBR–I. In the field of fast reactors the Experimental Breeder Reactor (EBR–I), also located at NRTS, now is being used exclusively for transient testing as reported earlier.

TREAT. A new facility known as TREAT (Transient Reactor Test) is being designed by Argonne National Laboratory. This thermal reactor is for the study of nuclear meltdown of both thermal

and fast reactor fuel elements. It will be built at NRTS and is expected to begin operation in late 1958 or early 1959.

Other safety programs. In addition to the active work in kinetics, the reactor safety program includes out-of-pile experimental projects dealing with chemical reaction hazards, containment of reactor systems, and certain other problems.

A problem of reactor design is to guard against *chemical reactions* which might result from a nuclear power surge that was not controlled quickly. For purposes of the safety experiments, it has been postulated that a power excursion could occur in the core of a thermal reactor. The probability of such a power excursion is exceedingly small. If one occurred, however, it would be possible for fuel elements and their cladding to melt, and for this molten metal to react with a water moderator or coolant, thereby releasing great quantities of heat. The chemical energy release could be greater than that from the nuclear excursion that precipitated it.

Another type of accident involving metal-water reactions might result from the loss of coolant in a water-cooled reactor. In this situation the heat of radioactive decay could cause fuel and cladding to melt and react with any residual water. Although considerable experimental and theoretical work has been done, the phenomena associated with this type of possible accident are not adequately understood.

Work on the metal-water reaction problem has been done at Aerojet-General Corp., Knolls Atomic Power Laboratory, and Columbia University. Data obtained by Aerojet indicate that the metal-water reaction increases as the metal temperature increases and as the particle size decreases. Work done at KAPL with a liquid sodium-potassium mixture indicates the reaction mechanism is influenced very markedly by diffusion processes.

Columbia University is studying the integrity of fuel elements under fast transient conditions up to 1 millisecond. In this work, an electrical technique is used to cause rapid heating and vaporization of simulated fuel elements surrounded by water. Steam explosions are produced which, in the case of zirconium, are followed by evidence of a metal-water reaction.

A few inpile tests have been made at the Materials Testing Reactor involving nuclear meltdown of small simulated fuel elements. This procedure more nearly reproduces actual conditions than do laboratory experiments. Tests to date, however, have not been conclusive and more work is planned. Further experimental work also is planned to investigate the basic mechanism involved in metal-water reactions.

Another problem which must be guarded against is the possible

release of fission products if a fuel element were to melt or rupture. For this reason, among others, reactor containment has been specified for large reactors in this country.

For purposes of research, it has been postulated that volatile fission products would be driven off if fuel melted in a loss of coolant accident, and particulates containing fission products could become airborne by oxidation or burning. To obtain specific data on these postulates, fission product release studies are being conducted at Oak Ridge National Laboratory by controlled melting of irradiated fuel materials. It has been shown that prolonged heating in air at temperatures in excess of the melting point results in the release of a large portion of the easily volatilized fission products; that moderate heating in air or steam sufficient only to melt a specimen results mainly in the partial volatilization of the gaseous and other easily volatilized fission products; and that actual release is dependent upon many factors, including the irradiation history of the fuel, the composition of the fuel alloy, and the atmosphere in which melting occurs.

A third problem, chemical in nature, is *spontaneous ignition* of uranium, thorium, zirconium, and other metals. Argonne National Laboratory is investigating the fundamental nature of these phenomena. A more empirical study directed at the determination of safe handling and storage procedures is being conducted by the United States Bureau of Mines at Pittsburgh, Pa.

The possibility of release of nuclear energy, chemical energy, and fission products points to the need for *reactor containment.* This and isolation are the principal means for protecting the health and safety of the public in the very unlikely event that all other safety devices might fail. Study in this field includes the following:

a) Investigation at the Naval Ordnance Laboratory, White Oak, Md., is directed at producing basic information that will assist in determining the optimum containment design for reactor core vessels. The study is a fundamental investigation of the structural response of water-filled, steel cylinders both to internal static and dynamic loading.

b) At Aberdeen Proving Ground, Md., experiments are being made on the outer or vapor containment shell of reactors. Model tests are under way to assist in determining scaling laws.

c) Stanford Research Institute, Menlo Park., Calif., is studying containment of flying fragments that may result in the event of a core vessel explosion.

d) Armour Research Foundation, Chicago, Ill., is doing theoretical and experimental work especially relating to the design of blast shields as a device to attenuate effects of an excursion.

e) Argonne National Laboratory in recent months has been engaged to assist in the planning and coordination of the containment program.

f) Lockheed Aircraft Corp. has been engaged to study earthquake effects.

Reactor control is partially a problem of reactor safety, although it is usually considered in the larger context of reactor operation. Oak

Ridge National Laboratory is conducting a study of factors affecting safety through reactor control. Included in this will be theoretical studies utilizing an analog computer to permit a wide variation in the parameters involved. The combinations of factors that prove most interesting can then be checked experimentally.

A device to prevent a power excursion in the core of a reactor is highly desirable. Such a device is called a reactor fuse. Research reactors, in particular, appear to be adaptable to the use of fuses. Present effort on research reactor fuses is directed at a mechanism storing a reactor poison in an unfavorable geometry—a shape in which it absorbs few neutrons—in a fuse mechanism above the core. The poison then is automatically released into an expansion chamber within the core—a favorable geometry for absorption of neutrons—whenever the power level rises too high, or when the rate of change of power becomes greater than a predetermined safe value. The objective is to develop fuses that are extremely fast, reliable, not subject to false "scrams" (reactor shutdowns) or triggered by small variations in power level, and that would be earthquake-proof, and tamper-proof.

Work is proceeding also on fuses for power reactors. Although the general operating principle is the same as in research reactors, the problem is much more difficult because of the wider variations in temperature and neutron flux levels.

Testing Reactors

Engineering Test Reactor (ETR). The Engineering Test Reactor, the Nation's largest and most advanced nuclear test facility, was brought to criticality on September 19 at the National Reactor Testing Station, Idaho, 23 months after start of construction. The ETR is a light water-cooled and moderated reactor using highly enriched uranium fuel and has a thermal rating of 175 megawatts. It will be used to test the effects upon reactor materials, fuel elements, and similar important substances of intense neutron and gamma ray bombardment. It is expected to play a key role as a research tool in the development of economic nuclear power.

The ETR average neutron flux above thermal, 1.9 million billion neutrons per square centimeter per second, is the highest known in a test reactor. The test spaces, measuring up to 9 by 9 by 36 inches, are the largest in any test reactor now in operation for insertion of reactor components for testing.

Until the Engineering Test Reactor was built, the Materials Testing Reactor, also located at the Idaho station, was the only generalized test reactor in the United States. Adding the ETR facilities to those

of the MTR by no means satisfies the needs of the atomic energy program and the atomic energy industry. Current Commission programs alone would require construction of additional facilities.

The Commission, with the cooperation of Kaiser Engineers, Phillips Petroleum Co., and General Electric Co., conducted an industrial preview of the ETR on October 2 and 3. Approximately 250 representatives of industry concerned with building and using nuclear test and research reactors participated. Members of Congress and representatives of the press attended.

Cost of developing and constructing the basic ETR was within the original estimate. Total cost will be approximately $16 million, of which $13.5 million is for construction, the remainder for engineering.

Design and construction work for the ETR was performed by Kaiser Engineers using a conceptual design developed by Phillips Petroleum Co. The major reactor components were designed by the General Electric Co. under contract to Kaiser Engineers. The ETR is operated for the Commission by Phillips Petroleum Co. It was officially dedicated by Commissioner Harold S. Vance on October 3.

Advanced Engineering Test Reactor. The Commission has been developing specifications for an advanced test reactor. Criteria prescribed for this undertaking include the following:

a) The reactor must represent a major advance in reactor technology.
b) It should provide a usable flux greater than any available elsewhere.
c) The purpose of the reactor is primarily to provide inpile loop facilities, and secondarily to provide high neutron fluxes for capsule-type, inpile tests.
d) The reactor should employ existing materials technology so that it could be built on a firm schedule.

Four groups were given 3-month contracts to make preliminary studies for a reactor meeting these criteria. Four different systems were proposed. One of these, the "flux trap" concept, in which an annular fuel section is cooled with light water and surrounded both internally and externally with neutron reflectors containing heavy water, was proposed by the Internuclear Co., Clayton, Mo., and was selected for further detailed study. Internuclear was awarded a contract to carry it out.

Westinghouse Electric Corp. is constructing at Waltz Mill, in Westmoreland County, Pa., a light water-cooled and moderated testing reactor designed to operate at a thermal power level of 20 megawatts. A construction permit for this facility was issued by the Commission in July 1957. Completion is scheduled before July 1959.

The Westinghouse testing reactor will be used for developing and testing power reactor fuel elements for radiation damage, testing materials and components, and for limited production of radioisotopes. Westinghouse plans to make the facility available to others on a commercial basis.

General Electric Co. has applied for a construction permit to build a materials-testing reactor at its Vallecitos Atomic Laboratory near San Francisco. It is scheduled for operation before the end of 1958, and will be used initially for developing nuclear fuels. The facility will be available to other users on a commercial basis.

Public hearings were held in January 1958 on proposed issuance of a permit to General Electric and also on a permit to the *National Advisory Committee for Aeronautics* to construct a large testing reactor at Plum Brook Ordnance Works near Sandusky, Ohio. The NACA reactor will operate at a thermal power level of 60 megawatts. Completion is scheduled for 1959. The reactor will be used in aircraft propulsion investigations.

Chemical Processing

The multiplicity of fuel types being contemplated and tested by reactor designers has made it necessary to conduct chemical reprocessing development on a very broad scale. The goal is development of chemical reprocessing and waste-disposal technologies applicable to all fuels developed in the civilian power and military reactor programs.

The three most promising general approaches are: (*a*) aqueous processing with the multiple headend [11] dissolution concept for dissimilar fuel types, (*b*) volatility processing with the same objective, and (*c*) integrated low decontamination processing systems utilized in conjunction with certain specialized reactor types.

Aqueous processing. The wide diversity of newly developed fuel types and compositions require entirely new processing techniques as compared with the established production reactor fuels. Development of aqueous technology is aimed at developing headend concepts for incorporation with standard solvent extraction procedures, the ultimate goal being development of an aqueous headend technology applicable to all fuel types. Aqueous processing development is being extended on the Darex headend for stainless-steel-type fuels, and on the Zircex headend for zirconium-type fuels, as well as on other feasible techniques. The work is being concentrated on im-

[11] A headend, in this usage, is the process required to dissolve and pretreat individual fuel types to allow subsequent separation in existing or common solvent nitrate extraction systems.

proving operating conditions and on studying the corrosion effects of the process chemicals. Development of the Darex process has progressed to the point where design criteria are being formulated for construction of a Darex headend for testing with irradiated fuels.

A program for handling and treatment of aqueous radioactive wastes is being conducted simultaneously. Development has been directed toward calcination of waste to the dry oxide form as an initial step in an ultimate disposal scheme. Cold laboratory and hot tracer pilot plant data are currently being used to produce design criteria for construction of a high-level residue calcination facility, scheduled for start of construction July 1, 1958.

Volatility processing. Volatility technology, though less advanced, is potentially competitive with aqueous techniques for reprocessing irradiated civilian power and military reactor fuels. Volatility techniques appear particularly suitable for the types of fuels used in submarines. Basic chemical techniques are being developed, as is the engineering of corrosion-resistant equipment. Volatility studies are progressing at both Argonne and Oak Ridge National Laboratories.

Integrated low decontamination processes. Low decontamination processes for fuel elements are of interest for partial removal of poisons so as to maintain reactor reactivity. Pyro-processing techniques are currently being studied for application to fuels for Experimental Breeder Reactor No. 2 and the Sodium Reactor Experiment. In conjunction with the expanded scope of the SRE program, a program was initiated in September 1957 on studies for low decontamination and remote refabrication of proposed SRE fuels, including thorium-uranium and uranium oxide. The chemical technology of pyro-processing is relatively simple, and, when applied to reactors which have fuel elements of such design as to allow remote refabrication, there is a possibility for reduced cost.

Recent events. Other recent developments affecting chemical reprocessing programs have included the following:

a) On a test basis, uranium was satisfactorily decontaminated and recovered from 75-day cooled Hanford fuel in the volatility pilot plant at Argonne National Laboratory in July 1956.

b) Extensive research and development conducted by Oak Ridge National Laboratory and Phillips Petroleum Co. culminated in design, construction, and successful operation in November 1956 of a new process facility for production of high-purity radiobarium from irradiated Materials Testing Reactor fuel elements. Very pure radiolanthanum, the daughter product of radiobarium, has been used since in biological research programs.

c) Installation and cold testing of a facility for recovery of USS *Seawolf* type fuels was completed in December 1956.

d) Recovery of fissionable material from irradiated zirconium-uranium fuel from the Submarine Thermal Reactor, Mark I, Core I, was successfully accomplished in January 1957. The recovery process, developed at Argonne, was thus first tested as a hot pilot plant operation.

e) The Thorex process for reprocessing short-cooled, irradiated thorium has been developed to the pilot plant testing stage. In hot runs at the Oak Ridge facility, results have been encouraging.

f) The concept of combining low decontamination and remote refabrication in a processing cycle has advanced to such a stage that the pyrometallurgical cycle is now planned for installation in conjunction with the EBR–2 reactor.

g) Fused salt volatility pilot plant testing with full radioactivity level fuels was started at Oak Ridge National Laboratory in December 1957.

Sanitary engineering research. Sanitary engineering activities in the Commission involve work in three major areas: (*a*) waste handling and disposal, (*b*) water supply, and (*c*) environmental sanitation. Close working relationships are established with Federal, State, and local agencies, and with private industry in the areas where problems arise.

The Commission's major objectives in support of this program are to: (*a*) develop practical systems for safe handling and ultimate disposal of gaseous, liquid, and solid wastes with emphasis on wastes emanating from chemical-processing plants and certain types of reactors; and (*b*) determine the capacity of specific environments to receive radioactive wastes from nuclear energy operations.

Early development work centered on handling and disposal of high-volume, low-level liquid wastes, and airborne particulate wastes, and on evaluation of the effect of low levels of radioactivity on public water supply and sewage treatment facilities.

Low-level wastes. The feasibility of using *biologic sewage treatment* processes for low-level wastes has been determined by research at Johns Hopkins, New York University, and the Universities of Texas and California. Related work has been carried out at several Commission sites. Results indicate that 70 to 90 percent of low-level mixed fission products can be removed by biological treatment.

Studies on relation between *fallout and public water supplies* have been conducted at Harvard University, Rensselaer Polytechnic Institute, and Massachusetts Institute of Technology. Through the co-

operation of 20 public water supply systems located in various sections of the Nation, raw and treated water samples were collected after the 1955 series of weapons tests at the Nevada Test Site. Samples analyzed for radioactivity at MIT revealed that during periods of maximum fallout, water treatment efficiencies ranged between 50 and 75 percent.

Research and development with aerosols conducted at the University of Illinois since 1950 produced results that have assisted in development of new and improved air-cleaning systems. In 1952 Arthur D. Little, Inc., developed a filter of increased capacity and life with a removal efficiency of at least 99.95 percent for particles 0.3 micron in diameter. Private firms utilized this information in manufacturing filters for regular commercial use.

Since 1950 the Harvard Air Cleaning Laboratory has prepared a "Handbook on Air Cleaning" and developed the use of synthetic or plastic fibers for filters where chemical resistance is required and the use of ceramic fiber filters for high-temperature conditions.

Under a Commission contract, the Bureau of Mines, Pittsburgh, Pa., in 1957 designed a package incinerator unit for handling solid, combustible, radioactive waste. The Harvard Air Cleaning Laboratory is developing a stack gas-cleaning system for the 30-pounds-per-hour developmental unit. The design will be made available to prospective commercial manufacturers.

The Commission sponsored during 1957 the Fifth Air Cleaning Seminar, held at the Harvard School of Public Health, which was the first meeting on this activity for access permit holders.

During 1954 extensive stream studies were conducted on the Mohawk River below Knolls Atomic Power Laboratory to obtain quantitative information on safe disposal of low-level radioactive wastes. Results indicated no harmful effects were being caused by KAPL low-level wastes, and economies in waste processing were achieved. Field tests were under the general direction of the U. S. Geological Survey, with active participation of the New York State Department of Health, General Electric Co. (KAPL), and Harvard University.

High-level residues. During the last 3 years, major emphasis has centered on the disposal of highly radioactive residues. Features of three major approaches to ultimate, safe disposal of high-level materials are (*a*) fixation of fission products, (*b*) selective removal of specific isotopes, and (*c*) direct discharge to selected geological formations.

Fixation of fission products in inert solid media so that release of radioactivity to the environment is eliminated or reduced to permissible limits is now under active development. Fixation of radioactivity in montmorillonite clay has been investigated by the Brook-

haven National Laboratory. A preliminary engineering evaluation has been completed at the Brookhaven rotary kiln system for conversion to the oxide form of aluminum nitrate and fission product nitrates. Work at Oak Ridge National Laboratory is aimed at fixing radioactivity in natural earth mixtures by using radioactive decay heat to sinter the mixture. At Johns Hopkins University, the fixing of radioactive wastes in synthetic highly insoluble feldspars is being investigated. Another promising fixation scheme for aluminum-bearing wastes is under investigation at Massachusetts Institute of Technology. The alteration of insolubility characteristics of fired waste oxides by the addition of vitrifying or glazing agents is being studied. An important project is the prototype conversion-to-oxide (fluidized bed calcination) plant which has been planned at the National Reactor Testing Station.

A working meeting devoted specifically to developments and progress on this approach to disposing of high-level residues, and including participation by representatives of Canada and the United Kingdom, was held at Johns Hopkins University in June 1957. The conference proceedings will be published.

The *selective removal of specific isotopes,* such as strontium 90 and cesium 137, is another approach. Because of the radiotoxicity and long half lives of these materials, their removal would substantially reduce the radioactive life of the remaining material and facilitate disposal. The possible research and industrial utilization of cesium and strontium provides an economic incentive.

Direct discharge to selected geologic formations also is being investigated. Preliminary discussions were held during 1957 with representatives of the American Petroleum Institute and the U. S. Geological Survey. Geologic formations that have shown sufficient possibilities to be investigated further include—

a) Underground basins 1 to 3 miles deep which contain connate brines with no hydraulic or hydrologic connections to potable water or other potentially valuable natural resources.
b) Space prepared by dissolution in salt beds or salt domes.
c) Special excavations in selected shale formations.

Laboratory investigations in these areas have been carried out by Oak Ridge National Laboratory, the U. S. Geological Survey, and the University of Texas.

Initial report of a special committee to the Earth Sciences Division of the National Academy of Sciences was published in 1957 as an NAS document, entitled "The Disposal of Radioactive Waste on Land." Specific recommendations of this committee were—

a) Storage in tanks is at present the safest and possibly the most economical method of containing waste.

b) Disposal in salt is the most promising method for the near future.

c) Next most promising seems to be stabilization of the waste in a slag or ceramic material forming a relatively insoluble product.

d) Disposal of waste in porous beds interstratified with impermeable beds in a synclinal structure is a possibility for the more distant future. This is of particular interest for disposal of large volumes of waste. Very difficult and complex problems have to be solved before it will become feasible.

e) The removal of cesium 137 and strontium 90 from the waste would make disposal somewhat easier for the waste free of these isotopes, but does not change qualitatively the recommendations made in the report.

f) Continuing disposal even of low-level waste in the water zone above the water table is of limited application and probably involves unacceptable long-term risks.

g) In the complex relations between (i) storage time of waste for cooling, (ii) transportation cost in shielded carriers, and (iii) distance to disposal site, the last of these factors must be considered before location of any plant producing large quantities of waste, remembering that there are large sectors of the country where disposal is not possible.

Other research and development efforts pertaining to quantitative assessment of specific environmental dilution and concentration factors have been continued during 1957. These projects included radioactive tracer studies in the Chicago Drainage Canal carried out by the Northwestern University Technological Institute and atmospheric diffusion studies by the U. S. Weather Bureau.

Investigations of criteria governing operation and movement of nuclear-powered surface ships in restricted waters were reported earlier.

General studies. A committee has been formed within the Commission to study the many technical and administrative problems involved in transportation of highly radioactive materials. During 1956 a survey was made of containers and their use for transporting radioactive materials. A committee report is in preparation.

The general radioactive waste disposal problem has been reviewed in detail in a report issued by the Commission in August 1957.[12] In addition to describing approaches to solutions of the high-level liquid waste problem, the report concludes that future industrial participation in various waste handling and disposal operations appears feasible and desirable.

[12] "Status Report on Handling and Disposal of Radioactive Wastes in the AEC Program," Wash 742, Office of Technical Services, Department of Commerce, Washington 25, D. C.; $1.25.

IV

GROWTH OF THE ATOMIC ENERGY INDUSTRY

During the 3½ years since passage of the Atomic Energy Act of 1954, the private atomic energy industry has developed rapidly. Federal contracts are an important factor for many private companies in the industry—a situation not unique to atomic energy—but there has been a steady growth of a foreign market for research reactors, and domestic plans for research, testing, and power reactors are impressive. Power reactors are being designed and built for the electric utilities; materials and components for all types of reactors are being provided by private concerns; some services are being supplied; and research and development activities in these fields are vigorous.

Three parts of the atomic energy industry, established in the early days of the Federal program, have continued their growth during recent years. These are the companies which produce and market radiation detection and measurement instruments; those which process and market radioisotopes and radioisotope devices; and the miners and millers of uranium ores.

The industry as a whole obviously still is in its infancy, but industry estimates are that, during 1957, private outlays for civilian power reactors, for example, were about a third of the national total.

Statistics being prepared by the Bureau of the Census for future years ultimately will provide firm data on investment, gross receipts, and employment in the industry. In their absence, the Commission offers the following figures as indicators of industry activity and scope:

- Four power reactors, principally or exclusively financed with private funds, are under construction and 12 more power reactors are proposed or planned. All these 12 involve some Federal financing and three are to be wholly Federally financed. In all, 82 utility organizations, separately or through corporate groups, were active in the atomic power field during 1957.
- The Commission's tabulation of reactors built, building or planned, maintained now for 18 months, shows that 89 reactors are being built in this country as of the end of December: [13] 36 research, training or test reactors (11 for export), 7 critical assemblies, and 46 power reactors: 36 military, 9 United States civilian, 1 for export.
- The Commission has issued 148 licenses to individuals to operate

[13] See appendix 8.

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reactors. These are not required for Commission or military service reactors.

- Twenty-one ore mills, involving private investments totalling $132 million, are operating or will be constructed.
- The Commission licensed 151 organizations to perform research and development work involving the use of special nuclear materials.
- Ten firms have licenses permitting them to fabricate fuel elements for reactors.
- Three firms have been licensed to perform chemical processing involving unirradiated special nuclear materials.
- Three firms have been licensed to process and recover scrap from atomic energy operations.
- One hundred twenty companies are manufacturing radiation detection instruments, with sales running $35 million a year.
- One hundred companies were producing radioisotope compounds or manufacturing devices using radioisotopes.
- The Commission has in force 1,404 permits to organizations and individuals, involving a total of 22,352 personnel cleared for access to classified documents in 26 major categories of United States industries.
- The Commission has issued 680 royalty-free licenses for use of its patents on atomic energy inventions.

These numbers add up to a picture of large growth in some parts of the industry and beginning activity in other areas. Some major functions, such as preparation of special nuclear materials and processing of irradiated fuel elements, both essential to fulfill the Federal mission of producing weapons, remain in Commission hands. Private industry has been chiefly active in those parts of the industry that offer great promise as in the production of ample, cheap electricity, or those parts that offer short-term prospects of a market, as in manufacturing research reactors, providing research and development services, or manufacturing materials or fuel elements for reactors. Young though it is the industry nevertheless seems soundly established and prepared for healthy growth.

It has been the policy of the Commission to encourage industry to carry on the various phases of industrial participation in atomic energy with a minimum of Government financial assistance and controls. The Commission has withdrawn from providing materials and services when it was determined that industry could provide such services at costs which would not discourage the continuing growth of atomic energy activities in industry. In cases where industry was not ready to participate, the Commission decided to continue providing the materials and services so as not to restrict the expansion of other phases of atomic energy in industry. For example, the Commission permits use of certain research facilities by industry, and recently announced it would process irradiated fuels returned from

reactor operators for an interim period until industry can provide the processing services at reasonable prices.

INCREASES IN PRIVATE INDUSTRY

The atomic energy industry, private and Federal, has three major sections, corresponding to functions of the major divisions of the atomic industry: (*a*) provision of nuclear materials, (*b*) reactors and reactor components, (*c*) reactor operation and products including the isotope field earlier discussed. The details of these activities are pictured in the flow chart, "The Atomic Energy Industry."

Provision of Nuclear Materials

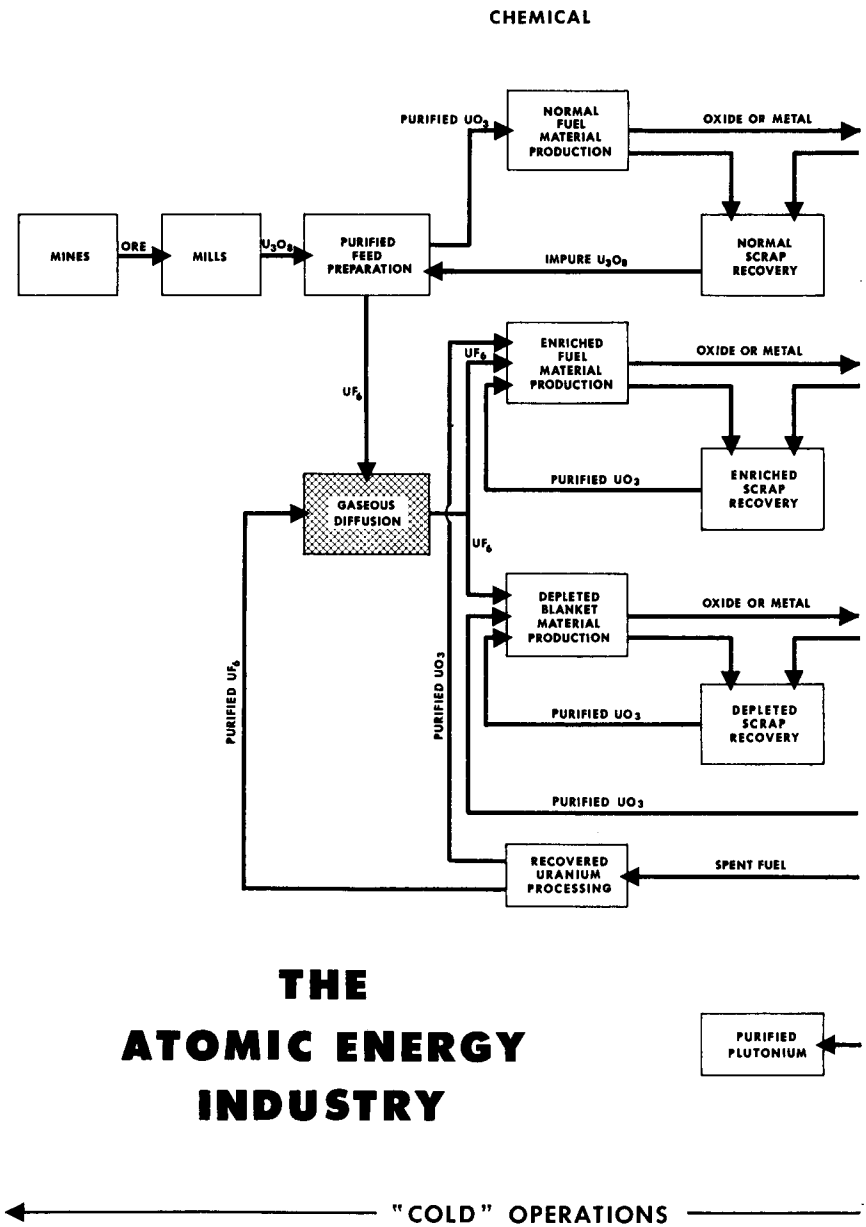
Mining and Milling

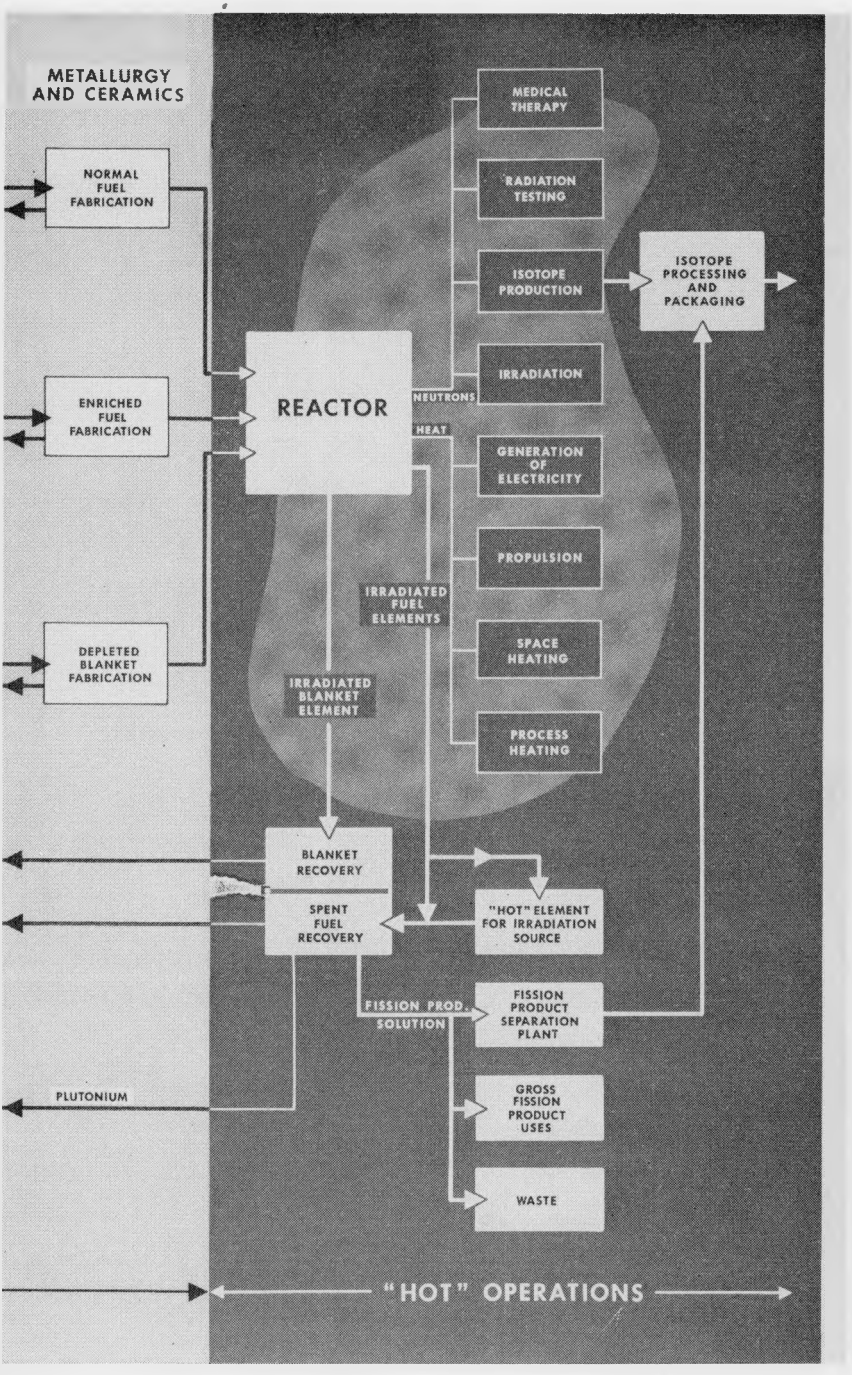
Since 1954 the uranium mining and milling section of the atomic energy industry has continued the rapid expansion begun in 1948. Even under the 1946 Act, private ownership of mines and facilities was possible. However, since uranium, prior to 1942, had been produced primarily as a byproduct of radium, and the rich Shinkolobwe mine of the Belgian Congo working at limited capacity, could supply the entire market, there had been little incentive to explore for uranium. Consequently, in 1948 there were few known uranium deposits and the possibilities of expanding existing sources of production were limited. The Commission stimulated exploration by offering various incentives, especially long-term purchase commitments.

Its efforts were concentrated on finding and developing new sources of uranium in the North American continent, particularly in the United States. Uranium mining and milling operations have greatly expanded and, except for incentives, have followed a normal commercial pattern from the beginning. With active private participation and the large increase in production assured by existing contracts, emphasis no longer is on expanding production but in maintaining and developing ore reserves for future needs.

As of 1955, and progressively since that time, the uranium industry has developed a pattern similar to that of other nonferrous metals. It has a full range of activities, from the small independent mine or group of mines supporting a local custom processing mill, to large-tonnage integrated mining and milling operations. The number of new small mines and prospects has fluctuated, and the major share of uranium production now is coming from large deposits lending themselves to integrated operations.

In 1954, there were eight privately owned mills, representing a total private investment of $40 million. In 1957 there were 16 privately owned mills, representing a total private investment of nearly $69


CHEMICAL
MINES
ORE
MILLS
U_3O_8
PURIFIED FEED PREPARATION
PURIFIED UO_3
NORMAL FUEL MATERIAL PRODUCTION
OXIDE OR METAL
IMPURE U_3O_8
NORMAL SCRAP RECOVERY
UF_6
GASEOUS DIFFUSION
ENRICHED FUEL MATERIAL PRODUCTION
PURIFIED UO_3
ENRICHED SCRAP RECOVERY
DEPLETED BLANKET MATERIAL PRODUCTION
PURIFIED UF_6
PURIFIED UO_3
DEPLETED SCRAP RECOVERY
RECOVERED URANIUM PROCESSING
SPENT FUEL
PURIFIED PLUTONIUM
THE ATOMIC ENERGY INDUSTRY
"COLD" OPERATIONS


METALLURGY AND CERAMICS
NORMAL FUEL FABRICATION
ENRICHED FUEL FABRICATION
DEPLETED BLANKET FABRICATION
REACTOR
NEUTRONS
HEAT
IRRADIATED FUEL ELEMENTS
IRRADIATED BLANKET ELEMENT
MEDICAL THERAPY
RADIATION TESTING
ISOTOPE PRODUCTION
IRRADIATION
GENERATION OF ELECTRICITY
PROPULSION
SPACE HEATING
PROCESS HEATING
ISOTOPE PROCESSING AND PACKAGING
BLANKET RECOVERY
SPENT FUEL RECOVERY
"HOT" ELEMENT FOR IRRADIATION SOURCE
FISSION PROD. SOLUTION
FISSION PRODUCT SEPARATION PLANT
GROSS FISSION PRODUCT USES
WASTE
PLUTONIUM
"HOT" OPERATIONS

million, and companies were building 9 more at a probable cost of some $63 million. (See Table I, Uranium Processing Plants.)

The number of mines has fluctuated widely from year to year, and even from season to season, since some small mines are operated only in summer, and a number of small ore deposits have been discovered and exhausted within a short while. Total production, however, has moved steadily upward. In July 1955 the Commission announced that the United States had become the world's leading

TABLE I.—URANIUM PROCESSING PLANTS [a]

OPERATING AS OF DEC. 31, 1957

Location	Company	Tons per day of ore	Estimated cost of mill
1. Rifle, Colo [b]	Union Carbide Nuclear Co	280	$1, 600, 000
2. Uravan, Colo	Union Carbide Nuclear Co	1, 100	5, 000, 000
3. Durango, Colo	Vanadium Corp. of America	430	813, 000
4. Naturita, Colo	Vanadium Corp. of America	350	1, 000, 000
5. Grand Junction, Colo	Climax Uranium Co	350	3, 088, 000
6. Shiprock, N. Mex	Kerr-McGee Oil Industries	500	3, 161, 000
7. Grants, N. Mex	Anaconda Co	3, 000	19, 358, 000
8. Salt Lake City	Vitro Uranium Co	550	5, 500, 000
9. Monticello, Utah	Government owned	600	5, 000, 000
10. Edgemont, S. Dak	Mines Development, Inc	300	1, 900, 000
11. Tuba City, Ariz	Rare Metals Corp. of America	250	3, 600, 000
12. Moab, Utah	Uranium Reduction Co	1, 500	8, 250, 000
13. Jeffrey City, Wyo	Western Nuclear Corp	400	3, 600, 000
14. Ford, Wash	Dawn Mining Co	400	3, 100, 000
15. Mexican Hat, Utah	Texas-Zinc Minerals Co	775	7, 000, 000
16. Maybell, Colo	Trace Elements Corp	300	2, 208, 000
Subtotals		11, 085	74, 178, 000
MILLS UNDER CONSTRUCTION OR CONTRACTED			
1. Rifle, Colo	Union Carbide Nuclear Co	1, 000	$8, 500, 000
2. Gunnison, Colo	Gunnison Mining Co	200	2, 025, 000
3. Fremont County, Wyo	Lucky Mc Uranium Corp	750	6, 900, 000
4. Grants, N. Mex	Homestake-New Mexico Partners	750	5, 325, 000
5. Grants, N. Mex	Homestake-Sapin Partners	1, 500	9, 000, 000
6. Grants, N. Mex	Kermac Nuclear Fuels Corp	3, 300	16, 000, 000
7. Grants, N. Mex	Phillips Petroleum Co	1, 725	9, 500, 000
8. Lakeview, Oreg	Lakeview Mining Co	210	2, 600, 000
9. Riverton, Wyo	Fremont Minerals, Inc	500	3, 500, 000
Subtotals		9, 935	63, 350, 000
Recap: 16 mills operating		11, 085	74, 178, 000
9 mills under construction or contract		9, 935	63, 350, 000
Grand total		21. 020	137, 528, 000

[a] With the exception of the Government-owned uranium mill at Monticello, Utah, all uranium-processing plants are owned and operated by private industry under individually negotiated contracts whereby the USAEC is the purchaser of the uranium concentrate product. The privately owned mills also are licensed to purchase uranium-bearing ores from producers.

[b] New Union Carbide mill at Rifle to replace existing one. Adjust totals accordingly

producer of uranium ore, whereas domestic production during the war years had been limited to the uranium extracted by reworking the tailings of vanadium ore mills. In 1957 domestic ore production reached a total of 3.7 million dry tons, and production of uranium oxide (U_3O_8) in concentrates totaled 8,600 tons. As of December 31, mill capacity had reached 10,560 tons of ore a day and is expected to increase to 13,475 by the end of June 1958. When all mills now under contract are completed by June 1959, the total capacity will be 20,410 tons per day.

Domestic uranium reserves during the war years consisted of the vanadium-uranium ores of the Colorado Plateau and mill tailings from previous vanadium operations. At the end of 1957, known and inferred uranium reserves were estimated at 75 million tons. While these reserves are comparatively large, they must be maintained or expanded by continued exploration if they are to supply the needs of a large nuclear-electric power industry. As this industry becomes established, it should provide the incentives for further exploration and development work. Commercial demands are small today in terms of delivery requirements, but the utility industry is concerned with long-term investments and rapid growth, and must have assurance of an adequate supply of fuel for its powerplants during the useful life of those plants.

Commission programs. The Commission in 1948 established minimum guaranteed ore prices and other incentives, but placed uranium production largely in the field of competitive private industry. The Commission also undertook supplemental activities designed to help industry raise its production. Since 1954, as a result of the considerable increase in production and further increases in sight, the Commission has gradually reduced its supporting activities and taken other steps designed further to encourage the establishment of a commercial uranium mining industry.

The Federal domestic *exploration program,* consisting primarily of airborne radiometric surveys, geological investigations, and exploratory drilling, expanded rapidly between 1948 and 1955. New and improved techniques and instruments were developed, and geological guides were furnished to mining companies and prospectors. These programs were carried out by the Commission's geological staff, by private contractors, by the U. S. Geological Survey and the U. S. Bureau of Mines, Department of the Interior, under contract with the Commission.

Private drilling for ore has increased steadily. In 1955, private industry completed nearly 5 million feet of drilling. In 1956, the Government discontinued its ore drilling activities.

As a result of the success achieved in uranium exploration, and the high degree of continuing private participation, many objectives of the domestic uranium program had been partially achieved by 1955, and Government effort was directed more toward defining basic geology and developing techniques fundamental to exploration; to evaluating private activities and discoveries; and to establishing and maintaining current ore reserve figures.

The Commission constructed and operated *ore-buying stations* in new areas pending development of sufficient ore to support economic milling operations. As milling facilities have been completed by private companies, providing a private market for ores, Commission ore buying in these areas has been discontinued. In 1956 and 1957, several Commission ore-buying stations were closed and no new ones are planned.

A few years ago the Commission bought directly most of the ore produced; as of December, nearly 90 percent was purchased by private mills. Government direct purchasing is expected to continue to decline until March 31, 1962, when the Government ore-purchasing program will end. A minimum of disruption should be occasioned to existing ore producers who by that time should have a market with established mills in all present major producing areas.

An important change in its *uranium procurement program* made by the Commission in 1956 anticipates a transition from a Government-controlled market to a commercial market, and provides a basis for long-range planning by the mining and milling companies. In May of that year, the Commission announced establishment of a new uranium procurement program for the period April 1, 1962, through December 31, 1966, which provides a guaranteed market, subject to certain conditions, for uranium concentrates produced from domestic ores.[14] A price of $8 per pound of U_3O_8 in acceptable concentrates was set. In this program, a concentrate price is guaranteed rather than an ore price, since a concentrate is the primary product desired by industry.

The need for *process development* became obvious during the early days of the Commission because of the low grade and chemical complexity of domestic ore deposits, and also because ordinary concentration processes were not effective in making suitable upgraded product. The only known methods for recovery of uranium involved treating the ore with chemicals to dissolve the uranium, separating the leach liquor from the spent ore, and chemically precipitating a crude concentrate. These methods were costly and recovery was low.

Through contract arrangements with a number of private laboratories, Commission-sponsored research developed improved processes

[14] See pp. 1–2, Twentieth Semiannual Report to Congress (January–June 1956).

to reduce costs and improve recoveries. The success of the work is exemplified by processes adopted for treatment of the gold tailings in South Africa, those for western ores of high lime content, and by solvent extraction methods.

The success of the exploration program in the western United States diminished the need for concentrated effort on very low grade materials, such as the Florida phosphates and Chattanooga shales. Engineering data on treatment of western ores by the most advanced process still called for critical laboratory examination and pilot-plant demonstration on ore samples typical of the feeds for new mills under consideration. These data formed a basis for negotiating contracts for the purchase of concentrates.

By advocating newer and more efficient operating methods, and by disseminating technical information through private engineering firms and consultants, the Commission has helped to bring about great advances in the art of uranium hydrometallurgy. The lower unit prices for uranium concentrates in later contracts as contrasted with earlier agreements are in a measure due to improved metallurgy. With the growth of the domestic industry, the need for Government participation in developing further processing improvements has decreased. The individual mills are expected to continue to improve extraction methods.

Support of the process development program by the Commission will cease as of June 30, 1958, except for a limited amount of work by the Bureau of Mines to include routine amenability tests and investigation of special problems that may arise in the future. Basic research work, however, which covers all parts of the uranium industry, is continuing at the Oak Ridge National Laboratory.

The Commission established several laboratories for *assaying and testing* uranium ore samples during the early period. Few private laboratories accepted samples for assaying, and the Commission encouraged the public to submit samples of radioactive minerals and rocks for inspection and testing. Results of the tests were furnished the sender, together with an evaluation of the sample material as a source of uranium. Private assaying laboratories, utilizing methods developed for the Commission, soon provided increasing services and permitted the Commission to limit its services to its own needs for information.

The Commission's activity on *instruments and methods* included (*a*) developing and improving surface and subsurface radiation detection instruments; (*b*) testing and applying electric and sonic velocity logging and seismic techniques; (*c*) use of dry rotary drilling techniques; and (*d*) development and use of carborne and airborne radiation detection techniques. These methods and instruments were

made available to private industry for manufacture and use. Further research and development of exploration tools were taken over by private laboratories and exploration companies; Commission activities were reduced accordingly.

Beginning in 1950, the Commission, in connection with its uranium procurement program, sponsored some 82 *road construction* projects in 6 States which resulted in construction and improvement of approximately 1,500 miles of road at a cost to the Federal Government, exclusive of State participation, of more than $14 million. These roads were constructed to standards recommended by the Bureau of Public Roads and under its general supervision. In addition to enabling the Commission to meet its uranium requirements for defense, these roads are of continuing benefit to the areas. With roads no longer a limiting factor in uranium procurement, the 1958 budget made no provision for access roads. Increased revenues resulting from expanded uranium operations and associated business activities should assist the uranium counties and States in meeting their road needs.

In 1955 and 1956, the Commission ordered *declassification* of information on methods of processing ores, and on domestic ore reserves and uranium production subsequent to June 30, 1955. The declassification of technology and statistics permitted publication of information needed by uranium processors and by producers to provide a firm basis for future plans.

The declassified statistics disclosed that uranium ore production in the United States by the end of 1956 totaled 3 million tons. Total domestic reserves were placed at 60 million tons, with an average grade of 0.25 percent uranium oxide.

Technological information about uranium dissolution or extraction by either acid or carbonate leaching had not been classified, but other details on recovery were held as restricted data. With declassification, the Commission and its contractors could freely discuss practically all processes developed at Government-owned and associated private laboratories throughout the country, including phosphate precipitation, ion exchange, resin-in-pulp, and solvent extraction.

Thorium program. The Commission's requirements for thorium have been limited to relatively small quantities for research and development. Thorium salts have been purchased under contracts negotiated with processors of monazite sands to meet these requirements and also to provide a modest stockpile against possible future needs. The procurement program will be fulfilled through deliveries under contracts entered into several years ago; no new contracts for thorium have been signed since 1955, and no further contracts are con-

templated at present. Thorium deliveries in the year ended June 30, 1957, totaled the equivalent of 223 tons thorium metal in the form of thorium salts and double that amount was expected to be acquired in the following year, ending June 30, 1958.

Highlights for 1957. The United States continued to be the world's leading uranium producer during 1957. By the end of the year the annual production rate was approximately 10,000 tons of uranium oxide (U_3O_8); production for 1958 is expected to be approximately 12,500 tons.

Sixteen mills were in operation in December, including the 1 Commission-owned mill at Monticello, Utah, and another 9 were under construction. The Commission now has under contract supplies of uranium in reasonable balance with projected requirements for the next few years. Since it would be undesirable from the standpoint of industry, as well as the Government, to expand uranium production rate beyond projected requirements, the Commission intends to limit mill expansion and new mill construction beyond present commitments.

Three Commission-operated buying stations (Grants, N. Mex., Riverton, Wyo., and Monticello, Utah) remained open at the end of the year. Four stations—Marysvale, Utah, Globe, Ariz., Crooks Gap, Wyo., and White Canyon, Utah—were closed during the year. Ores in these areas may be sold by independent producers directly to private mills.

Uranium ore production in the United States totaled about 2 million dry tons during the last 6 months of 1957, as compared to approximately 1.70 million dry tons for the first half of 1957 and 1.66 million dry tons for the last 6 months of 1956.

Uranium ore reserves in the United States at the end of 1957 were estimated at approximately 76 million tons averaging 0.27 percent U_3O_8. This is an increase of 9 million tons over the estimate at the end of June 1957. Continued development in the Ambrosia Lake area of New Mexico and the Wind River Basin of Wyoming accounted for most of the increase.

Despite the projected increase of North American supplies of uranium, overseas sources are expected to continue to supply a substantial portion of the national atomic energy program's needs. The Combined Development Agency, which holds contracts for production from South Africa, Belgian Congo, Portugal, and Australia, continued to receive uranium at scheduled rates from those countries for delivery to the United States and the United Kingdom.

At the end of 1956, South African ore reserves were officially estimated at 1.1 billion tons containing 370,000 tons U_3O_8. Pro-

duction was estimated at a rate of 6,000 tons a year at the end of 1957. Canada, with estimated ore reserves in excess of 320 million tons containing 380,000 tons of U_3O_8, is scheduled to produce at the rate of 14,000 to 15,000 tons U_3O_8 a year by the end of 1958. The major share of production from Western countries now comes to the United States. Developed and partially developed free-world reserves of presently commercial ore contain in excess of 1 million tons of uranium. With full development of the known uranium occurrences, and the adjacent areas, reserves should reach 2 million tons.

Feed Materials Preparation

All feed materials for Federal use currently are produced under cost-plus, fixed-fee contracts in Government-owned plants.

On October 27, 1955, the Commission announced that it was interested in receiving proposals to process uranium feed material at a rate of 5,000 tons of U_3O_8 per year for 5 years. An information program was conducted for firms expressing interest in submitting proposals.

On October 1, 1956, seven proposals were received, and the one from the Allied Chemical & Dye Corp. was selected as most favorable to the Government. A contract was entered into with this firm which provides, over a 5-year period, for processing 5,000 tons of uranium oxide (U_3O_8) annually into uranium hexafluoride for the Commission.

Early in 1957, Allied Chemical & Dye selected a site at Metropolis, Ill., for construction of its plant. Allied has completed its pilot plant for testing the new production processes it will employ, and construction of the full-scale production plant is now underway. Operations are scheduled to begin by April 1, 1959.

Uranium and Thorium Metal and Compounds

Most uranium metal and compounds being produced now are used in Commission programs, but private demand is growing. To serve the current needs for fuel elements in private reactors and to meet future demand, four companies will supply natural uranium oxides on a commercial basis: Mallinckrodt Chemical Works, S. W. Shattuck Chemical Co., Davison Chemical Co., and Nuclear Materials & Equipment Corp. Small quantities of natural uranium oxide are available through regular chemical supply houses.

The Mallinckrodt Chemical Works also will convert enriched uranium hexafluoride from Commission plants into uranium oxides, sulfates, and nitrates on a commercial basis. Davison and Nuclear

Materials will convert the green salt (uranium tetrafluoride) into normal uranium metal, and now is quoting prices on conversion into uranium metal of normal, depleted, and slightly enriched uranium hexafluoride.

Thorium compounds are processed and marketed by Maywood Chemical Co.; Rare Earths, Inc.; Davison Chemical Co.; Heavy Mineral Co.; Nuclear Materials & Equipment Corp.; and Lindsay Chemical Co. Six companies have offered to supply thorium metal on a commercial basis: Davison Chemical Co.; Horizons, Inc.; National Research Corp.; Sylvania-Corning Nuclear Corp.; Nuclear Materials & Equipment Corp.; and Vitro Corp. of America.

Fuel Element Fabrication

Increased private activity in building and operating power and research reactors has created commercial opportunities for fabricating fuel elements. The Commission also contracts with private companies to produce fuel elements for two large reactors. Naval requirements during 1958 are expected to generate $50 million worth of reactor core business, although much of this is performed in Government-owned plants.

A few years ago, fuel elements were manufactured only under Government contracts, in Government-owned, contractor-operated plants.

In September 1955, the Commission announced it would not fabricate fuel elements for private reactors. Meetings were held with industry representatives to provide technical background. Bids were asked from private concerns for manufacturing fuel elements for the high-flux Materials Testing Reactor, operated for the Commission at the National Reactor Testing Station, Idaho. The bid of the Babcock & Wilcox Co., of New York City, was selected from among those of 12 companies, and the contract signed in July 1956.[15] For 1958, the MTR fuel element contract went to Clevite Corp., of Cleveland.

The same practice was followed in obtaining fuel elements for the Engineering Test Reactor.

Through December 1957, ten concerns had received licenses to fabricate fuel elements in their own facilities:

THE BABCOCK & WILCOX Co., Lynchburg, Va., plant.
BATTELLE MEMORIAL INSTITUTE, Columbus, Ohio.
DAVISON CHEMICAL Co., Erwin, Tenn.
GENERAL ELECTRIC Co., Atomic Power Equipment Department, San Jose, Calif.
THE MARTIN Co., Baltimore, Md.
METALS & CONTROLS CORP., Attleboro, Mass.

[15] See p. 46, Twenty-first Semiannual Report to Congress (July–December 1956).

NUCLEAR MATERIALS & EQUIPMENT CORP., Apollo, Pa.
NUCLEAR METALS, INC., Cambridge, Mass.
SYLVANIA-CORNING NUCLEAR CORP., Bayside, N. Y.
WESTINGHOUSE ELECTRIC CORP., Blairsville, Pa.

Examples of private investment in this field include:

Babcock & Wilcox built and is operating new nuclear facilities at Lynchburg, providing specialized service on design, fabrication, testing, and erection of complete nuclear steam-generating systems from fuel elements to turbine throttle. The plant includes a critical experiment facility.

General Electric announced that construction has begun on a 32,000-square-foot addition to its 15,000-square-foot fuel development facility completed in 1956, in San Jose, Calif. The new addition, in which they will fabricate fuel elements, will cost about $500,000. The plant will contain $1 million worth of machinery and tools.

Two more firms building plants for fuel element fabrication are Sylvania-Corning Nuclear Corp. and D. E. Makepeace Co. Sylvania-Corning is building a 25,000-square-foot plant at Hicksville, Long Island, N. Y., to produce fuel elements, and D. E. Makepeace, of Attleboro, Mass., is building a 53,000-square-foot plant at Plainville to work and treat uranium for fuel.

Chemical Processing of Irradiated Fuels

The Commission announced in January 1956 a program to encourage private industry to build and operate chemical processing plants. A program of meetings was held to provide industry with the technology. Documents were made available through normal services. The Commission also offered certain irradiated fuels under contract as a guaranteed base load for a private plant. However, private industry did not undertake the program.

Still, the reactor industry required a prompt firm cost base on this process for its calculations. Accordingly on February 18 and March 12, 1957, the Commission announced it would enter into contracts with private reactor operators to process irradiated fuels on the basis of firm charges, until such time as commercial facilities having the required processing capability became available. Commission contracts with the reactor operators would be canceled upon not less than 12 months' notice when commercial processing services become available at reasonable prices.[16] Prices in the order of 15 percent

[16] For basis of charges, see pp. 41–42, Twenty-second Semiannual Report (January–June 1957).

higher than the charges computed by the Commission would be considered reasonable prices for industry.

The Commission will continue to explore with industry the possibility of constructing a plant to process fuels from licensed reactors with the assurance of a base load of Commission-irradiated fuels. It is hoped that industry will begin processing the fuels from licensed reactors before the June 30, 1967, expiration date of the Commission contracts with reactor operators.

Unirradiated Enriched Scrap Recovery

Private industry has undertaken to process unirradiated enriched uranium scrap. Throughout the manufacture of fuel elements a large amount of uranium scrap is generated which has a monetary value up to $7,000 a pound. The Commission publicized the opportunity and stated that it would provide scrap recovery service to the industry only until private companies undertook the job.

Baker & Co., Newark, N. J., has equipped a small plant to recover scrap and has been granted a license. The first batch of commercial-enriched uranium scrap was processed in 1957. Nuclear Materials & Equipment Corp. and Davison Chemical Co. have been licensed in this field.

Low-Level Waste Disposal

Seven commercial firms have received licenses to dispose of low-level radioactive byproduct and source material wastes: Atomic Energy Waste Disposal Service, Oakland, Calif.; Crossroads Marine, Boston, Mass.; Isotopes Specialties Co., Burbank, Calif.; Nuclear Consultants, Inc., St. Louis, Mo.; Nuclear Engineering Co., Inc., San Francisco, Calif.; Radiological Service Co., Long Island City, N. Y.; Reed-Curtis Nuclear Industries, Inc., Culver City, Calif. These companies are generally limited to handling small quantities of radioactive waste material. The wastes are disposed of at sea, are stored, or in some instances are returned to the Commission for permanent burial. The hazards, both operational and long term, are comparatively slight.

Disposal of high-level radioactive residues presents a particular problem to the atomic energy industry because of long-term hazard. Presently, they are concentrated and held in underground storage tanks maintained by the Commission.

Reactors and Reactor Components

Industry has made its heaviest commitments for power reactors and for research and development contributing to their design or improvement. The Federal Government also makes large expenditures for military reactors, for experimental civilian power reactors, for research and development in this field, or in contributions to cooperative contract arrangements to build power reactors with non-Federal organizations. Commission tabulations show that 46 power reactors are under construction—36 of them being for the armed services.[17] Their capital costs are high—five civilian power reactors licensed by the Commission are valued at $223 million. Power reactors built or building range from 5,000 to 180,000 electrical kilowatts, and cost from $2.5 million to more than $70 million each. They are the dominant element in the growth of the atomic energy industry.

The 36 research, training, and test reactors, exclusive of 7 critical assemblies, shown by the Commission tabulation as being built at the present time nevertheless form an important part of the total industry effort. They range in size from less than 1 kilowatt up to 30 megawatts (thermal). One company offers small research reactors for sale "off the shelf," and advertises a complete line of research, testing and power reactor designs.

Federal expenditures for civilian and military power reactors made up the major part of industry totals. Under the Commission's program in which it contracts with publicly and privately owned concerns for cooperative effort in building power reactors, two reactors are under construction, contracts have been signed on two others, and seven others were under study or negotiation.

This phase of the atomic energy industry, as reflected by the Commission's tabulation over the last 18 months, has shown sound development. The total number of reactors built, building, and planned increased sharply during the first 12 months when some years of study culminated in firm proposals from industry, when the major Commission programs were getting underway, and when the success of the first nuclear submarine resulted in authorizations for many more. (During the last 6 months, the total of reactors increased 11 percent, as compared to an increase in the previous 6 months of over 15 percent and in the 6 months before that of over 10 percent.) Reactors previously listed as planned were moving into the construction stage, or were actually operating. The number of reactors which had either operated or were being built increased by 36 percent during the last

[17] See appendix 8.

6 months, compared with 27 percent and 7 percent in the two earlier 6-month periods. The following table shows nuclear reactors built, building, and planned in the United States during the 18 months between June 30, 1956, and December 31, 1957.

United States reactors as of	Operated [1]	Being built	Planned	Total
June 30, 1956	80	48	80	208
Dec. 31, 1956	91	46	94	231
June 30, 1957	108	66	93	267
Dec. 31, 1957	149	89	67	305

[1] Includes those which have been dismantled.

There were 238 reactors operated or building in the United States as of December 31 and 67 planned. Six months before there were 174 operated or building and 93 planned.

Power reactors, larger, more expensive, and of more varied design, show steadier trends throughout the 18-month period. The number operated and the number building have increased regularly; the number planned has dropped as units move from that list into the building column. Reflected in the "total" and "planned" columns for December 31, 1957, which show a drop from 6 months before, is the Commission's judgment that a number of reactors now seem unlikely to be built as originally announced and so are no longer carried in the Commission's tabulation.

The power reactors operated, building, and planned in the United States are given in the following table.

United States power reactors as of	Operated [1]	Being built	Planned	Total
June 30, 1956	14	22	46	82
Dec. 31, 1956	15	24	47	86
June 30, 1957	18	32	41	91
Dec. 31, 1957	23	46	19	88

[1] Includes those which have been dismantled.

Special Reactor Materials

Private industry has assumed responsibility for supplying many special reactor materials required in private and Government reactors. The Commission, as a consequence, has curtailed or discontinued

entirely supplying boral, zirconium, beryllium, and reactor-grade graphite.

Zirconium, hafnium. Of these two metals, produced from the same ore, zirconium with low neutron absorption is used primarily as a cladding material for fuel elements; hafnium with high neutrons absorption is used in reactor control rods.

In 1955, all the zirconium used by the Commission was produced in Government-owned facilities. Because of the expanding requirements for the material, the Commission decided that, instead of building additional Government-owned plants, it would offer industry an opportunity to supply the metal under a fixed-price contract.

Formal awards for a total supply of 2 million pounds of zirconium metal a year were made to three companies. The National Distillers Products Corp. will furnish 1 million pounds a year from its new plant being built at Ashtabula, Ohio. NRC Metals Corp., a subsidiary of National Research Corp., will furnish 700,000 pounds a year from a new plant being built near Pensacola, Fla. Carborundum Metals Co. will furnish 500,000 pounds a year from a new plant being built at Parkersburg, W. Va.

In addition, the Commission contracted with the Wah Chang Corp., of New York, for continued operation of the Government-owned plant at Albany, Oreg. Zirconium also is being provided from a source in Japan.

Boral. Originally produced only by the Government, boral, a lightweight shielding material developed by Oak Ridge National Laboratory, now is supplied on a commercial basis by Brooks & Perkins and Aluminum Co. of America.

Graphite. Graphite, used extensively as a moderating material for nuclear reactors, is made available in reactor-grade purity on a commercial basis from a number of manufacturers including National Carbon Co., Speer Carbon Co., United Carbon Products Co., and Great Lakes Carbon Corp.

Beryllium. Reactor-grade beryllium for the Government, as well as the private atomic energy industry, now is supplied by private firms. Commission needs for beryllium, a highly important moderator, have been supplied previously by a Government-owned plant. To meet the growing Commission demand for this metal, private industry was invited to submit proposals to supply 500,000 pounds over a 5-year period. Contracts were signed with Beryllium Corp., which is building a new plant near Reading, Pa., and with Brush Beryllium Co., which is constructing a new plant at Elmore, Ohio. The resulting

increased production is expected to meet both Commission and private needs.

Boron 10. Boron 10 is an important material to the nuclear industry since it has the property of readily absorbing neutrons without itself becoming radioactive. It is used in nuclear reactor shield and control mechanisms and can be employed in radiation-measurement instruments. On February 12, 1957, the Commission announced that the boron 10 isotope was being made available for sale to the civilian atomic energy program in kilogram quantities. Enriched boron 10 in metal form and in certain other chemical forms is produced at the Commission's plant near Niagara Falls, N. Y. The plant is capable of producing enriched boron at assays ranging from 30 percent to 90 percent boron 10.

Development of Instrument Industry

The design and manufacture of instruments for detecting and measuring radiation, essential in reactor operation, in prospecting for ores, research, and many other atomic activities, was the first branch of the private atomic energy industry established.

The instrument industry, in 1948 a $4-million-a-year industry, reached $20 million in 1951–52, and included some 80 companies manufacturing some 250 types of instruments. It is estimated that in 1957 industry sales totaled some $35 million by about 120 companies manufacturing approximately 1,500 types of instruments, detectors, special components, and accessories.

During the war, atomic laboratories contrived their own equipment. After 1945, the Manhattan Engineer District, and later the Commission, undertook to stimulate industry development.

The Manhattan District declassified almost all the information developed about the instruments. The Commission centralized procurement of instruments for all its operations, and issued specifications and bid invitations to manufacturers on quantities of 50 to 100 or more instruments of each type required. This practice helped manufacturers meet initial investment costs. Small orders for commercial equipment were placed for test and evaluation, and the reports guided manufacturers to product improvement. Development contracts were let for production engineering of Commission-designed instruments to broaden the inventory of equipment types.

By mid-1948 the growth of the industry permitted centralized procurement to give way to purchases by individual operating sites. Small quantities of new instruments still were procured centrally for evaluation.

The 1951–52 survey indicated the industry had become normally competitive and could supply not only the Government but also users of radioisotopes in industry, universities, hospitals, and other institutions.

Since much of this industry cannot support basic research, the Commission has sponsored research and produced a steady flow of new instrument designs, materials, and procedures.

In the past 3 years, research has developed photomultiplier tubes for use in radiation detection instruments employed in research, radiation monitoring, and industrial hygiene programs. During 1955 sponsored research at the Radio Corp. of America resulted in completion of development on a high-speed multiplier structure with fast photoelectron collection characteristic from a nominal 2-inch-diameter photocathode. This tube type was ordered into production during 1956. Sponsored research at A. B. DuMont Laboratories, Inc., developed tubes with a 12½-inch-diameter, with a 16-inch-diameter, and with a 21-inch-diameter photocathode.

During 1956, in addition to the 2-inch-diameter high-speed tube, a 4½-inch-diameter tube was developed by Radio Corp.—devices used by the University of California Radiation Laboratory, Berkeley, in their studies on heavy particles. A contract was let with DuMont Laboratories to start design and development of a large-diameter image converter tube for radiography to permitting a major reduction in X-ray exposures for both fluoroscopy and radiography. The tube now is moving toward final development.

During 1957, DuMont Laboratories have produced some new higher speed structures for millimicrosecond techniques of radiation detection for multiplier phototubes to improve techniques of physics measurements.

The tubes developed under Commission contracts are in commercial production and widely utilized for general industrial and scientific applications as well as in atomic energy programs.

Reactor Operation and Products

Reactors are being built today chiefly for research, to produce electricity, and to test reactor materials and fuel elements. Commission reactors produce plutonium and radioisotopes for industrial and medical use and for research. Two reactors are being built for special medical uses, and others have been considered for producing process steam or space heating, and to provide radiation for food preservation experiments. In addition to the Navy use of reactors to propel ships, Army and Air Force plan to build reactors for propulsion and other uses.

There is every reason to believe that further uses for reactors will be developed. This section of the report estimates the present status of that portion of the industry dealing with reactor operation and reactor products.

The largest number of high-power reactors already in use for a single purpose is the 13 production reactors at the Hanford and Savannah River Works operated for the Commission to transmute uranium into plutonium. Aside from research, probably the largest group planned for the future is designed to propel ocean vessels. The Commission's numerous research reactors are employed directly as sources of radiation for experiments; a few produce radioisotopes for a variety of investigations in physical and life sciences. Those operated or being built by academic and research organizations assist in research and, in some cases, in training. Research and training will be the usage of many of the reactors which other countries are proposing to build under agreements for cooperation with the United States. The Commission also has built two large testing reactors, is planning a third, and two private corporations have begun construction on high-flux reactors for similar purposes.

The Commission's experimental power reactors, reported in detail in Chapter III, Progress With Power Reactors, were planned and built to produce technical and economic information which will assist in designing safe, reliable, and economic power reactors.

Reactors being built by public and private organizations, independently and in cooperation with the Commission, also help advance technology and will generate central power for distribution to residential, industrial, and commercial users.

At present, the manufacture, sale, processing, and distribution of reactor-produced radioisotopes for research and industrial applications (reported in Chapter II, Progress With Radioisotopes), includes considerable commercial activity. The manufacture of equipment for radiation laboratories, and for work in connection with certain types of reactor operation, has been a growing business for some years. The Commission has prepared a catalog of this equipment.[18]

The Radioisotope Business

More than 100 commercial firms are supplying radioactive pharmaceuticals, labeled radioisotope compounds, and sealed sources of radioactivity to licensed purchasers in industry and research organizations. These firms purchase bulk quantities produced by the Commission, and process and retail them. During the last 3 years, Com-

[18] "Hot Laboratory Equipment," Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., December 1957.

mission laboratories correspondingly have moved toward becoming producer-wholesalers, rather than retailers, of radioisotopes.

An indication of the growing use of radioisotopes is reflected in the number of shipments made from the Oak Ridge National Laboratory, the largest single source of radioisotopes in the United States.[19] The total amount of radioactivity shipped has risen rapidly during the past 3 years—from 28,879 curies in 1954, to 49,383 curies in 1955, to 109,500 curies in 1956, and about 160,000 curies in 1957. The gross income from these sales increased from $1.2 million in 1954 to $2.2 million in 1956, and $2.7 million in 1957.

A total of 5,963 shipments of radioisotopes has been distributed to foreign countries. At the end of May 1954, 43 foreign countries had received 2,743 shipments of radioisotopes from the United States. At the end of this December, 13 additional countries had started purchasing radioisotopes from the United States.

TABLE II.—RADIOISOTOPES SALES AT OAK RIDGE NATIONAL LABORATORY

Fiscal year [1]	Shipments [2]	Curies	Fiscal year [1]	Shipments [2]	Curies
1947	1,070	21	1954	12,426	12,341
1948	2,743	73	1955	12,775	40,056
1949	4,665	153	1956	13,035	83,003
1950	6,860	776	1957	13,754	149,185
1951	8,935	2,972			
1952	10,187	9,679	Total	97,604	303,648
1953	11,150	5,389			

[1] First shipment made Aug. 2, 1946.

[2] Includes shipments to domestic, foreign, and project users.

Other business developments that have taken place as radioisotope uses expanded include an announcement by the Westinghouse Electric Corp. that the test reactor it is building at Waltz Hill, Pa., will produce a limited amount of radioisotopes for sale. General Atomics, Inc., proposes to market an "off-the-shelf" reactor that would produce short half-life radioisotopes as well as be used for research and training purposes. Three companies have informed the Commission that they are carrying out studies on the feasibility of building chemical separation plants that would remove useful radioisotopes from reactor wastes.

The Commission issued general licenses to a number of firms during 1957 authorizing them to use radioisotopes as sealed sources of radia-

[19] Appendix 4 gives radioisotope distribution data.

tion in a number of devices to be placed on the general market. The devices include light meters, vacuum tubes, static eliminators, and ion generators to ionize air in conditioning systems.

Typical of the accelerating use of radioisotopes is the fact that Picker X-Ray and Budd Co. of Philadelphia, which previously had marketed only to licensed industrial consumers have announced that they will prepare radioisotopes for authorized medical users also. Tracer-Lab, Inc., of Boston, which previously handled only medical and life-science research materials, has undertaken to service some industrial users as well.

Irradiation service. Some 60 industrial and research concerns have been licensed by the Commission to receive a total of 300 or more curies each of cobalt 60 for radiation research and development. At least 16 licensees, with facilities employing more than 1,000 curies of cobalt 60 or spent fuel elements, offer commercial gamma irradiation services with gamma fluxes up to 10 million roentgens an hour.

The Commission reduced prices for radioactive cobalt 60 effective August 1, 1957, a step made possible primarily through improved production techniques and increased markets. The lower price has encouraged more widespread distribution and use of cobalt 60 in industrial, medical, and research applications. The new prices range from $2 to $5 a curie, and are based on the specific activity (number of curies per gram of material) and the quantity purchased. Discounts are given on bulk purchases to encourage participation of private industry in cobalt 60 distribution. A standard charge of $100 an order for source selection and handling also was established.

Previously, cobalt 60 prices were $50 a curie for the first 2 curies or fraction thereof, and ranged from $2 to $10 a curie for larger purchases. Prices in the $2 to $10 range were based on specific activity without regard to quantity purchased. In addition, there was a source handling charge of $10.

To date, all cobalt 60 in this country has been produced by the Commission, and currently about 300,000 curies a year are manufactured. The Commission does not plan to increase its output, and hopes that increased demand may cause industry to undertake production.

Large source encapsulation. Two private firms have announced their intention to enter the business of preparing sealed sources of large amounts of radiation. These firms are Nuclear Systems, a division of Budd Co. of Philadelphia, and Picker X-ray Co. of Cleveland, Ohio. Pursuant to its general policy, the Commission made known its decision, effective March 1, 1958, to discontinue providing encapsula-

tion service to the public for large cobalt 60 sources. Private industry already provides encapsulation service for small cobalt 60 sources.

Nuclear Systems is prepared to encapsulate cobalt 60 sources up to 50,000 curies. Picker X-ray is designing a hot cell to handle cobalt 60 sources of up to 1 million curies.

Isotope production program. The Commission's radioisotope production programs are designed (*a*) to assure an adequate supply of these materials at reasonable cost; (*b*) to increase utilization of isotopes; (*c*) to provide for production in privately operated facilities; and (*d*) to encourage private companies to perform various auxiliary services, such as encapsulation of large radioactive cobalt sources.

Steps designed to increase utilization of radioisotopes have been primarily price reductions. Reduced prices for carbon 14 and iodine 131 were made effective July 1, 1956. These are two of the most widely used radioisotopes, especially in medicine and biological research.

Carbon 14 now sells at $28 a millicurie for shipments through 199 millicuries (mc.); for shipments above 199 mc., the unit price drops to $22. The previous price range was $36 and $32 for these quantities.

Iodine 131 now sells at $0.50 a millicurie for shipments through 499 mc.; for shipments above 499 mc., the unit price drops to $0.40. The previous price range was $0.75 and $0.65 for these quantities.

In 1956 the Commission revised its radioisotope licensing provisions to provide for a "possession limit"—the amount of radioactive material which a user expects to have on hand at any one time—permitting the user to purchase an unspecified total amount of radioactive material provided his ceiling is not exceeded at any time. Prior to this change, users had to submit separate applications for the total amount of each radioisotope they expected to procure during a year.

Restrictions also were relaxed on the sale and distribution of stable isotopes. In 1954, stable isotopes were made available for foreign distribution on the same terms and conditions pertaining to radioisotopes. At that time, these stable isotopes were available only on a loan basis to domestic users, but this was changed in late 1954 to outright sales. In 1956, the procedure for obtaining stable isotopes was further simplified when direct Commission authorization was discontinued and purchasers could apply directly to the supplying laboratory.

The Revised Byproduct Material Regulation, effective February 10, 1956, increased the amount of radioisotopes which may be possessed without submitting an application or obtaining a specific license from the Commission. The revised regulation lists 65 radioisotopes and the amount of each which may be possessed under a general license,

though only 10 generally licensed quantities may be possessed by any one person at one time. This same regulation simplified procedures for foreign users desiring radioisotopes of elements 3 through 83, by authorizing direct purchase from the Commission or from commercial suppliers. Previously, foreign users were required to act through their country's representative here. The requirement for reports on request on research work performed was eliminated.

PROGRAMS SUPPORTING INDUSTRY GROWTH

Development of the atomic energy industry necessarily has depended primarily upon the initiative of private enterprise organizations. The Commission has played a principal role also because of the peculiar nature of the special nuclear material on which the industry rests, its military importance, the Government activities and industry based on its processing and use, the secrecy that necessarily surrounded so much of the technology and cost data, and the possible hazards to public health and safety created by radioactivity. Much of the Commission's efforts, as described in the preceding report on industry activities and summarized in Chapter I, have been directed toward helping private enterprise groups to overcome the obstacles created by Federal dominance of the field and by the continuing paramount position of national defense considerations.

To promote the use of radioisotopes, the Commission has conducted research and published information about their application in industry, medicine, and agriculture; reduced prices and restrictions on use of radioisotopes; and issued general licenses for various devices depending on radioisotopes.

To assist with power reactors, the Commission has financed a program of experimental power reactors, assisted in financing power reactors proposed by utilities and others, sponsored and conducted supporting research, and recommended supportive legislation; for example, to provide indemnity of possible public damage in the unlikely event of reactor accidents.

In general support of the industry, the Commission has increased production of ores and materials, obtained release of large quantities of special nuclear materials for use in reactors, provided research facilities and other services and facilities not otherwise available, and published prices and charges for services and materials to provide cost data. The Commission also has disseminated technology and inventions through patents activity, through declassification, special writing and publication of technical information, and issuing permits for access to classified information. It has sponsored education and

training programs to increase the supply of technical manpower, and provided a firm structure of regulations, licensing, and inspection.

To increase industry participation, the Commission offered to withdraw from fields of interest to private enterprise, and invited proposals from companies to supply industry and the Commission with various services and materials.

These actions were in addition to the Commission efforts in international cooperation, described in Chapter V, Progress in International Cooperation, which has helped open a foreign market for domestic manufacturers and suppliers of materials and services.

The policies and programs adopted by the Commission which have been of assistance to the growth of the industry, outlined here, are described throughout this report. The following pages summarize a number of key programs in research, in providing technical information to the industry, in patents and inventions, in providing the regulatory framework of the industry, and in enlarging the supply of technical manpower.

Research and Development

All the research programs of the Commission, except for those areas primarily of military importance, are conducted in the ultimate general support of progress in the peaceful uses of atomic energy. This includes the broad underlying structure of research in biological and medical fields which contribute to safety and health, not covered in this report except from the standpoint of work with radioisotopes (see ch. II); the fundamental work in the fields of chemistry and physics, of metallurgy and materials, of controlled thermonuclear reactions, as reviewed in Chapter VI, Progress in Physical Research; and research on fundamentals of reactor design, reactor materials and processes, and reactor safety, as well as in the specific field of attaining economic power, as reported in Chapter III, Progress With Power Reactors. Current contracts for research in private industrial and academic organizations are listed in Appendix 9.

Supplying Technical Information

The Commission maintains an active, positive program throughout its activities for preparation of technical reports. Scientists and engineers are constantly urged and assisted to publish the results of their endeavors. In addition, the Commission publishes thousands of technical reports annually, some treating with minute details and some with broad perspectives; it also prepares special compilations in

key areas and publishes them both in book form and as periodical releases.

Research organizations and interested industrial and commercial groups can become informed of progress in all these areas through the extensive program of distributing technical information. Declassification to the extent consistent with national security permits the public sale of most of these documents. Industrial and research organizations, and individuals concerned with peaceful uses of atomic energy, also are permitted under certain restrictions and after investigation to have access to many documents which still are classified. Seminars are conducted; compendiums of information in various fields are prepared and issued. By means of the foregoing and other programs, the Commission has made useful technical information rapidly and broadly available.

The cluster of programs designed to distribute essential technical information has been broadened and intensified in the last 3 years.

Since 1954, the Commission has authorized two new Declassification Guides which together make available all essential information for civilian power reactors, and open up other wide areas of technology, at the same time that the national security is adequately safeguarded. The new guides were followed by two accelerated reviews of all useful Commission technical documents which remained classified to determine which could be released to the public, which could be given a lesser classification, and which must remain classified. As a result of these reviews, about 20,000 documents were declassified.

Since 1954, the Commission has instituted its access permit program under which organizations and individuals may have access to classified material if they can establish need for the information, and meet certain security standards. A total of 1,411 permits is in force as of December 31.[20]

Since 1954, the Commission's program for distribution of technical information has been broadened to assist sale of all newly declassified material, to prepare compendiums of knowledge in a new series of books on key industrial subjects, to install classified libraries in key localities and establish unclassified libraries throughout the country, to support programs for translation of Russian-language documents, and to increase knowledge of nuclear technology and of programs for its distribution through exhibits and seminars.

Since 1954, and through 1957, a total of 1,017,000 copies of Commission technical reports, engineering drawings, and other information material, classified and unclassified, in full-size and microcopy form, has been purchased by the public.

[20] See appendix 7.

Declassification

The Commission's program of classification and declassification has the dual purpose of protecting information essential to national security, and making available the maximum amount of information to assist progress in nuclear technology and in developing peaceful applications of the principles and techniques of the nuclear energy fields.

The Commission since its inception has thus been following the policy which subsequently was stated in the 1954 Act (sec. 142a and b) as follows:

(*a*) The Commission shall from time to time determine the data, within the definition of Restricted Data, which can be published without undue risk to the common defense and security and shall thereupon cause such data to be declassified and removed from the category of Restricted Data.

(*b*) The Commission shall maintain a continuous review of Restricted Data and of any classification guides issued for the guidance of those in the atomic energy program with respect to the areas of Restricted Data which have been declassified in order to determine which information may be declassified and removed from the category of Restricted Data without undue risk to the common defense and security.

The 1954 Act, in contrast with the 1946 legislation and reflecting the shift in emphasis in atomic energy development, specifically provides for a program "* * * for the control, dissemination, and declassification of Restricted Data, subject to appropriate safeguards, so as to encourage scientific and industrial progress." [21]

Between 1946 and 1954, major declassification guides were significantly revised six times by Canada, the United Kingdom, and the United States, whose representatives have jointly decided on areas of information requiring safeguards as an outgrowth of their partnership during the war. Further major revisions of declassification policy were promulgated, the seventh in July 1955 and the eighth in December 1956. The seventh revision resulted in declassifying and publishing all information needed for the design and construction of research reactors including the nuclear data, chemical processing of fuel elements, and of raw materials.

Specific benefits have been evident in the simultaneous release of information in 600 papers published pursuant to the 1955 guide during the international Atoms for Peace conference in Geneva. In December 1955, a special review project was conducted which reviewed approximately 31,000 documents and declassified about 11,000.

The eighth revision made it possible to declassify almost all information on nonmilitary and nonproduction reactors, including research reactors, civilian power reactors, and test and experimental reactors.

[21] Atomic Energy Act of August 30, 1954, Sec. 3b.

In addition, considerable data on specific processing methods involved in the construction and operation of plants for the preparation of reactor fuel elements and the chemical processing of spent reactor fuels have been declassified. Current figures on raw materials production also were declassified.

This new policy goes far toward enabling industry to design, construct, and operate civilian power reactors entirely on an unclassified basis. Technical and economic data that have been declassified as a result of the adoption of the new policy will benefit the atomic energy industry in general, from uranium mining to the chemical processing of spent reactor fuels.

In 1957 a second special review project, applying the new guide, reviewed about 18,000 documents and declassified about 9,000.

Access Permit Program

The Commission's access permit program, instituted in 1955, established a new pattern for distribution of classified information. It made available to permittees confidential and secret categories of restricted data when the data deal with civilian uses of atomic energy, when the private company or individual could show a potential use or a need for the data, and when the company and individuals concerned had received proper security clearances and made suitable arrangements for safeguarding classified information. A showing of potential use is the basic requirement for access to confidential information. In the case of secret information, a need has to be demonstrated.

Aside from individuals and companies active in the Federal program, where the basic criterion for access was the value to the Government of their participation, no large numbers of persons previously had been allowed access to information of industrial advantage. An early study was carried out in 1949 by representatives of the utility industry who were granted access to certain categories of information.[22] In response to their report, a permanent committee [23] was established to help funnel unclassified technical information to industry, or to seek the declassification of material useful to industry. In 1951, several industrial groups proposed to the Commission, and undertook with the Commission's assistance, studies of the technical and economic feasibility of building dual-purpose nuclear reactors to produce electricity and plutonium [24]—an activity which led to some of the current proposals to construct central power stations fueled with

[22] See p. 191, Seventh Semiannual Report to Congress (July–December 1949); p. 25, Tenth Semiannual Report to Congress (January–June 1951).

[23] See p. 145, Eleventh Semiannual Report to Congress (July–December 1951), and pp. 48 and 135, Thirteenth Semiannual Report to Congress (July–December 1952).

[24] See p. 20, Tenth Semiannual Report to Congress (January–June 1951).

fissionable material. The program ultimately involved 25 study groups including 81 companies.

As of December 31, 1957, of the 1,404 access permits in force (111 have been terminated or expired), 57 percent allowed access to secret and confidential restricted data and 43 percent were for access to confidential data only. The 1,404 access permittees have a total of 13,385 active "Q" clearances for individuals permitting access to secret information, and 8,967 active "L" clearances for access to confidential only.

An indication of the extent of industry participation in the access permit program is given by the sale of classified reports. Between 1955 and the end of 1957, permittees had purchased 27,875 confidential reports and nearly 8,500 secret reports.

The Commission has conducted periodic information briefings on special topics to enable industrial representatives to keep abreast of recent developments. One or more meetings have been held on six advanced reactor types, controlled thermonuclear research, feed material processing, reactor fuel processing, methods for measuring the isotopic content of uranium, and other technical subjects.

Distribution of Information

The Commission's programs for organized distribution of technical information to the public and to industry expanded sharply after passage of the Atomic Energy Act of 1954. Since its inception in 1946, the Commission has encouraged the widest feasible dissemination of its technical information—as unclassified documents to the public, including scientific and industrial groups—and to the extent that this was possible without impairing security, as classified documents within the atomic energy program.

Up to 1954, more than 6,000 articles on Commission-sponsored work had been published in scientific and technical journals. An equal number of unclassified or declassified individual Commission research and development reports had been placed on sale for science and industry through the Office of Technical Services, Department of Commerce. The Commission's abstract journal, *Nuclear Science Abstracts*, covering Commission-originated literature and documents from other sources around the world, has been published since 1947.

Within the Commission, classified documents circulated among its contractors, its employees, and individuals in the Department of Defense and other Government agencies who required information in the fields involved. This exchange was organized so that those who originated documents sent them automatically to a preselected list.

Classified abstract journals kept these widely separated groups in touch with developments.

The *National Nuclear Energy Series* of 31 classified and 40 unclassified titles summed up technical knowledge developed by the work of the wartime Manhattan Engineer District. Other summary volumes surveying the main bodies of data such as the *Sourcebook on Atomic Energy* and the *Reactor Handbook* were prepared under Commission sponsorship and published through commercial sources.

With the progressive declassification of information under changing policies since 1954, and with development of the access permit program, the document-distribution services were expanded.

Additional documents were prepared for unclassified distribution. The total rose in 1957 to approximately 40,000 documents, of which about 10,000 had been published in professional or technical journals. The remainder are for sale through the Office of Technical Services either in full-size or microcopy reproduction, or are available to be consulted at 79 continuously supplied depository libraries donated by the Commission to cities and universities throughout the United States.

Classified reports are sold to access permit holders through the Commission's Oak Ridge, Tenn., extension, and are available in a few classified libraries in key areas.

A technical book program has been inaugurated to help meet the need for new texts and handbooks; a guide was published to familiarize users with the information available and the methods of obtaining it; an automatic distribution system against prepaid deposits was opened for access permit holders; a reference center was opened where searches of literature are performed for a fee; technical information exhibits were offered at symposia and conferences; and the Commission's support of a program for translation of Russian-language documents was broadened.

Upon both the rapidly increasing fund of declassified atomic information and the classified literature available under the access permit program, the Commission has built its program of information services to industry and science. New services have been added and older ones improved and expanded as summarized in the succeeding sections.

Sale of technical reports. Commission information materials, including classified reports, engineering drawings, abstract journals, etc., purchased from the Oak Ridge extension office have totaled more than 148,000 copies between 1955 and December 31, 1957, of which 83,175 copies were sold this year.

Technical reports on unclassified subjects, sold by the Office of Technical Services, U. S. Department of Commerce, totaled 294,500 copies during the same period. During 1957, OTS sales were about 112,000 copies.

Since 1955, approximately 575,000 copies of reports in microcopy form have been sold.

Guide to atomic energy literature. In 1957, the Commission published the "Guide to Atomic Energy Literature for the Civilian Application Program" (TID–4575), which explains what information is available to participants in the civilian application program, how to locate and use this information, and how to obtain classified information materials from the Commission and unclassified materials through the 77 depository libraries and the Office of Technical Services.

The guide is free to those who request it from the Technical Information Service Extension, Oak Ridge, Tenn.

Automatic distribution. Beginning in 1957 the Commission authorized a service which enables access permit holders to open advance deposit accounts with the Commission and automatically receive classified technical reports keyed to their special requirements within the scope of their access permits. The Commission completed arrangements with the Office of Technical Services for a parallel advance deposit distribution system.

As of the end of this report period, 40 firms were using this service.

Reference center. In 1956 a reference center was installed at the Technical Information Extension Service for use of industrial firms. Material available to them includes a complete collection of Commission-developed reports, both classified and unclassified, a master card catalog, bibliographies, lists of available documents, and other reference aids.

Literature search service. For firms that do not wish to send literature search teams to Oak Ridge, and do not have independent library sources, the Commission established in 1956 a literature search service at a cost of $6 an hour, supplying on any requested topic either literature titles or specific tabulated data.

Depository libraries. One long-range service goal of the Commission (originated late in 1949) has been to establish complete collections of useful unclassified information throughout the United States. The total is now 79, of which 13 were added in 1957, and there is at least

one depository library in each metropolitan area of 500,000 or more population.

In addition, classified libraries were established in 1957 in six centers across the country for use by access permit holders.

Translations. During 1957 the Commission enlarged its program of translating useful foreign scientific literature on nuclear subjects to include 4 monographs, 4 conference proceedings, 95 journal articles, and abstracts covering 553 papers presented at two Soviet Union Academy of Sciences meetings in March and April of 1957. Representative of the translations are the following:

PROBLEMS OF METALLOGRAPHY AND THE PHYSICS OF METALS, a symposium held by the USSR Central Scientific Research Institute of Ferrous Metallurgy, 1955. AEC–tr–2924. Paperbound, $2.20.[25]

ALL-UNION CONFERENCE ON THE APPLICATION OF RADIOACTIVE AND STABLE ISOTOPES IN THE NATIONAL ECONOMY AND SCIENCE, abstracts of approximately 500 papers presented at USSR Academy of Sciences conference, April 1957. AEC–tr–2925. Paperbound, $2.20.[25]

PROJECT OF A 420 MW ATOMIC ELECTRIC STATION, Committee for Participation of USSR in International Power Associations, June 1957. AEC–tr–2941. Paperbound, $0.25.[25]

FIRST ALL-UNION CONFERENCE ON RADIATION CHEMISTRY, USSR Academy of Sciences conference, March 1957. AEC–tr–2925. Paperbound, $2.65.[25]

QUANTUM ELECTRODYNAMICS, PARTS I AND II, A. I. Akhiezer and V. B. Berestetsky, 1953. AEC–tr–2876. Paperbound, $2.65.[25]

The Commission continued its support of the joint translation program with the National Science Foundation and other Government agencies to make available complete translations of the most important foreign scientific periodicals on a current basis.

Rewriting program. After completion of the 1957 rapid declassification review, the Commission established a program for editing, rewriting, and publishing reports on military reactors which reviewers decided could be declassified with deletions. More than 100 of these rewritten reports have been completed and issued.

Technical book program. To help meet the need for new texts and handbooks useful to industry and based on the whole range of nuclear developments, the Commission has steadily increased the number of arrangements for the writing and publication of summary volumes—some as a part of projects under research and development contracts; others under specific writing contracts. The Commission is cooper-

[25] Available from the Office of Technical Services, Department of Commerce, Washington 25, D. C.

ating closely with the publishing industry in carrying out this program. Technical books published during the current year include:

ATOMIC ENERGY FACTS, a handbook of Commission and atomic energy activities for engineers and management. Contains many photographs, drawings, and flow diagrams. Paperbound, $2.[26]

EXPERIMENTAL BOILING WATER REACTOR, a detailed technical description of this new, experimental atomic powerplant at the Argonne National Laboratory. Paperbound, $2.25.[26]

NEUTRON AND GAMMA IRRADIATION FACILITIES, compiled by F. G. Minuth and John H. Martens of Argonne National Laboratory. Describes and catalogs facilities available at research reactors, spent fuel installations, and cobalt 60 sources. Paperbound, $0.60.[26]

HOT LABORATORY EQUIPMENT, compiled by Louis G. Stang, Jr., of Brookhaven National Laboratory. Describes and catalogs equipment used in working with radioactive materials. Paperbound.[27]

CORROSION AND WEAR HANDBOOK, edited by D. J. DePaul, Bettis Plant. Deals with the use of water in a nuclear reactor system. Paperbound, $2.25.[26]

U. S. RESEARCH REACTORS, edited by J. W. Chastain, Battelle Memorial Institute, summarizes technical information on the major types of research reactors developed in the United States. Paperbound, $1.50.[26]

Quarterly technical progress reviews. Since published books in rapidly developing fields cannot be kept sufficiently current to meet the needs of the atomic energy industry, the Commission undertook in 1957 to prepare and issue quarterly Technical Progress Reviews in specific subject matter areas.

These reviews digest and evaluate the latest findings in nuclear technology and science. The first issue of *Power Reactor Technology* was published in November. A second issue of this review and the first issues of *Spent Fuel Processing* and *Solid Reactor Core Materials* are scheduled for appearance early in 1958.

Industrial releases. The Commission's industrial release system has been expanded to provide business and research management with details of present and prospective Commission policies, programs, services, and technical data which directly or indirectly affect their interests. The releases, mailed to the technical and business press and to interested individuals upon request, cover topics in nine general areas: materials, services, facilities available from the Commission; regulations, licenses, patents, administrative proceedings; reactors, reactor fuels and materials; radioactive waste disposal; safety and health protection; activities abroad; radiation applications; training and education; and procurement.

[26] With the exception of "U. S. Research Reactors," available from Office of Technical Services, Department of Commerce, Washington 25, D. C., these books may be ordered from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

[27] Being printed.

Proceedings of symposia. In 1956, the Commission expanded its program of publishing the papers presented at scientific and technical meetings, conferences, and symposia to make this information more widely available to industry and the scientific community. Proceedings published during 1957 include:

SYMPOSIUM ON THE REPROCESSING OF IRRADIATED FUELS, held at Brussels, Belgium, May 20–25, 1957. Paperbound, $10.50.[28]

SYMPOSIUM ON NUCLEAR-POWERED SHIPS FOR AMERICAN SHIP OPERATORS, held at Washington, D. C., July 30, 1957. Paperbound, $4.50.[28]

A CONFERENCE ON RADIOACTIVE ISOTOPES IN AGRICULTURE, held at Michigan State University, East Lansing, January 12–14, 1956. Paperbound, $3, Superintendent of Documents, Government Printing Office, Washington 25, D. C.

HRP CIVILIAN POWER REACTOR CONFERENCE, held at Oak Ridge National Laboratory, May 1–2, 1957. Paperbound, $1.60.[28]

SYMPOSIUM ON MODERN APPROACHES TO ISOTOPIC ANALYSIS OF URANIUM, held at Chicago, February 5–7, 1957. Paperbound, $4.75.[28]

Information workshops. The Commission held two technical information workshop meetings in 1957 (Oak Ridge, May 22–24, and Berkeley, October 8–9) to inform access permit holders about Commission technical information services. The workshops stressed reference and bibliographical tools for searching the literature and ascertaining sources of atomic energy information, and gave guidance for organizing information materials for highest utility. The final-day individual discussions were held with permit holders on specific problems.

Technical information exhibits. Since January 1956 the Commission has sponsored technical information exhibits to acquaint industry with nuclear developments and opportunities stemming from them. An exhibit entitled "Assistance to Industry" was shown at three major industrial engineering gatherings last year. It was also shown at "The President's Conference on Technical and Distribution Research for small Business," Washington, September 23–25. A display entitled "Isotopes Work for Industry" was shown at "The Atom Fair," New York City, October 28–31; and "The National Metals Exposition," Chicago, November 8–11.

PATENTS FOR INDUSTRIAL USE

The Commission's acquisition and royalty-free licensing of patents upon basic inventions made throughout its operations opens technological doors to industry. While it often is difficult to say when an

[28] Available from Office of Technical Services, Department of Commerce, Washington 25, D. C.

individual invention or contribution technology covered by Commission-owned patents has been employed by industry for commercial purposes and not in Federal contract activity, specific areas can be cited where industry has used inventive concepts and is manufacturing equipment or employing methods developed under Commission sponsorship. These include companies working in such fields as raw materials, reactors, instrumentation, and separation chemistry. Processing of raw materials has resulted in inventions and improvements in recovery of uranium from ores of all types. Improved acid-leaching techniques to open up the ore, and strong-base anion exchange resins to recover a high-grade uranium product, are used not only in the United States but in most countries producing uranium. New developments employing solvent extraction for recovery of uranium are being put into private plant operation.

Similarly many basic inventions and developments pertaining to nuclear reactors, as well as the fields of metallurgy, mechanical, and electrical technologies, are being freely used. Research reactors of the boiling water and pool types as built by private industry incorporate contributions from the Commission patent program. The remote control manipulators and many dosimeters, monitoring and survey instruments, and radiation counters that are privately manufactured employ developments made by the Commission and its contractors. The recent expansion in the rare earth chemical field similarly has been made possible. Many radiation techniques employed by industry for quality control, purification analysis, improvement of products, and for medical and biological uses were developed by or as a result of stimulation by the Commission.

The policies and practices of the Commission and its predecessor, the Manhattan Engineer District, in acquiring the rights in inventions and discoveries made in connection with contracts, and securing patents upon them, as well as the acquisition of the proprietary rights in technical data prepared in the course of contracts, has permitted the Commission the widest possible freedom of action in dissemination and utilization of these technical data and inventions. Some Government departments and agencies acquire only license rights in inventions for limited Government use, and only limited rights for use of proprietary technical data developed in the course of contracts. If this course had been followed in atomic energy, the Commission would not have been in as favorable a position to disseminate technical information or to make the inventions freely available to the general public.

By these procedures, the individual or corporation not under contract with the Commission has been placed in the same position as a contractor in being permitted to utilize the technical data and

inventions made under Government sponsorship without the need for making individual agreements with private developers.

The inventions that have resulted from Commission contract work have been made available to all applicants, and lists of available patents, as well as technical publications, have been circulated to interested individuals and industry. More than 1,300 United States patents have been secured by the Commission and released for licensing, 212 of these during 1957.[29] Under these, the Commission has issued some 680 nonexclusive, royalty-free licenses to individuals and corporations, over 400—including 110 in 1957—issued since January 1, 1954.

In September 1956, the Commission negotiated a tripartite agreement among the Governments of Canada, the United Kingdom, and the United States on patent rights in certain inventions. Under the agreement the United States acquired all rights in Canadian and United Kingdom inventions that were the subject matter of United States patents up to November 1955, and such inventions became part of the portfolio of patents which the Commission makes available to the United States public. At the same time United States-owned inventions, rights to which were accorded British and Canadian Governments, are subject to a nonexclusive license to the United States Government in the United Kingdom and Canada. Provision was made that the Canadian and United Kingdom Governments would not discriminate against American industry in according licenses within Canada and Great Britain. This agreement secures to American industry royalty-free rights in United States patents that resulted from work sponsored by the Governments of Canada and Great Britain in the field of atomic energy, and at the same time assured American industry of nondiscrimination as respects corresponding atomic energy patents in Canada or Great Britain.[30]

The Commission looks to further international arrangements which will provide for nondiscrimination against United States industry in its foreign activities as well as permit the United States Government and industry to use United States patents which may form the subject matter of any international interchange arrangement.

The Commission, subject to security limitations, has since 1954 pursued an active program of filing foreign patent applications on unclassified subject matter in order to assure United States industry generally an opportunity to participate in the foreign market. Prior to the declassification guides of 1955 and 1956, much atomic energy information useful to industry was classified so that foreign filings

[29] Appendix 5 lists the patents the Commission secured between July and December 1957. Previous semiannual reports similarly list current acquisitions.

[30] See pp. 104–106, Twenty-first Semiannual Report to Congress (July–December 1956).

were not permissible since there were no arrangements for exchange of classified information. Since further declassification and negotiation of several bilateral agreements allow exchange of classified information, it has been possible for the United States to file in some countries on inventions in classified fields. Elsewhere, foreign filings are undertaken only on unclassified inventions.

The modifications of the patent provisions in the Act of 1954 in effect restored atomic energy inventions to the normal patenting systems with several exceptions. There is evidence that the patent system is taking on a more normal function in the atomic energy field by virtue of the number of independent private patent applications filed with the Commissioner of Patents, and reported to the Commission pursuant to section 151 (d) of the 1954 Act.

In 1955, 130 applications were reported; in 1956, approximately 450; and in the first 11 months of 1957, over 850. It is interesting to note that as respects these applications reported, less than 1 percent were placed under secrecy order. This means that more than 99 percent of the applications filed by private parties are unrestricted and the inventors are able to communicate their inventions domestically and to persons abroad, and to file foreign applications as they see fit, and in other normal ways seek to promote the use of these private-developed inventions in the field of atomic energy.

Regulatory Framework and Indemnity

Progress in the field of peaceful uses of atomic energy requires the assurance of safety and the protection of public health, and, because of the potential military uses of special fissionable materials, it requires also the assurance that the materials themselves and the equipment are safeguarded in the interest of the national defense and security.

Under the Atomic Energy Act of 1954, the Commission has laid a regulatory foundation for the industry to satisfy these two basic requirements in the public interest. The Commission has undertaken to organize and execute these functions in such a way as to leave private initiative the maximum feasible latitude.

Public Law 85–256 of September 2, 1957, provides for the Federal Government to indemnify any person found liable for nuclear accidents when the losses exceed the amount of private insurance available, and thus offers assurances of financial protection to the industry and to the public.

Regulation, Licensing, and Inspection

The Act of 1954, which signalized the expansion of private activities in atomic energy fields, placed upon the Commission the responsibility for regulating and licensing private activities in this field, and for carrying out inspections to assure compliance, in the interest of the public health and safety, and of the common security and defense.

For the atomic energy industry, definite benefits are expected from regulation. The need to protect health and safety in all activities relating to nuclear materials and facilities was widely understood. The Congress laid upon the Commission the responsibility for enforcing safety requirements. It executes this responsibility through regulations which lay down basic requirements, through licensing, which requires safety studies of each significant proposed use of certain facilities and materials, and through its inspection system to provide assurance that its requirements are being fulfilled. This cluster of regulatory services supports industry in its efforts to build and operate reliable and safe nuclear reactors. It helps assure public acceptance and support of these ventures, and provides reasonable assurance to the public of the safety of the devices and operations.

In developing the basic *regulations* in this field, the Commission has sought, within the limits required for the protection of the public, to impose no unnecessary restrictions upon the developing industry. Thus far, seven regulations have been issued in this field and, with one exception—that dealing with source materials—all have become effective since 1954. The two regulations issued in 1957 deal with indemnification of the public under the new law cited earlier and with standards for protection against radiation.

The regulations are:

10 CFR Part 20—Standards for Protection Against Radiation, effective February 28, 1957.
10 CFR Part 30—Licensing of Byproduct Material, effective February 10, 1956.
10 CFR Part 40—Control of Source Material, effective March 31, 1947, with amendments from time to time.
10 CFR Part 50—Licensing of Production and Utilization Facilities, effective February 18, 1956.
10 CFR Part 55—Operators' Licenses, effective February 3, 1956.
10 CFR Part 70—Special Nuclear Materials Regulations, effective March 4, 1956.
10 CFR Part 140—Financial Protection Requirements and Indemnity Agreements, effective September 11, 1957.

During 1957, the Commission also published for comment 10 CFR Part 71, "Regulations To Protect Against Accidental Conditions of Criticality in the Shipment of Special Nuclear Materials," requiring

Commission approval of licensee transportation procedures whenever shipped quantities exceed specified limits. It also amended its Rules of Practice (effective October 27, 1957) setting up a period prior to issuing of export licenses when interested groups may petition leave to intervene. Minor amendments also were made to 10 CFR Part 25, "Access to Restricted Data," and 10 CFR Part 30, "Licensing of Byproduct Material." Except for the regulation on indemnity, described in the following section, this report will not summarize the requirements of these regulations. Text of the 1957 regulations cited above appear in appendix 6. The regulations have been printed both in the *Federal Register* and the other six basic regulations have appeared in the appendices of previous semiannual reports to Congress. The safety effects of these regulations, the precautions of the licensing procedure, and the way in which inspection functions are accomplished were described in the Twenty-first Semiannual Report to Congress, in the special section dealing with "Radiation Safety in Atomic Energy Activities" (pp. 118–131).

Licenses are issued for construction or operation of facilities, or for use of nuclear materials and radiation sources, only when the Commission has reasonable assurance that operations will be such as to comply with its regulations and, in cases where regulations cannot be entirely specific, with the underlying principles of assuring public health and safety, and the protection of the common defense and security. The standards for nuclear reactors, for example, cannot be laid down precisely since the art is young and the variety and complexity of designs still considerable. The Commission's review, with the assistance of a specialized staff, and with the separate study by the Commission's Advisory Committee on Reactor Safeguards, established on a statutory basis in September 1957,[31] must precede the issuance of a license.[32]

During 1957, the Commission received 44 applications to construct and operate research and test reactors. As of the end of the year, 19 research reactors had been licensed to operate. United States firms requested authority to export 15 research and test reactors. The first license to operate a power reactor was issued to General Electric for its plant at the Vallecitos Laboratory, near Pleasanton, Calif. One new power reactor construction permit was issued. This year, 121 persons were licensed as reactor operators.[33] Special nuclear material licenses applications totaled 114 this year, double last year's figure. Ninety-one were issued, one and one-half times last year's total.

Inspection responsibility begins when the Commission issues a

[31] Public Law 85–262, amendment to the Atomic Energy Act of 1954.
[32] The licensing activity for July–December 1957 is given as appendix 7.
[33] Details in appendix 7.

license or permit. The 1954 Act (sec. 25c) established an Inspection Division responsible for gathering information to show, among other things, whether or not licensees comply with the appropriate rules and regulations of the Commission.

Pursuant to this section, the Commission promptly created a Division of Inspection in September 1954. Standards, policies, and procedures relating to inspections have been established, cooperation with the States developed, and actual conduct of inspections delegated, to the extent feasible, to operations offices of the Commission.

Through December 1957, more than 1,000 inspections had been carried out by the Commission, including 40 inspections of privately owned reactors either under construction or in operation.

Continuing with the work of establishing inspection procedures, the Commission during 1957 was determining the necessary frequency of inspections for the various kinds of licensed activities, as indicated by the relative health hazard associated with the amounts and kinds of materials, and types of operations licensed.

A series of meetings was held with certain State organizations to advance the Commission-State cooperation program for inspection of Commission licensees, and formal contact points arranged for several States. Representatives of inspection agencies in many States continue to accompany Commission personnel on inspection visits, and State agents have participated in investigations of radiation incidents.

Indemnity for Public Liability

The problem of providing insurance and indemnity for the private atomic energy industry was recognized and studied during the preparation of the Atomic Energy Act of 1954. The remote possibility that privately owned nuclear reactors might have a catastrophic accident created the problem that private organizations building or operating the facilities might incur a public liability larger than could be met either by the financial structure of their organization or by the resources of the insurance industry. An early study which focused attention on this problem was sponsored by the Atomic Industrial Forum and conducted by Columbia University.

To help clarify the problem, and the possibilities for its solution, the Commission arranged early in 1955 for a group of insurance executives, representing the major associations of property and liability insurance underwriters, to study the prospects for providing insurance for private atomic energy activities. The Commission generally has negotiated insurance programs for its contract work on a cost basis wherein the insurance companies assume no risk.

The insurance representatives concluded that workmen's compensa-

tion insurance could be provided by existing insurance facilities; that finances for property insurance for private atomic energy installations could be organized; but that, while public liability insurance could be provided in relatively large amounts, the private capacity to underwrite this type of insurance might not be adequate to cover the claims which could arise in the event of a serious nuclear incident involving release of radioactive materials over large areas, even though the possibility of such an accident was vanishingly small.[34]

The studies of insurance company executives lead to the formation, in January 1957, of three syndicates or pools to provide insurance for atomic energy activities.[35] One of these is composed of stock companies and provides property insurance on atomic energy facilities; the second, of stock companies to provide public liability insurance; and, the third, of mutual companies to provide both types of insurance. The liability policies would cover the facility licensee, all his suppliers of equipment and services, and others who might be held liable in event of a nuclear incident.

The Commission believed that insurance coverage was adequate except in the public liability field. While the amount of liability insurance coverage was far greater than that provided for any other industry, it still was inadequate to cover the maximum possible liability which could result from a catastrophic nuclear incident, no matter how remote the probability of the incident. The Commission therefore recommended to the Congress that, to enable private atomic energy industry development to proceed, the Government provide indemnification of companies engaged in certain activities.

After enactment of H. R. 7383 (title of Act) as Public Law 256, 85th Congress, signed by the President on September 2, 1957, the Commission promptly issued (September 11, 1957) a temporary regulation effective until definitive regulations were issued (10 CFR 140, Financial Protection Requirements and Indemnity Agreements).

The provisions of the Act are (*a*) that all facility licensees and, at the discretion of the Commission, certain materials licensees, are required to furnish proof of financial protection against public liability in an amount determined by the Commission except "* * * that for facilities designed for producing substantial amounts of electricity and having a rated capacity of 100,000 electrical kilowatts or more, the amount of financial protection required shall be the maximum amount available from private sources"; (*b*) that such licensees and their suppliers of materials, equipment, and services and any others who may be liable are indemnified in the amount of $500 million over the

[34] For report on study on this subject, see pp. 45–47, Twenty-first Semiannual Report to Congress (July–December 1956).

[35] See pp. 43–45, Twenty-second Semiannual Report to Congress (January–June 1957).

financial protection required; and (*c*) that the public liability of all those liable is limited for each accident to the amount of financial protection plus the $500 million indemnity.

The temporary regulation requires each licensee authorized to operate a nuclear reactor to maintain financial protection in the amount of $150,000 per thousand kilowatts of thermal capactiy authorized by his license. This amount is established as a temporary basis for determining financial protection required. Public Law 256 requires financial protection equal to the total amount of private liability insurance available (expected to be approximately $60 million) for all power reactors with a capacity of 100,000 electrical kilowatts or more. Such a relationship applied to all reactors needs to be expressed in thermal capacity since many reactors (e. g., research or testing reactors) will not be used in connection with the generation of electricity. The ratio of thermal to electrical capacity varies somewhat among different types of reactors. For the purpose of this regulation, this ratio has been assumed as 4 heat (thermal) kilowatts to 1 electric kilowatt. Therefore, a capacity of 400,000 thermal kilowatts would require $60 million of private insurance, or $150,000 per thousand kilowatts of thermal capacity. The minimum amount of financial protection under this regulation is $250,000.

The Commission is revising this formula and will issue later a permanent indemnity regulation. The new formula will attempt to take into account such additional factors as population density in fixing the amount of financial protection required for a facility.

Helping to Supply Manpower

With the accelerated drive toward putting atomic energy to work for the welfare and economic advantage of this country and the free world, the supply of scientists and engineers trained in the difficult arts of the nuclear energy field threatened to become a limiting factor upon progress.

By 1955, the Commission could make it clear to the world that the supply of uranium was adequate for future needs; its production machinery was abreast of the increasing flood of materials. On the other hand, the numbers of technically trained people, especially those experienced and capable in the complicated art of reactor design, testing, and operating, and in research in supporting fields, had been limited. The passage of the Atomic Energy Act of 1954 broadened the opportunity for commercial development, established a policy of active cooperation with other nations in promoting the use of atomic energy and advancement of nuclear research, and called for positive Federal encouragement of private reactor construction. Increased

demand in nuclear fields occurred at a time when defense requirements for technical manpower continued at a high level, and when the upsurge of the Nation's total economy was emphasizing the demand for all types of trained manpower.

The initial manpower needs of the rapidly expanding private atomic energy industry inevitably were met chiefly by the transfer of personnel from work under Commission contracts to private work. The Commission urged its major contractors to step up programs for on-the-job training and upgrading of personnel. To date, the Commission, as a result of this foresight, has been able to expand its own programs while simultaneously providing some trained personnel for private industry. No major dislocations have occurred and it has been unnecessary to "freeze" personnel to avoid serious disruption of programs. Industrial and academic needs also have been met without critical shortages. (See report on Commission surveys in Part Two, Organization and Personnel.)

The Commission's educational programs, supporting Government-wide, industrial, and academic efforts, were undertaken to help meet the increasing needs of atomic energy programs, to assist in supplying trained people for the expanding commercial activity, and to provide specialist training for scientists and engineers from other nations cooperating with the United States in its effort to increase the contributions of the nuclear sciences to human welfare and advancement. Existing programs in education and training were temporarily expanded, and others initiated in three broad categories:

a) By opening a graduate school at Argonne National Laboratory, the International School of Reactor Technology, which, with the Oak Ridge School of Reactor Technology, has graduated 590 persons in 3 years;

b) By assisting universities and colleges in establishing or broadening curricula in nuclear technologies through various faculty-training programs in which, to date, several hundred have participated, and through grants of materials, facilities, equipment, and services to universities and colleges. More than 70 colleges and universities now offer courses in atomic energy fields; 16 have subcritical assemblies of fissionable materials; 12 are constructing training reactors; and

c) By increasing the range and number of fellowships awarded. A first group of 85 students accepted fellowships in nuclear technology for the 1957–58 school year.

Prior to the 1954 Act, the Commission operated only the Oak Ridge School of Reactor Technology, and a few training programs in health physics, radiobiology, and basic radioisotope techniques. A limited number of graduate fellowships were offered in radiological physics,

industrial hygiene, and industrial medicine. The largest program which provided some training was the research participation program whereby graduate students and faculty members of colleges and universities worked on research projects at Commission laboratories or at the installations of other Commission contractors. Also, exchanges of technical personnel and lecturers were arranged between Commission laboratories and industrial and educational institutions within the locales of the laboratories.

There follows a general summary of Commission educational and training programs with particular emphasis upon progress during the last 3 years.

Commission-Sponsored Schools

During the past 3 years, 297 students have completed the graduate level course at the Oak Ridge School of Reactor Technology (ORSORT). Students completing the coprse numbered 84 in 1954–55, 95 in 1955–56, and 118 in 1956–57.

This school was established at Oak Ridge National Laboratory in 1950 to train employees of Federal agencies and private industry in the design and development of reactor systems. Last year, the program was altered so that each student, instead of spending the entire year at ORSORT, works 6 months at one of six cooperating colleges or universities, and 6 months at Oak Ridge. With the expansion of the curricula and facilities of the Nation's colleges and universities, these special arrangements were cancelled late in 1957.

In March 1955, the International School of Nuclear Science and Engineering was inaugurated at Argonne National Laboratory, primarily to train able nuclear scientists from other countries as part of the Atoms-For-Peace program. The first class consisted of 31 students from 19 foreign countries and 9 students from the United States. As of the end of December, 273 students from 44 foreign countries, and 91 from the United States have attended the school. Initially, the 7 months' course was held exclusively at Argonne National Laboratory. At present a 17-week term is conducted at either North Carolina State College or Pennsylvania State University, followed by a second 17-week term at Argonne. Two such sessions are conducted each year with about 65 students a session.

Graduate Work Among Commission Contractors

At the Commission's laboratories, and at the installations of other Commission contractors, opportunities exist for outstanding students

to do research which becomes the basis for master's and doctor's degrees. Applications are made by universities and colleges for students who have completed courses in chemistry, biology, mathematics, and other sciences. Each national laboratory makes arrangements directly with institutions participating in this program.

The Massachusetts Institute of Technology has assigned graduate students for work participation at Oak Ridge. Plant problems are submitted for solution by students under an MIT resident staff. Ordinarily, a student is assigned 8 or 9 different problems in 1 semester, thus acquiring actual engineering experience.

Virtually all principal Commission contractors offer graduate-level courses for their own employees, though not directed toward degrees. Contractors who make arrangements for their employees to go on for advanced degrees include General Electric at Hanford Works, Richland, Wash.; at Knolls Atomic Power Laboratory, Schenectady, N. Y.; and at its Aircraft Nuclear Propulsion Division, Evendale, Ohio; Westinghouse, at the Bettis Plant, Pa.; National Lead Co., Portsmouth, Ohio; and Los Alamos Scientific Laboratory, Los Alamos, N. Mex. Those contractors that have programs of graduate work for university students include Ames Laboratory, Argonne National Laboratory, Brookhaven National Laboratory, Los Alamos Scientific Laboratory, Oak Ridge National Laboratory, and University of California Radiation Laboratory.

Fellowship Programs

At the time the 1954 Act was signed, the Commission provided graduate fellowships only in radiological physics, industrial hygiene, and in industrial medicine. The program in radiological physics has aided 344 participants since its beginning in 1948, and an additional 84 students have been appointed for the 1957–58 school year. The numbers of fellowships granted in radiological physics for the past 3 years are 44 in 1954–55, 43 in 1955–56, and 75 in 1956–57. Since 1955 about eight appointments have been made each year both in the industrial hygiene program and in the industrial medicine program. In 1956 a program was established to provide fellowships in nuclear energy technology, with emphasis on reactor development. For the academic year 1957–58, a group of approximately 100 students accepted fellowships in this program.

All fellowships are administered by the Oak Ridge Institute of Nuclear Studies, except those in industrial medicine which are administered by the University of Rochester, Rochester, N. Y.

Assistance to Schools

Although undertaken for the primary purpose of producing basic knowledge in fields of interest to nuclear sciences, the Commission's broad research programs conducted under contract by universities and colleges have assisted in training many students and have helped to supply instruments and facilities for research. Research contracts of these sorts are listed in appendix 9. This section reports Commission programs specifically intended to strengthen the training and educational activities of universities, colleges, and secondary schools.

Provision of materials, facilities, equipment, and services. Financial grants of $3.4 million have been awarded to 34 colleges and universities for the purchase of teaching aids, demonstration apparatus, and laboratory equipment for courses in nuclear technology. Twelve universities that received grants are constructing nuclear reactors primarily for educational purposes. These universities are University of California (Berkeley), Catholic University of America, Colorado State University, University of Florida, University of Michigan, North Carolina State College, Oklahoma Agricultural and Mechanical College, University of Oklahoma, Pennsylvania State University, Rice Institute, Agricultural and Mechanical College of Texas, and University of Utah.

A grant of $216,950 went to the University of Puerto Rico, where instruction in Spanish will be available to students from Central and South American countries. (See International Activities.)

Natural uranium and neutron sources have been lent without cost to educational institutions with established curricula in nuclear technology. Loans have been made to 17 colleges and universities. Sixteen subcritical assemblies have been built at the following colleges and universities within the United States: Alabama Polytechnic Institute, Cornell University, University of Florida, Georgia Institute of Technology, Iowa State College, University of Maryland, Massachusetts Institute of Technology, New York University, City College of New York, North Carolina State College, Ohio State University, Reed College, Rensselaer Polytechnic Institute, Stanford University, Virginia Polytechnic Institute, and Yale University.

In August 1957, an additional program of assistance was initiated for schools of medicine, biology and agriculture, public health, and for colleges and universities which offer courses in the life sciences. Under this program, grants are made toward the cost of acquiring specialized equipment for training courses in radiation biology and in the use of radioisotopes.

Thirty proposals for aid under this program have been reviewed,

and grants totaling $340,000 have been made to 21 educational institutions in this program since its initiation.

The Commission's program to furnish nuclear fuel and provide for the fabrication of fuel elements for research reactors being constructed by nonprofit educational or medical institutions was established in August 1955. Institutions which have obtained research reactors and have benefited by this assistance are: Pennsylvania State University, North Carolina State College, University of Michigan, and Massachusetts Institute of Technology.

Visiting lectures, symposia, and conferences. The Oak Ridge Institute of Nuclear Studies (ORINS), operated by an association of 36 Southern colleges under Commission contract, manages a traveling lecture program under which scientists, drawn principally from Oak Ridge National Laboratory, are scheduled into colleges and universities throughout the country. Other Commission and contractor installations have similar unformalized programs. The scientists lecture and conduct seminars or discussion sessions before members of faculties and student bodies. For the 1955–56 school year, 163 lectures were presented through the ORINS program; the total for 1956–57 was 177.

The Commission participated with the American Institute of Biological Sciences in a program initiated in March 1957 to provide special lectures in biology to colleges and universities throughout the country. Forty-one members of the staffs of the Commission installations volunteered to give lectures at nearby institutions during visits of 3 to 5 days. Consultations with students were included with the lectures.

Since 1954, ORINS has carried out an active program of university-sponsored regional and topical symposia for college and high school faculties and students. In 1955, 2 regional and 1 topical symposia were held at ORINS-sponsoring universities; in 1956, 4 regional and 1 special symposia; and in 1957, 3 regional and 1 special conference on high energy physics were held.

A conference was held in September 1956 at Gatlinburg, Tenn., at which Commission personnel discussed with deans of the colleges of engineering and university and college presidents the need for scientists and engineers. The Commission's programs of assistance were explained to 293 administrators from 151 institutions represented at the conference.

Advisory committee. In August, through the services of the American Institute of Biological Sciences, a committee was established to advise the Commission on educational and training programs in the field of

biology and medicine. The members, chosen from six universities, represent the specific areas of radiation physiology, agriculture and veterinary medicine, medical sciences, biology, health physics, and educational administration.

Information Activities

Published material, talks, motion pictures. During the past 3 years the Commission has received from individuals, schools, and organizations some 50,000 requests for information regarding atomic energy and the career opportunities available in this field. The Commission responded to these requests by preparing and distributing six types of kits of published material. The contents of the kits varied, depending upon the background and interests of individuals requesting information. The Commission has also been supplying information for distribution at high school science fair projects. Requests for educational literature from students in foreign countries have increased since 1955.

The Commission has presented a large program of films and talks on atomic energy. In 1957, more than 2,500 talks were given by Commission staff and contractor employees to audiences throughout the country. In the same year, 27,872 film showings were made before audiences of 870,532.

Library facilities. The Commission has provided nonclassified depository libraries on nuclear technical information to 60 universities conducting graduate work in nuclear science and engineering. (See "Information" section.)

High school demonstration units. Three units of an educational atomic energy demonstration, "This Atomic World," were sent on tour during 1956 and 1957. The demonstration, which was designed especially for use at secondary-school assembly programs, presents the fundamentals of atomic energy, discusses radiation and fission, explains the uses of atomic energy products in medicine and the applications of nuclear energy to industry. During the fiscal year ended June 30, 1956, these units made 223 appearances at schools in 14 States before an estimated total audience of 148,000. During the year ended June 30, 1957, demonstrations were presented at 440 high schools for 347,870 students. At the beginning of the 1957–58 school year, three additional units went into operation. Through December, the six units had visited 311 schools in 13 States, and their demonstrations were attended by 214,611 students. The total audience in the 30 months of operation was 710,481 students in 978 schools located in all 48 States and the District of Columbia.

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The units are operated for the Commission by the Oak Ridge Institute of Nuclear Studies.

Visits by high school students. High school students have been invited to visit major Commission laboratories and production facilities in 1957. A special program was arranged on February 11, Thomas A. Edison's birthday. On this occasion over 4,400 high school students visited unclassified areas in eight key laboratories and production centers. Biweekly visits are presently being made to Argonne, Brookhaven, and Oak Ridge National Laboratories. For example, during the academic year 1956–1957, 15 tours were conducted at Oak Ridge for high school and college groups, during which 2,400 students from 66 schools in 10 States were conducted through facilities at the national laboratory. A visitors' day, October 11, at Brookhaven National Laboratory was attended by almost 5,700 students.

Other Programs

Radioisotope instruction. Twenty courses in basic radioisotope techniques have been given to 636 persons from the United States and foreign countries during the past 3 years at the Oak Ridge Institute of Nuclear Studies. In this past year, a method of instruction has been employed in which each foreign student is teamed with a United States student as his partner. The courses, offered to scientists and physicians, cover instruction in the safe handling and use of radioisotopes.

Work experience program. The Commission announced a program on March 28, 1957, whereby privately employed nuclear scientists and engineers may obtain specialized work experience in Commission laboratories. The primary purpose of this program is to help people already generally educated and trained in nuclear science and technology to become familiar with specific applications of nuclear energy; it is not intended as a program offering basic training.

The program is not entirely new. Heretofore, some contractors operating Commission-owned facilities have made arrangements similar to those involved in the work experience program.

Faculty training. In 1956, the first summer institutes for engineering faculty members were held at Argonne National Laboratory and Brookhaven National Laboratory. These 2-month institutes were conducted by the Commission laboratories in cooperation with the National Science Foundation and the American Society for Engineering Education. Faculty members were given training in nuclear

energy as related to their individual engineering specialities. A total of 90 engineers and scientists representing 48 different educational institutions attended in 1956.

The program of five summer institutes for 1957, given by the Commission in cooperation with the American Society for Engineering Education, offered a basic course for persons newly entering the nuclear field at Brookhaven National Laboratory, attended by 30; advanced programs of specialized training, including reactor physics at Oak Ridge National Laboratory, attended by 14; a chemical processing course at Hanford Facilities, attended by 8; a nuclear metallurgy course at Ames Laboratory, attended by 31; and a training program utilizing the Argonaut reactor at Argonne National Laboratory, attended by 9. The five summer institutes of 1957 were attended by a total of 80 university faculty members from 52 institutions.

A total of 72 universities was represented at the 1956 and 1957 summer institutes.

Faculty members from universities also participate in research at national laboratories during summer months. Some 300 university personnel accept summer employment each year at Commission facilities. A number of the Commission's industrial contractors accept faculty members in formal courses conducted for their own personnel and also hold symposia to which faculty members are invited.

University use of computer. The services of the ORACLE (Oak Ridge Automatic Computer and Logical Engine) have been available to universities in the Oak Ridge area since 1956. The program is designed to assist universities with computational problems arising in connection with their research activities. To date, six universities have made use of this service and several others are negotiating for it. The program is administered by ORINS and the Oak Ridge National Laboratory Mathematics Panel.

Courses for high school teachers. Eight-week summer training courses are provided for high school science teachers in the handling and use of radioisotopes and radiobiology. Fifty-nine teachers in 1956 and 101 teachers in 1957 completed these courses.

These courses were offered at 3 universities in the summer of 1956, 5 in the summer of 1957, and proposals have been received from 15 universities for the same type of courses in the summer of 1958.

The summer training courses are supported jointly by the Commission and the National Science Foundation, the Commission providing funds to the universities for necessary equipment and operational costs, and the Foundation providing stipends and family allowances to the high school teachers.

Teachers completing the courses were presented with kits of equipment which enable them to perform experiments in radiation physics and radiobiology for instruction of students.

Two other summer courses for high school teachers have been supported by the Commission. A 1-month Summer Institute in Secondary School Science Teaching has been held annually at ORINS since 1955, attended by a total of 192 teachers. This institute is sponsored by the National Science Foundation in cooperation with the Commission. In 1957 in the Chicago area, 40 teachers participated in the two 2½-week summer institutes which gave laboratory courses covering science related to atomic energy.

"Traveling teachers" program. In the academic year 1956–57, 7 selected high school teachers visited 195 schools and 123 civic groups throughout the Nation, giving in each a week of lecture demonstrations before science classes, and conferring with faculty members on science teaching techniques. These teachers undertook training the previous summer at Oak Ridge and each carried some 800 pounds of science-demonstration equipment in a station wagon.

In 1957–58, 10 teachers received training and, besides visiting schools, will participate in science teacher and other professional meetings.

This program is sponsored cooperatively by the National Science Foundation and the Commission.

V

PROGRESS IN INTERNATIONAL COOPERATION

In the area of international cooperation to promote peaceful uses of atomic energy, 4 years of United States leadership have laid the groundwork for sound expansion of research work and of its practical application throughout the free world.

When President Eisenhower on December 8, 1953, proposed that world atomic resources be mobilized to advance peaceful applications of atomic energy, only 19 nations of the free world, including the United States, had established government agencies that could assist in the program. Ten of these were in Western Europe, where scientists in the 1930's made most of the basic discoveries that provided the foundation for atomic development.

By the end of 1957, there were 50 nations sufficiently interested in atomic energy to organize special government agencies to promote its use: 19 in Europe, 17 in the Western Hemisphere, 11 in Asia, 2 in Africa, and 1 in Australia. The United States Atoms-For-Peace program, dedicated to applying nuclear energy products and techniques to human welfare and economic betterment, thus has found partners throughout the free world. In addition, many Communist nations have set up official organs to advance civilian nuclear programs.

This international cooperation in peaceful nuclear development makes a substantial contribution to the United States efforts toward achieving an enduring world peace. The Commission works in close cooperation with the Department of State in negotiating the international agreements and other instruments under which much of the country-to-country cooperation, and United States participation in regional and international organizations takes place.

The International Cooperation Administration, the Export-Import Bank, and the United States Information Agency are among other Government agencies which give important support to the program.

Highlights of progress in the 4 years since 1953 include—

International Atomic Energy Agency. Fifty-nine nations in October 1957 become charter members of the International Atomic Energy Agency first proposed by President Eisenhower in the 1953 address before the United Nations General Assembly. Other nations among

the 80 states that signed the agency statute in October 1956 are expected to become members.

Agreements for cooperation. Thirty-seven nations now have in effect with the United States 39 agreements for cooperation on developing peaceful uses of atomic energy, agreements which became possible with passage of the Atomic Energy Act of 1954. Ten of the agreements provide for assistance in developing nuclear power. The other 29 are research agreements. Another 10 accords, which when in force will increase the number of cooperating nations to 43, are in various stages of ratification. Many agreements have been amended to enlarge the areas of cooperation. In addition, negotiations are in progress with 5 nations looking toward comprehensive agreements including power reactors, and 1 that will provide an amendment for research cooperation.

Materials commitments and shipments. Between August 1955 and December 1957, 70 shipments of reactor and research materials were made to 17 countries. Of these, 50 shipments were made during 1957. Fifty thousand kilograms of fissionable uranium 235 to be contained in fuel for research and power reactors abroad have been designated by the President for sale or lease from the Commission as required, generally in enrichments up to 20 percent; approximately 35,000 kilograms of this have been committed. Charges have been established for these materials, for purchase of materials produced in reactors using United States fuels, and for processing irradiated fuel elements.

Atoms-For-Peace reactor projects. As of December 31, six research reactors manufactured in the United States were in operation in other countries, of which four achieved criticality during the last 6 months. Nineteen other reactors, including an experimental power project, are under construction or on order. Several other power projects which have been under contract are being restudied. Additionally, there were a number of foreign reactor projects in the planning stage on which it was expected that United States firms would have an opportunity to submit bids. Manufacturers placed a value of $7.5 million on 16 reactors for which export licenses have been issued (8 during the last 6 months). The United States had committed a total of $2.450 million in grants of $350,000 each to seven nations for research reactor projects.

Management and technical exchanges. The Commission was a cosponsor or supported 10 international conferences in various areas of nuclear

science and technology during 1957, and it sent abroad its third and fourth Atoms-For-Peace missions, approved presentation of 6 additional technical libraries—increasing to 68 the total number given to foreign nations or international organizations. A total of 1,226 visitors from abroad toured atomic installations or industries during 1957, raising to 2,459 visitors from 72 countries the number that has come to this country on atomic business since 1955.

The Commission conducted symposia in specific areas of power reactor technology; explored means of financing projects abroad; formulated its licensing regulations and agreements with an objective of encouraging the use of commercial channels for trade in nuclear reactors, components, and equipment. The Commission and the Department of State are undertaking studies on the problem of third-part liability insurance for commercial nuclear power systems abroad.

Regional programs. More than 50 leading industrialists from the six Euratom countries visited Commission and industrial installations during this reporting period in connection with the program of their countries which are considering installations of 15 million electrical kilowatts of nuclear energy capacity. In other regional programs, the United States Government is lending assistance to the Organization for European Economic Cooperation, helping in connection with the Asian Nuclear Center, and is sponsoring establishment of an Inter-American Nuclear Energy Commission within the Organization of American States.

Education and training. Since limited trained manpower is recognized as a threat to progress in using atomic energy, the Commission in 1955 established a reactor science and engineering school; greatly enlarged the training of foreign nationals in radioisotope techniques; is working with the University of Puerto Rico to develop a Spanish-language training center; and is providing individual guidance to hundreds of foreign students seeking training in the United States. As of December, 273 students from 44 nations have been enrolled at the reactor training school or selected for it, and 228 students from 46 nations at the radioisotope school. The Commission has given guidance in response to approximately 375 requests from some 45 countries.

Disarmament. Assisting in the United States effort for control over world armaments, the Commission has provided technical counsel on nuclear armaments and controls.

International Atomic Energy Agency

The First IAEA Conference

On October 1, the International Atomic Energy Agency, proposed nearly 4 years previously by President Eisenhower, was formally inaugurated in Vienna, Austria.

President Eisenhower's message, delivered by Lewis L. Strauss, who headed the United States delegation to the First IAEA General Conference, summarized the overall purpose of the agency:

> You hold in your custody the conscience of the people of the world. They look hopefully to you to further the practical program whereby the fissioned atom will cease to be a symbol of fear and will be transformed into the means of providing them with richer, healthier and happier lives.

Speaking on behalf of the United States delegation, Mr. Strauss told the conference that the Commission is formulating a program of detailed assistance and cooperation with the agency.

"Based upon the usual consideration of congressional concurrence," he said, "we are considering offering to the Agency a research reactor, an isotopes laboratory, and a comprehensive technical library on the peaceful uses of atomic energy."

Mr. Strauss formally tendered to the IAEA organization the United States offer to make available 5,000 kilograms of uranium 235 to the agency and to match contributions from member states up to July 1960. In addition to the offers of 20 kilograms and 50 kilograms made to the IAEA by the United Kingdom and the Soviet Union, respectively, Portugal at the Vienna meeting offered to supply 100,000 kilograms of normal uranium oxide concentrate. The United States delegation announced that these offers would be matched.

The General Conference elected as Director General of the Agency, W. Sterling Cole of the United States, former Representative from New York, and former Chairman, Joint Committee on Atomic Energy. It chose Vienna as its permanent headquarters, and elected 10 nations to membership on the Board of Governors: Argentina, Egypt, Guatemala, Indonesia, Italy, Korea, Pakistan, Peru, Rumania, and Turkey.

The General Conference also approved the work program and its related budget which had been developed by the Preparatory Commission and approved by the IAEA Board of Governors. Funds were advanced by the Government of Austria to cover operating costs until regular receipts from member states had been deposited.

The Preparatory Commission, created by the Statute Conference in 1956 as an interim body, held its final meetings in Vienna in Septem-

ber and designated the other 13 nation members of the first board: Australia, Brazil, Canada, Czechoslovakia, France, India, Japan, Portugal, Sweden, Union of South Africa, Union of Soviet Socialist Republics, United Kingdom, and United States.

History of Agency's Formation

From the time of President Eisenhower's proposal late in 1953, the United States worked to make the agency a reality. After initial Soviet Union opposition, the proposal for developing such an agency won unanimous support by the United Nations General Assembly on December 4, 1954, almost a full year after the President's address.

In November 1954, the President named Morehead Patterson as a special ambassador to conduct early negotiations on a statute for the proposed agency. The first formal draft was prepared and agreed upon in July 1955 by an eight-nation group consisting of Australia, Belgium, Canada, France, Portugal, Union of South Africa, the United Kingdom, and the United States. The draft statute was distributed for comment to all nations that were members of the United Nations or of its specialized agencies.

After the 1955 session of the United Nations General Assembly, Brazil, Czechoslovakia, India, and the Soviet Union joined the original eight-nation group. During February following, the 12-nation group met in Washington to consider the comments of more than 40 nations on the draft statute, and on April 18, 1956, reached unanimous agreement on the statute.

New York City in September and October of 1956 was the scene of one of the largest conferences of nations in the history of international cooperation. Eighty-one nations met, and on October 26 approved unanimously a final draft statute for the agency. The statute was then opened for signature and subsequent ratification, and 80 nations signed. This conference also created the interim Preparatory Commission.

At the close of the 1956 conference on the statute, Chairman Strauss read a message from President Eisenhower in which he pledged to make available the special nuclear materials later formally offered to the IAEA.

In ratifying the statute on behalf of the United States on July 29, 1957, the President noted that—

> If we are to continue to live with the power we have released, new rules and patterns of international life are required. The known facts of atomic science remind us that the interests of the nations of this age are indivisible. Nations must unify their actions if this new found power and knowledge are to create, not to destroy.

The Senate approved ratification of the statute on June 18 and, with the House, authorized United States participation in the Participation Act of 1957 (Public Law 85–177, signed August 28).

The Participation Act includes an amendment to the Atomic Energy Act of 1954 which stipulates that the United States may make allocations of special nuclear materials to the IAEA or other groups of nations only within limits established by Congress and that generally this country shall be compensated for all such materials. However, to assist and encourage research on peaceful uses or for medical therapy, the Commission may distribute without compensation such quantities of special nuclear materials as do not exceed $10,000 in value for a single nation or $50,000 for a group of nations. The Participation Act further authorizes the Commission to distribute to the IAEA 5,000 kilograms of contained uranium 235 and to match in amount the quantities of special nuclear materials made available by all other IAEA members to July 1, 1960.

In the event that an amendment to the Agency statute is adopted to which the United States Senate, by formal vote, refuses its advice and consent, the authority of United States to participate in the IAEA would be terminated. The President must make reports at least once a year to Congress on IAEA activities and United States participation therein. The Department of State and the Commission are required to keep the Joint Committee on Atomic Energy, House Committee on Foreign Affairs, and Senate Committee on Foreign Relations currently informed regarding Agency activities and United States participation.

To assist in making qualified United States nationals available for IAEA employment, the act allows Federal employees under certain conditions to accept up to 3-year tours of duty with the IAEA without losing their Federal job, retirement, and insurance rights.

Functions and Organization of Agency

The *purposes* of the International Atomic Energy Agency under its statute are, first, to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world, and, second, to insure that the assistance it provides is not used to further any military purposes.

Its *functions* are: (*a*) to encourage and assist research, development, and the practical application of atomic energy; (*b*) to make provision for materials (including nuclear materials), services, equipment, and facilities required for atomic energy programs; (*c*) to foster the exchange of scientific and technical information; (*d*) to encourage the exchange and training of scientists; (*e*) to establish and administer

safeguards designed to insure that special fissionable materials and other assistance are not used to further any military purposes; and (*f*) to establish or adopt standards of safety for the protection of health and minimization of danger to life and property.

To help accomplish its objectives, the Agency will establish international standards of inspection and control over civilian development of atomic energy designed to prevent diversion to military purposes of nuclear materials as come under its administration.

The three principal components of the Agency's *organization* are the General Conference, the Board of Governors, and the Director General. The Conference, composed of all nation members, each with one vote, meets annually to approve Agency budgets and applications for membership, and to consider any proposals to amend the statute. It elects 10 members of the Board of Governors. The Conference may make recommendations to the Board on any matter within the competence of the agency.

Since the countries most advanced in nuclear energy activities have great responsibilities in carrying out IAEA functions, they will have continuing representation on the Board of Governors. Provision also is made for representation by geographical areas.

The Director General is charged with the execution of approved Agency programs, and is provided with a permanent staff to be recruited on the basis of scientific and technical qualifications. He is responsible directly to the Board of Governors, but he and his staff are independent of control by any national government.

Initial Agency program. The Agency's initial program emphasizes the need for technical training; the immediately applicable potential of radioisotopes in industry, medicine, and research; and the need for technical information. It will provide guidance and technical consultant advice to countries interested in establishing atomic energy programs or expanding their present activities. Advice will be available in the areas described and also in the more substantive fields of reactor design, siting problems, health and safety techniques and standards, waste disposal and other subjects related to research and power reactors.

Agreements for Cooperation

Progress in 1957

Five new agreements for cooperation between the United States and other nations in developing and advancing peaceful uses of atomic energy went into force during the last 6 months, raising to 9 the new agreements that became effective during 1957, and to 39 the total in

effect with 37 different nations and with Germany on behalf of the city of West Berlin.

The five new agreements were with the Federal Republic of Germany, the Netherlands, and South Africa covering research and power reactors, and with Cuba and with Germany for the city of West Berlin, covering research reactors. Earlier in 1957, three agreements on research and power reactors with Australia, Norway, and Switzerland, and one with Guatemala covering research only, went into effect.

Eight other agreements were signed and are in the process of ratification. Power agreements were negotiated this year with Brazil, Italy, Peru, and Spain. Research agreements were negotiated with Ecuador, Iran, Iraq, and Nicaragua.

Four agreements were amended. The power agreement with France, negotiated during 1956, was amended this year to increase from 40 to 2,500 kilograms the quantity of contained uranium 235 which may be transferred. Amendments to the comprehensive agreement with the Netherlands and to the research agreements with Portugal and Thailand also were concluded during 1957.

At the end of the year, negotiations were in progress with Argentina, Cuba, Japan, Sweden, and Venezuela for comprehensive agreements, and with Sweden for an amendment to its research agreement to authorize transfer of 90 percent enriched fuel for a high flux research reactor.

The Commission has in progress the formulation of a program to carry out the provisions for safeguard and control of special nuclear materials under its agreements for cooperation. In addition to assuring that no special nuclear materials transferred out of the United States are used for other than peaceful purposes, the program will accumulate technical and administrative experience that will be useful to the International Atomic Energy Agency's future operations.

Commission technical representatives have held consultations with representatives of governments and with contractors concerned in the startup during 1957 of research reactors at the Amsterdam Fair, the Netherlands; Japan's first facility at the Japanese Atomic Research Institute's new nuclear center at Tokai-Mura; Denmark's two reactors at Risoe; and the Munich and Frankfurt research facilities in the Federal Republic of Germany. Similar visits will be made to other reactor sites as other projects involving fuel supplied by the United States go into operation.

Table I, Agreements for Cooperation, in Effect and Pending, lists alphabetically the nations with which the United States has agreements, or with which agreements are pending, gives the type of each accord, and the amount of uranium 235 authorized by each.

Government-to-government cooperation in the Atoms-For-Peace

program is accomplished largely through these agreements for cooperation. Section 54 of the Atomic Energy Act of 1954 authorized the Commission to distribute special nuclear material abroad under the terms of such agreements. Section 123 of the 1954 Act requires that the scope of cooperation be set forth, provides what guaranties the agreements must contain, and specifies procedures for approval of agreements.

Before an agreement can go into effect, the President determines in

TABLE I.—AGREEMENTS FOR COOPERATION, IN EFFECT AND PENDING

COUNTRY	SCOPE OF EXCHANGE	EFFECTIVE DATE	FUEL ARTICLE PROVISION (U 235)
Argentina	Research	July 29, 1955	6
Australia	Research and power	May 28, 1957	500
Austria	Research	July 13, 1956	6
Belgium	Research and power	July 21, 1955	[a]
Brazil	Research	Aug. 3, 1955	6
Brazil	Research and power		[b] 550
Canada	do	July 21, 1955	[a]
Chile	Research	Aug. 8, 1955	6
China, Republic of	do	July 18, 1955	6
Colombia	do	July 19, 1955	6
Costa Rica	do		[b] 6
Cuba	do	Oct. 10, 1957	6
Denmark	do	July 25, 1955	[c] 12
Dominican Republic	do	Dec. 21, 1956	6
Ecuador	do		[b] 6
France	Research and power	Nov. 20, 1956	[c] 2,500
Germany, Federal Republic of	do	Aug. 7, 1957	2,500
Germany: City of West Berlin	Research	Aug. 1, 1957	6
Greece	do	Aug. 4, 1955	6
Guatemala	do	Apr. 22, 1957	6
Iran	do		[b] 6
Iraq	do		[b] 6
Ireland	do		[b] 6
Israel	do	July 12, 1955	6
Italy	do	July 28, 1955	6
Italy	Research and power		[b] 7,000
Japan	Research	Dec. 27, 1955	6
Korea, Republic of	do	Feb. 3, 1956	6
Lebanon	do	July 18, 1955	6
Netherlands	Research and power	Aug. 8, 1957	500
New Zealand	Research	Aug. 29, 1956	6
Nicaragua	do		[b] 6
Norway	Research and power	June 10, 1957	500
Pakistan	Research	Aug. 11, 1955	6
Peru	do	Jan. 25, 1956	6
Peru	Research and power		[b] 800
Philippines	Research	July 27, 1955	6
Portugal	do	July 21, 1955	6
South Africa	Research and power	Aug. 22, 1957	500
Spain	Research	July 19, 1955	6
Spain	Research and power		[b] 500
Sweden	Research	Jan. 18, 1956	[c] 12
Switzerland	do	July 18, 1955	6
Switzerland	Research and power	Jan. 29, 1957	500
Thailand	Research	Mar. 13, 1956	6
Turkey	do	June 10, 1955	6
United Kingdom	Research and power	July 21, 1955	[a]
Uruguay	Research	Jan. 13, 1956	6
Venezuela	do	July 21, 1955	6
			[d]

[a] The specific amounts of fuel to be made available are not stated in the Belgian, Canadian, or United Kingdom accords.
[b] Agreements signed and in process of ratification.
[c] Fuel commitment as amended. (French amendment effective Aug. 19, 1957.)
[d] Adding the additional amounts of uranium 235 necessary for pipeline and inventory purposes, and the 5,000 kilograms pledged to IAEA, the total considered as obligated is approximately 35,000 kilograms.

each case that the activities to be authorized will not constitute an unreasonable risk to the common defense and security of the United States. The agreement then must lie for 30 days before the Joint Committee on Atomic Energy while the Congress is in session. Similar procedures apply to amending agreements.

The first atomic energy agreement under the act was a research accord concluded with Turkey on May 3, 1955, and it also was the first agreement to go into force, the effective date being June 10, 1955. The first agreements providing for the exchange of classified information on civil uses of nuclear energy under specified conditions were those signed with Belgium, Canada, and the United Kingdom, all of which went into effect on July 21, 1955.

Pattern of Agreements

All agreements for cooperation in development of atomic energy provide for exchange of information. Most of them authorize transfer of specific amounts of special nuclear material for reactor fuel and for research purposes. In general, agreements limit to 20 percent the degree of uranium 235 enrichment of special nuclear materials transferred for reactor fuel. They permit the transfer of other materials, not available commercially, that are useful in atomic energy technology.

The United States has the right to obtain maintenance, production, and operating records and other data necessary to accomplish accountability for special nuclear materials, and to afford access to all places and data necessary to verify compliance with the terms of the agreements. The United States may also under the agreement approve the facilities to be used for chemical reprocessing.

Agreements negotiated to date remain in force for periods ranging from 5 to 20 years. Those which authorize lease of special nuclear materials contain stipulations that the cooperating government will hold the United States Government harmless against all liability (including public liability) arising from use of the special nuclear material made available by the Commission. Some earlier agreements do not contain this provision, but lease contracts negotiated under them do include it.

The *research agreement* generally permits lease to the cooperating government of reactor fuel for agreed-upon reactor projects, providing that no more than 6 kilograms (13.2 pounds) of uranium 235, in enrichments up to 20 percent, plus amounts necessary to support the reactor while in operation, is in the country at any one time. In some cases more than 6 kilograms is specifically provided. Agreements with Denmark and Sweden, for example, were amended to

increase the amount of 12 kilograms to meet demonstrated research needs in those countries.

Research agreements provide for exchange of unclassified information on general research and on design, construction and operation of research reactors, and on health and safety problems involved, and contain language anticipating later comprehensive agreements including power reactors. The agreements also contain provisions concerning the safeguarding of the materials or reactor transferred.

Gram quantities of uranium 233, uranium 235 enriched above the 20-percent limit, and plutonium may be transferred for research purposes.

Comprehensive *power reactor agreements* provide for transfer of larger amounts of contained uranium 235 for use in power reactors. Each cooperating country estimates its fuel requirements independently on the basis of reasonably foreseeable projects. These requirements are reviewed and approved by the Commission. Actual transfer of fuel is subject to a separate agreement between the Commission and the cooperating government.

Where the cooperating country plans to build a materials testing reactor, fuel enriched up to 90 percent of uranium 235 by weight may be made available up to 6 kilograms of contained uranium 235. In one case, that of the Belgian power agreement, an amendment permits transfer of 8 kilograms of 90-percent enriched fuel.

In addition to the safeguards provisions common to all agreements, the power agreements specially provide: for United States review of the design of reactors and pertinent associated facilities; storage of byproduct materials in Commission-designated facilities; and a first option to the United States to purchase all special nuclear materials that such reactors generate in excess of the civilian needs of the cooperating nation.

These safeguard provisions conform closely to similar provisions of the statute of the International Atomic Energy Agency.

Power agreements authorize a broad exchange of technical information including power reactor technology; six agreements provide for exchange of classified information—those with Australia, Belgium, Canada, the Netherlands, Switzerland, and the United Kingdom. Power reactor agreements negotiated since the major Commission declassification action of 1956 provide for exchange on an unclassified basis.

As atomic energy programs have developed in cooperating countries, comprehensive agreements frequently have been negotiated, incorporating and superseding earlier research agreements.

Materials Commitments and Shipments

During 1957, the Commission made 50 shipments abroad to 16 countries of special nuclear materials or of heavy water under the Atoms-For-Peace program. Of these shipments, 23 were made during the last 6 months to 8 nations. The special nuclear materials shipped were part of the 50,000 kilograms of contained uranium 235 which the President has designated as available to cooperating countries. Heavy-water sales are individually approved in the Commission.

Twelve of these purchases were for a total of 160 tons of heavy water by Australia, Belgium, Canada, France, Norway, Sweden, Switzerland, and the United Kingdom. The previous year, 21 tons were shipped to India.

Fuel for nine research reactors containing a total of approximately 38 kilograms of uranium 235 was shipped to Argentina, Brazil, Canada, Denmark, the Federal Republic of Germany, Japan, the Netherlands, Norway, and the United Kingdom.

Materials for research, usually in quantities of less than 10 grams of uranium 235, were supplied to Belgium, Canada, Denmark, France, Japan, Malaya, and the Netherlands.

Commitments through 1957 total approximately 35,000 kilograms of contained uranium 235, including the quantities offered to the IAEA.

Table II, Materials Shipments to Foreign Countries, shows the distribution of special nuclear materials and heavy water since delivery of the first reactor fuel to Switzerland for its "Geneva" reactor in August 1955 through December 1957.

Designations for Reactor Fuel

The quantity of special nuclear material to be used for peaceful and military purposes is determined by the President at least once a year, on recommendations of the Commission, pursuant to section 41 of the Atomic Energy Act of 1954.

After initial designations totaling 200 kilograms in 1954 and 1955,[36] the President and the Commission announced on February 22, 1956, the first major allocation for peaceful purposes, of which 20,000 kilograms of contained uranium 235 was for the international Atoms-For-Peace program, and 20,000 for the domestic civilian reactor program.[37]

[36] See p. 12, Eighteenth Semiannual Report to Congress (January–June 1955).
[37] See pp. viii–ix, Twentieth Semiannual Report to Congress (January–June 1956).

TABLE II.—MATERIALS SHIPMENTS TO FOREIGN COUNTRIES

DATE SHIPPED	COUNTRY	URANIUM		OTHER MATERIALS	TYPE OF TRANSACTION	PURPOSE AND REMARKS
		Kg U-235	Percent U-235			
1955						
Aug. 2	Switzerland	5.87	20		Lease	For Geneva demonstration reactor.
Aug. 9	Canada			Heavy water, 20 tons.	Sale	NRX reactor, Chalk River.
Oct. 6	Canada	11.22	90		Lease	NRX reactor fuel.
Dec. 15	Canada	2.21	7		Sale	Research.
Dec. 20	U. K.			Heavy water, 11 tons.	Sale	For civilian power program.
1956						
Mar. 14	France			Heavy water, 5.5 tons.	Sale	EL-series reactors at Saclay.
Mar. 15	Canada			Heavy water 400 pounds.	Sale	NRU reactor.
Early	Canada			Heavy water, 10 tons.	Sale	NRX reactor.
Mar. 28	India			Heavy water, 5 tons.	Sale	Research, Trombay reactor.
Mar. 29	Belgium			Heavy water, 5 pounds.	Sale	For research.
Apr. 27	India			Heavy water, 6 tons.	Sale	Research, Trombay reactor.
May 25	U. K.			Heavy water, 22 tons.	Sale	Civilian power program.
June 1	India			Heavy water, 5 tons.	Sale	Research, Trombay reactor.
June 6	India			Heavy water, 5 tons.	Sale	Research, Trombay reactor.
June 14	U. K.	.05	85		Gift	Research: highly enriched in fission wastes.
Aug. 5	U. K.			Heavy water, 11 tons.	Sale	Civilian power program.
Oct. 5	France			Heavy water, 11 tons.	Sale	EL-series reactors at Saclay.
Oct.	Canada	1.15	90		Sale	Research.
Dec.	Canada	1.15	90		Sale	Research.
Dec.	Canada	.85	10		Sale	Research.
1957						
Jan. 23	Canada			Heavy water, 50 tons.	Sale	NRU reactor.
Feb. 10	Malaya	(a)	Normal		Gift	For research at University of Malaya.
Feb 18 and Apr. 19.	Netherlands	4.69	20		Lease	Amsterdam Fair reactor fuel.
Mar. 26	Belgium			Heavy water, 500 pounds.	Sale	Research.
Mar. 27	Canada	3.3	20		Sale	Fuel element research.
Apr. 9	Netherlands	(a)	24		Lease	Fission counters for Amsterdam Fair reactor.
Apr. 13	U. K.	(a)	.4 [b]		Exchange	Depleted uranium for U. K. niobium.
May 1	France	(a)	.4 [b]		Gift	Highly depleted uranium for research.
May 7	Canada	(a)	90		Gift	Research quantity.
May 24	Japan	1.98	20		Lease	Tokai-Mura water boiler research reactor fuel.
May 24	Japan	(a)	20		Lease	Fission counters.
May 29	U. K.			1 mg. Pu	Gift	Research discharge tube for spectrographic research.
May 31	Denmark	1.4	20		Lease	Danish water boiler research reactor fuel.
May 31	Denmark	(a)	20		Sale	Fission counters.
June 3	France			Heavy water, 5.5 tons.	Sale	EL-series reactors at Saclay.
June 7	Belgium	.085	(b)	6.6 gm. Pu	Sale	Contained in 12 irradiated slugs for chemical research.
June 14	Belgium	.45	90		Sale	Research uses by CEAN.

See footnotes at end of table.

TABLE II.—MATERIALS SHIPMENTS TO FOREIGN COUNTRIES—Con.

DATE SHIPPED	COUNTRY	URANIUM		OTHER MATERIALS	TYPE OF TRANSACTION	PURPOSE AND REMARKS
		Kg U-235	Percent U-235			
June 25	Canada	5.72	90		Lease	PTR Chalk River research reactor fuel (total 6.357 kg. U 235).
June 25	Canada	.008	90		Lease	PTR Chalk River research reactor fuel (total 6.357 kg. U 235).
July 15	Denmark	.001	90		Sale	For use in exploration in Greenland.
July 16	Denmark	.003	90		Sale	Contained in 2 fission counters for use in reactor.
July 17	Norway			Heavy water, 17.6 tons.	Sale	Halden reactor.
July 23	Germany	1.8	20		Lease	For Frankfurt water boiler and fission tub
July 29	Canada	.63	90		Lease	PTR Chalk River research reactor fuel (total 6.357 kg. U 235).
Aug. 2	Brazil	5.86	20		Lease	Fuel elements in Sao Paulo reactor.
Aug. 3	U. K		101	101 gm. Pu	Exchange	Metallurgical research.
Aug. 3	U. K	(a)	.4		Exchange	High purity U Trade for U. K. niobium.
Aug. 9	Sweden			Heavy water, 28.5 tons.	Sale	R-3 space heat reactor, Stockholm.
Aug. 16	Canada			Heavy water, 5 tons.	Sale	NRU reactor.
Aug. 19	Australia			Heavy water, 11 tons.	Sale	Research.
Aug. 23	Canada			Heavy water, 3.5 tons.	Sale	University of Toronto research reactor (subcritical assembly).
Aug. 28	France	(a)	0	Highly depleted labratory material.	Gift	For fission counter research.
Aug. 29	Germany	5.93	20		Lease	Fuel elements in Munich research reactor.
Sept. 6	France	(a)	.4 [b]		Sale	2 kg. for research use.
Sept. 9	Belgium	(a)	0	Uranium Oxide U 308.	Sale	Research.
Sept. 9	Belgium	(a)	90		Gift	Plated on Belgium gold foils for World Fair demonstration.
Sept. 20	Canada	(a)	0	2 gm. Pu	Exchange	Exchange for Canadian Pu.
Sept. 26	Belgium	(a)	90		Sale	Uranyl sulfate crystals for gas loop experiment in Br.-1.
Sept. 26	Belgium	(a)	.4		Sale	1 kg. metal for research.
Sept. 27	France			10 gm. Pu	Sale	For metallurgical research.
Oct. 9	France			Heavy water, 5.5 tons.	Sale	EL-series reactors at Saclay.
Oct. 18	Canada			Heavy water, 5 tons.	Sale	NRU reactor.
Nov. 1	Switzerland			Heavy water, 9 tons.	Sale	"Reactor, Ltd." research reactor at Wuerenlingen.
Nov. 8	Netherlands	(a)	0	2 mg. Pu	Loan	Spectographic research.
Nov. 15	U. K	(a)	0	Depleted U metal 0.01.	Loan	Single crystal research.
Nov. 13	U. K	(a)	0	250 gr. depleted U metal.	Loan	Single crystal research.
Nov. 15	U. K	(a)	90 mg		Gift	Glass wool research.
Nov. 22	U. K			Heavy water, 11 tons.	Sale	Civilian power program.
Dec. 5	Spain	4.04	20		Lease	Research reactor Espanola.
Dec. 10	Argentina	6.00	20		Lease	Argentina Argonaut.

[a] Amount less than 10 grams contained U 235.
[b] Depleted uranium, containing less than 0.71 percent of U 235.

On July 3, 1957, the President announced that an additional 59,800 kilograms of uranium 235 would be made available, raising to 100,000 kilograms the total amount for peaceful purposes, half in this country and half for the Atoms-For-Peace program.[38]

The Commission expects that additional designations of special nuclear material may be recommended from time to time to sustain existing nuclear research and power projects, and to broaden the total effort.

Material drawn from the amounts designated by the President is distributed to a cooperating country over the period covered by the agreement only when required in specific projects approved by the Commission.

Terms and Charges

In the Atoms-For-Peace program, as in domestic policy, the Commission furnishes materials, equipment, or services only until these are available commercially, meanwhile offering them at full cost including overhead. Uranium 235 is leased under research agreements and sold under power agreements.

The Commission makes enriched uranium available in the form of uranium hexafluoride (UF_6), the process material of its gaseous diffusion plants. Cost of converting the UF_6 to metal or to other uranium compounds is borne by the buyer. Charges for enriched uranium hexafluoride furnished under agreements for cooperation were published in November 1956.[39] They vary according to the degree of enrichment of the material, the 20-percent grade costing approximately $16 a gram of contained uranium 235. A 4-percent-a-year use charge is made for leased uranium 235, based on the value of the uranium as determined from the November schedule.

In exercising its option to purchase special nuclear material generated in reactors abroad using fuel supplied by the United States, the Commission announced in November 1956 that, subject to the future availability of funds, plutonium metal produced from materials supplied by the United States would be purchased at $12 a gram and uranium 233 nitrate at $15 a gram of uranium 233, prices based on their use as fuel.[40] Prices paid for material delivered in forms other than those specified would be lower by the cost of conversion. Material thus acquired under the Atoms-For-Peace program will be used only for peaceful purposes.

[38] See pp. xvii-xviii, Twenty-second Semiannual Report to Congress (January-June 1957).
[39] See p. 339, Twenty-first Semiannual Report to Congress (July-December 1956).
[40] See p. xxii, op. cit.

The announcement on March 7, 1957,[41] of the terms and conditions under which the Commission will provide chemical reprocessing services under individually negotiated contracts, until commercial services become available, removed a major unknown factor from operating cost equations of potential builders abroad of nuclear powerplants.

Heavy Water Sales

Heavy water was offered for sale by the Commission in quantities needed for use in reactors on August 8, 1955, the price being $28 a pound, f. o. b. Savannah River. There is no general limitation on quantities that may be sold, and an agreement for cooperation is not a prerequisite, but sales are arranged in accordance with individual sales agreements. The Commission markets heavy water in units of 500 pounds (a 55-gallon drum), with a purity of 99.75 mole percent of heavy water (D_2O).

Smaller amounts for research purposes are sold commercially and these require export licenses.

Atoms-For-Peace Reactor Projects

Besides the 7 research reactors purchased in the United States under Atoms-For-Peace agreements in operation in other countries during 1957, 5 more reactors were scheduled to go critical early in 1958.

A power reactor was under construction for Belgium, and United States firms were participating in design studies or experimental work on five powerplants projected in three more nations.

Heavy water purchased from the United States was being used in two reactors abroad, and uranium oxide had been leased by another nation which will make its own fuel elements.

As of December 31, the Commission had issued 16 export licenses for research reactors valued at $7.5 million. No applications had been made up to that date to export power reactors.

United States firms participating in the design and construction of these reactors include ACF Industries, Inc., Aerojet General Corp., AMF Atomics Inc., Atomics International, The Babcock & Wilcox Co., Foster Wheeler Corp., General Electric Co., The Martin Co., Nuclear Development Corp. of America, Vitro Engineering Co., and Westinghouse Electric Corp.

United States companies offer consulting services for selection of reactor design or manufacturer, or for design of associated facilities

[41] See pp. 42-43, Twenty-second Semiannual Report to Congress (January-June 1957).

such as feed material or fuel fabrication plants. Domestic firms also have authorized their subsidiaries abroad or foreign companies to manufacture components or complete reactors according to their designs. Several companies have arrangements with foreign firms to market reactors in other countries.

Nation-by-Nation Summary

Following are examples of reactor projects abroad involving participation by the Commission and United States firms.

Argentina. The Argentine Atomic Energy Commission is constructing an Argonaut-type research reactor at Buenos Aires which is expected to go critical early in 1958. Uranium oxide leased from the United States was shipped in December. Argentina will be the first nation in South America to fabricate its own fuel elements, and the reactor is being built by Argentine firms.

Belgium. The Belgian Government has contracted for an 11,500-electric-kilowatt, pressurized water, power reactor. The reactor was planned for exhibition at the Brussels Fair in 1958, but it has been decided to build it instead at Mol, the research establishment of the Centre d'Etudes pour les Applications de l'Energie Nucleaire (CEAN), the Belgian Government research organization.

CEAN will also have at Mol a high-flux, materials testing reactor for which the Belgian Government is requesting financial assistance from the Commission. The Mol Laboratory is planning to install a medical reactor to be used especially for research in the field of radiobiology.

These reactors are expected to be in operation by the end of 1959.

Brazil. The first reactor constructed in South America under the Atoms-For-Peace program is the 5-thermal-megawatt pool reactor of the University of Sao Paulo in Brazil. Fuel for the reactor was leased from the United States and the project has been approved for a $350,000 grant from the United States. Criticality was attained on September 16, 1957.

Denmark. Facilities at the research and development center of the Danish atomic energy organization, Risoe Laboratory, 30 miles west of Copenhagen, include a 5-thermal-megawatt tank reactor which was scheduled to begin operation in December. The United States approved a contribution of $350,000 toward the cost of the reactor project.

The Risoe Laboratory has had in operation since August a 500-watt, water-boiler research reactor.

France. France bought from the Commission the heavy water used as a moderator-coolant in its 15-thermal-megawatt EL–3 test reactor which went into operation in July at Saclay, the largest research laboratory of the French Atomic Energy Authority.

Federal Republic of Germany. West Germany has bought four United States research reactors, more than any other country. The pool reactor at the Technische Hochscule Muenchen, Munich, went critical October 31, 1957. By early 1958, a homogeneous reactor built for Farbwerke Hoechst, A. G., at Frankfurt and a pool reactor for the Society for the Utilization of Nuclear Energy in Shipbuilding & Navigation, Inc., at Hamburg, were scheduled to be in operation.

Under the authorization of a special agreement with the Republic for the West Berlin Senat, a homogeneous reactor is under construction at the Institute for Nuclear Research in West Berlin.

Several German companies have under active study designs for projected large-scale, nuclear power projects.

Greece. A nuclear research center is being established near Athens and the Greek Atomic Energy Commission has ordered a United States-built pool reactor scheduled for completion sometime in 1958.

India. In February 1955, the first sale of heavy water approved under the Atoms-For-Peace program was to India. The 21 tons shipped in 1956 is being used as moderator in a research reactor at Trombay, New Bombay, which began operation in the spring of 1957. Its fuel elements were made in Canada.

Italy. Several Italian utilities are planning nuclear power projects. Edisonvolta Co. of Milan has announced that it will build a 134,000-electric-kilowatt, pressurized water reactor similar to the Yankee Atomic Electric Co. project in this country. Another Italian group, Societa Italiana Meridionale Energia Atomica (SIMEA), is planning a pressurized water reactor of 125,000- to 150,000-electric-kilowatt capacity to be located near Rome. Both evolved from the Commission's Pressurized Water Reactor (PWR) at Shippingport, Pa.

In southern Italy, the nuclear energy subsidiary of Finelettrica, Societa Electro-nucleare Nazionale (SENN) is planning to construct a large-scale nuclear powerplant. The International Bank for Reconstruction and Development, under an agreement with the Italian Government, is making its first nuclear power project study in connection with

the SENN project. British, Canadian, French, and United States experts are serving as consultants.

In northern Italy, at Ispra, the National Committee for Nuclear Research is expected to have in operation in 1958 a heavy-water-moderated research reactor. The Societa Ricerche Impianti Nucleari and the Enrico Fermi Nuclear Study Center of Politechnico, both located in Milan, have contracted for research reactors.

Japan. Japan's first nuclear research reactor began operation in August 1957. The uranium 235 fuel for the 50-thermal-kilowatt water-boiler reactor was leased from the Commission by the Japanese Atomic Energy Research Institute, acting for the Japanese Government. The reactor, the first in the Far East to use fuels leased from the United States, is located at the JAERI Research Center, Tokai-Mura, 75 miles northeast of Tokyo. For a second CP–5 type of research reactor, presently under construction at the same location, the United States has approved a $350,000 grant.

The Netherlands. A pool reactor went into operation in June 1957 at the Amsterdam International Atomic Exhibition where it was run at 10-thermal-kilowatts level of power. When moved to its permanent location at the University of Delft, it will operate at 100 thermal kilowatts.

The Netherlands Government has ordered a 20-thermal-megawatt, high-flux pool research reactor to be located at Petten near The Hague. The United States has approved a $350,000 grant toward the cost of this project.

Portugal. The Portuguese Nuclear Energy Board is purchasing a 1-thermal-megawatt pool research reactor and the United States will contribute $350,000 toward the cost of this project. It will be located near Lisbon and is due to be completed in 1959.

Spain. The first nuclear project in Spain will be a 3-thermal-megawatt pool research reactor now under construction for the Spanish Atomic Energy Commission near Madrid and to which the United States will contribute $350,000.

Sweden. The Aktiebolaget Atomenergi is planning a tank reactor to be located at Studsvik and a United States export license for this facility is pending. Sweden also is interested in negotiating a power agreement.

Switzerland. The first United States reactor operated abroad was the exhibition pool research facility designed and constructed by the Oak

Ridge National Laboratory for the United States technical exhibit at the United Nations Conference on the Peaceful Uses of Atomic Energy held in Geneva, August 1955.

After the conference, the reactor was turned over to Switzerland to which it had been sold and its fuel was transferred by a lease contract. Subsequently, Reactor, Ltd., a Government-sponsored organization of some 140 private companies in Switzerland, established a nuclear research center at Wuerenlingen, near Zurich. On that site, the company has rebuilt the Geneva reactor and it went into operation in May 1957.

Venezuela. Near Caracas, the Institute for Neurology and Brain Research is constructing a 3- to 5-thermal-megawatt pool reactor in a project that will receive a $350,000 grant from the United States. It is scheduled to begin operation in early 1958.

Financial Assistance on Reactors

Research grants. In 1957, the Commission added 3 approved grants of $350,000 each for research reactor projects to the 4 approved in 1956, all listed in the Nation-by-Nation report.

These grants are the result of the offer made June 11, 1955, by President Eisenhower that the United States would contribute to the cost of research reactor projects undertaken by "free nations who can use them effectively for the acquisition of the skills and understanding essential to peaceful atomic progress." [42]

The grant to each nation can be made only under an agreement for cooperation, and is limited to $350,000 or half the cost of the research project, whichever is less. The grants, made from mutual security funds, may be applied to the cost of the reactor plus the ancillary equipment and supporting facilities necessary to make it an effective research and training device.

Before a grant is made, the Commission reviews a proposal to determine whether or not the project qualifies and conforms to the agreement for cooperation. Approval of a project for assistance does not imply Commission endorsement of the reactor design. The grants are payable upon completion of the project.

Power and research loans. In October 1956, the Commission and the Export-Import Bank agreed on joint action under which the bank would consider extending credit for the construction of nuclear power-

[42] See pp. 12–13, Eighteenth Semiannual Report to Congress (January–June 1955) and pp. 14–15, Twentieth Semiannual Report to Congress (January–June 1956).

plants, as well as for research reactors, in nations which enter into agreements for cooperation with the United States.[43]

The bank will consider loans to both governments and industries. The Commission will provide technical assistance in connection with the bank's study of loan applications. To qualify for bank assistance, a cooperating country must submit a comprehensive engineering survey, have an arrangement for securing atomic fuels for the term of the loan, and demonstrate the economic and financial soundness of the project, the availability of funds to defray local costs, and the ability to service the dollar debt.

As with all Export-Import Bank loans, the funds for nuclear projects may be spent only for equipment, materials, and technical services purchased in the United States.

In November 1957, the Export-Import Bank further agreed to consider applications for loans necessary to finance nuclear fuel inventories purchased from the United States and required for the operation of foreign nuclear powerplants. Such action will be of considerable assistance in furthering the President's Atoms-For-Peace program and in helping United States manufacturers in their efforts to sell powerplants abroad.

Management and Technical Exchanges

Exchange of information on management and technical aspects of atomic energy research and development continued at an accelerated pace during 1957. Areas on which information may be exchanged without use of classified documents and arrangements for distribution of documents have expanded steadily, as is reported in chapter IV.

Beginning with the 1955 United Nations International Conference on the Peaceful Uses of Atomic Energy, the United States has taken part in 10 conferences on various aspects of atomic energy during 1957. It is preparing to participate in the United Nations' second conference scheduled for September 1958 in Geneva. Classified conferences have been held with representatives of those countries which have close ties with the United States.

These activities are reported on here as are the Atoms-For-Peace missions, the presentations of technical libraries, and the visits of foreign representatives.

Management Assistance

Atoms-For-Peace missions have proved effective in assisting various countries in their surveys of needs for developing peaceful uses of

[43] See p. 15, Twenty-first Semiannual Report to Congress (July December 1956).

atomic energy. These missions assist distribution of technical information on the use of radioisotopes and radiation in research, and help appraise local needs for training and education.

A first Atoms-For-Peace mission visited South America in June 1956, a second in December of that year. In May 1957, a mission visited Japan, the Republic of China, and the Philippines. The fourth mission held discussions with American Republics in Central America in November 1957.

Besides these formal missions, scores of United States experts have visited many nations at their request to advise on specific problems encountered in developing programs for civilian nuclear energy development as well as in various technical matters.

The Commission also arranges conferences, symposia, and personal consultation between Commission personnel and representatives of cooperating countries to assist in establishing atomic energy administrations and in beginning technical programs. Management and administration was a principal topic on the agenda of the Inter-American Symposium on Peaceful Uses of Atomic Energy which the Commission arranged at Brookhaven National Laboratory in May 1957.

The Commission further gives assistance in reactor hazard evaluation under agreements for cooperation. The Commission does not certify or approve reactor safety abroad, but will provide detailed information on the methods it employs in evaluation of reactors designed, constructed, and operated in the United States.

Technical assistance. In 1956, the Commission announced a program for continuing and expanding cooperation with other countries on uranium exploration. As part of the program, a group of geologists and engineers from 18 countries examined uranium deposits and inspected exploration and laboratory projects during 1956, and they were followed by other groups during 1957.

Formal requests have been received from Greece, India, Japan, Pakistan, Turkey, and Thailand for training of geologists and technicians in the United States. Personnel from Argentina, Japan, and Norway are currently being trained here.

The Commission assigned technical personnel to uranium resource investigation programs in Australia, Brazil, and Peru. Cooperative programs are being planned with Chile and Colombia. Requests have been received from other countries for assistance in establishing exploration programs.

International Conferences

The Commission continued to take advantage of international conferences and exhibitions to advance its Atoms-For-Peace programs, to distribute information on peaceful uses of nuclear energy, and to discuss and acquire information from other nations. The Commission sponsored a symposium for scientists of the American Republics, arranged United States participation in the 1955 United Nations conference, and is preparing for the parallel 1958 United Nations conference. The Commission gave technical advice on preparing exhibits for international fairs at Paris and Amsterdam, and for the 1958 World's Fair in Brussels. In addition, the Commission and contractor personnel participated in a number of international conferences and colloquia on aspects of atomic energy development.

To forward exchanges of this type, the Commission announced on January 16 of this year a program for financial support of selected international unclassified conferences.

Inter-American Symposium. The Inter-American Symposium, conducted by the Brookhaven National Laboratory May 13–17 of this year, covered all phases of the broad field of atomic energy and applied these to the specific needs of the American nations. The symposium (*a*) clarified the present and future uses of atomic energy for the American Republics; (*b*) called attention to the practical efforts necessary to support and accelerate the development of atomic energy; and (*c*) stimulated increased efforts in the development of atomic energy.

The symposium offered the first large-scale opportunity for the scientists, engineers, and atomic energy officials of the Americas to exchange information and ideas on a common ground. It was jointly sponsored by the Atomic Energy Commission, the Department of State, and the International Cooperation Administration. One hundred and one leading Latin American scientists, engineers, and government officials attended. A summary was presented to the Congress in the Twenty-second Semiannual Report (January–June), pages 23–25.

One direct result of the symposium was the establishment of an Atomic Energy Commission of Costa Rica.

United Nations conferences. The first International Conference on the Peaceful Uses of Atomic Energy, held by the United Nations in Geneva, Switzerland, August 8–20, 1955, opened doors of scientific communication which had been closed since 1939. A total of 1,428 delegates from 73 nations and the 8 specialized agencies of the United Nations attended, and scientists from all over the world were able to

meet and exchange ideas as well as to present papers on all aspects of peaceful uses.

United Nations plans for a second International Conference on the Peaceful Uses of Atomic Energy, suggested in closing statements from many world leaders as the first conference closed, began to take shape at the meeting in New York on September 28, 1956, of the Advisory Committee on Atomic Energy Affairs to the Secretary General of the United Nations. The United States was represented by Dr. I. I. Rabi, to whom the Commission supplied staff assistance. At this meeting of the Advisory Committee the approximate date of the next conference was established.

At the May 1957 meeting in Geneva of the Advisory Committee, the Secretary General determined that the 1958 International Conference would be held in Geneva, Switzerland, September 1–13, 1958, and approved a provisional agenda. The agenda is to be of wide scope with special emphasis on atomic power.

Previously, the Department of State requested the Commission to plan, direct, and coordinate the United States technical participation in the conference. The Commission established an Office for International Conference for this purpose, and is arranging the presentation of technical papers, a technical exhibit, and technical films.

Results of the 1955 conference, initiated by the United States, have fulfilled the formal report of the United States delegation of their conviction that the conference * * * "made a genuine contribution toward opening the way for worldwide cooperation to place atomic energy at the peaceful service of all nations." [44]

The accomplishments of Atoms-For-Peace programs in the 2½ years that have elapsed since the conference, as reported in this chapter, are an indication of the impetus provided to international scientific cooperation. At the conclusion of the 1955 conference many of the represented nations were firmly dedicated to promote this cooperation and to share their scientific knowledge and resources.

The United States has fullfilled its pledge to "share with others in a spirit of cooperation what we know of the peaceful atomic art," by its agreements for cooperation, its presentations of libraries, its exchanges and missions, and in the spirit of the 1955 conference, through various succeeding regional and topical conferences.

At these special, less conspicuous international meetings, scientists and leaders in the nuclear field concentrated on problems unique to their areas and scientific disciplines. These technical meetings established valuable personal contacts between scientists and provided the ground work for future cooperation. The exchange of specific technical

[44] See "U. S. Participation in the International Conference on the Peaceful Uses of Atomic Energy," pp. 3-27, Nineteenth Semiannual Report to Congress (July–December 1955).

information and ideas applicable to various scientific endeavors in many instances has created a joint effort or joint utilization of scientific facilities. The Inter-American Symposium on the Peaceful Application of Nuclear Energy was such a meeting.

The months since the 1955 conference have witnessed a steady reestablishment of worldwide communications among atomic scientists and engineers. Meetings such as the International Conference on Low Temperature Physics and Chemistry, August 1957, at the University of Wisconsin, and the International Conference on Neutron Physics, September 1957, at Columbia University, are outstanding examples of this country's effort to expand the knowledge of recent scientific advances and lower the barriers impeding the exchange of information among nations.

The Commission's undertaking to give financial support to selected unclassified international conferences on specialized scientific subjects relating to atomic energy supports the pledge of Dr. Isidor I. Rabi, United States representative to the United Nations Committee on Atomic Energy, that the "best work of the best brains" would be made available to the world.

Through massive exchanges of scientific and technical information, the peoples of the world are acquiring a greater understanding of the United States desire and efforts to support peace by providing human betterment through the advances of science and technology.

International fairs. The United States will have atomic energy exhibits both in the International Science Section and in the United States Pavilion of the Universal-International Exhibition, Brussels, Belgium (World's Fair), scheduled for April through October 1958.

The Department of Commerce, Office of International Trade Fairs, chose "The Atom and Life" as the theme of the United States exhibit at the Paris Trade Fair, held May 25–June 10, the first such exhibit in France by the United States. At the request of the Department of Commerce, the Commission provided technical assistance in planning the exhibit and equipment.

The Commission assisted in providing exhibit material for the Amsterdam atomic energy exhibition, "Het Atoom", Schiphol Airport, Amsterdam, the Netherlands, June through September. The Commission provided items of equipment from various laboratories and installations. There were no exhibits for separate nations.

Tripartite technical cooperation program. Under bilateral agreements for cooperation made possible by the Atomic Energy Act of 1954, the United States, Canada, and the United Kingdom, have collaborated on a tripartite basis on several aspects of nuclear research, de-

velopment, and technology. This tripartite cooperation, especially that involving fields which still are classified, provides continuous exchange among the technical groups of the three nations in the development of basic and applied information.

The latest in a series of discussions on controlled thermonuclear projects between British and United States scientists took place at Princeton University on October 17–18 (see Ch. VI, Progress in Physical Research).

Other conferences. In November 1956, a very successful *power reactor symposium* was held at Mol, the Belgian research center, under the agreement for cooperation with Belgium. In Brussels in May 1957, an outstanding unclassified symposium on chemical processing of irradiated fuel was held. It was attended by personnel from 13 of the countries that are members of the Organization for European Economic Cooperation.

Fuel element technology was the topic of an unclassified conference sponsored by the atomic energy commissions of France and the United States in Paris, November 18–22, 1957. Over 100 scientists from a score of nations, including members of the Organization for European Economic Cooperation, received information on the latest developments in this important area of reactor technology. The 20-man United States delegation presented 23 papers. Scientists and engineers from seven other nations also gave papers.

A United States-French symposium on the use of *graphite in reactors* was held at the Commission's Brookhaven National Laboratory in November.

The Commission, in cooperation with the National Science Foundation, the Office of Naval Research, the University of Rochester, and Rochester industries, sponsored the Sixth Annual University of Rochester Conference on *High-Energy Nuclear Physics*, April 3–7, 1956, at Rochester, N. Y. This meeting was devoted to unclassified experimental and theoretical developments in the field of fundamental high energy nuclear physics.

Another international conference, the Council for European Nuclear Research (CERN) Symposium on *High Energy Accelerators and Pion Physics*, was held in Geneva, Switzerland, June 11–23, 1956, attended by approximately 200 of the world's leading scientists in this field, including 50 from the United States.

Financing conferences. A program for financial support to selected unclassified international conferences on specialized scientific sub-

jects relating to atomic energy was inaugurated on January 16 of this year.[45] The Commission-approved program has these objectives:

a) Expanding knowledge of recent scientific advances among United States scientists;

b) Lowering the barriers impeding the exchange of unclassified information among nations; and

c) Promoting the peaceful uses of atomic energy throughout the world in accordance with and in furtherance of the Atoms-For-Peace program.

The first conferences supported under this new program were the Fifth International Conference on Low Temperature Physics and Chemistry, August 25–31, 1957, at the University of Wisconsin, and the International Conference on Neutron Physics and Chemistry, September 9–14, 1957, at Columbia University. These conferences were under the auspices of the International Union of Pure and Applied Physics. Also supported under this program was the Conference on Standards and Measurements of Radioactivity, October 9–11, 1957, in Easton, Md., under the auspices of the National Academy of Sciences. The 1958 International Semi-Conductor Conference to be held at the University of Rochester, August 18–25, 1958, will also receive financial support from the Commission.

Atoms-For-Peace Libraries

Through December 1957, the Commission approved the presentation of 68 depository libraries to 51 countries, 5 international organizations, and the City of West Berlin. Fifteen were presented before inauguration of the Atoms-For-Peace program. These libraries consisted of 53 Atoms-For-Peace collections and 15 which had been established earlier.

Six libraries were authorized for presentation in 1957, to Colombia, Ireland, Mexico, West Berlin, the International Atomic Energy Agency, and the Organization for European Economic Cooperation.

In November 1954, the United States announced to the United Nations that the Commission would give a special library, containing a comprehensive collection of unclassified atomic energy publications, to any foreign nation as part of its Atoms-For-Peace program. In return, the United States asked the nations receiving the libraries to provide collections of similar papers. The first formal presentation was to Japan in November 1954.

A system for regular updating of the libraries with new reports is in operation. In return, the United States receives an increasing

[45] See p. 28, Twenty-second Semiannual Report to Congress (January–June 1957).

flow of reports and publications originating in countries that have received these gift libraries.

It is not necessary for a country to have an agreement for cooperation with the United States in order to receive a library.

Visitors

Effective assistance in broadening participation in the Atoms-For-Peace program has come through the person-to-person exchange afforded by the stream of visitors from other countries coming to the United States to visit Commission installations, United States industrial plants, and Commission headquarters.

The visitors have come singly, in small teams, and, on occasion, in large groups such as 137 of the delegates to the 1956 Conference on the IAEA Statute who toured the power reactor under construction at Shippingport, Pa. Included on the visitor roster are scientists, engineers, political leaders, doctors, industrialists, geologists, educators, and journalists.

Principal points of interest have been the Commission's Argonne, Brookhaven, and Oak Ridge National Laboratories; the power project at Shippingport, Pa.; and United States plants where reactors, fuel elements, and reactor components are being made.

In all, more than 2,400 visitors from 72 nations have been logged since 1955. In 1957, the average has been about 100 per month.

Regional Programs

Euratom. Ratification of the treaty establishing the Community of six Western European nations known as Euratom—Belgium, France, Republic of Germany, Italy, Luxembourg, and the Netherlands—was completed late in 1957, and organization of the executive body of the community was to follow promptly.

During July 1957, some 50 leading industrialists from Euratom countries conferred with the Commissioners in Washington and visited Commission contractor and private industrial installations to study the type of facilities which United States industry can offer to the Euratom program. Several published reports of the visit indicate that the group was impressed with the scope and comprehensiveness of the United States approach toward the goal of economic nuclear power.

A report, "A Target for Euratom," submitted in April by a committee of the organization's experts to the governments of the European Atomic Energy Community, estimated at "some 15 million kilowatts the nuclear power capacity that can be accommodated in

the electricity system of the six countries during the next 10 years."[46] This is the most ambitious plan in the world today for the peaceful utilization of atomic energy.

Technical experts from Euratom conferred at length with the Commission in February. The Commission sent a technical mission to Luxembourg last spring to advise on problems involved in the huge undertaking.

Organization for European Economic Cooperation (OEEC). The Commission is cooperating with the atomic energy programs of the Organization for European Economic Cooperation. At OEEC's request, a Commission consultant went to Paris last September to advise on establishment of a committee on reactor hazards and operations.

The Organization is preparing a statute for a European Nuclear Energy Agency which it hopes will come into force early in 1958, and is studying such problems as security control, coordination of national measures, and trade rules. Investigations during the past 2 years have shown definite possibilities for joint undertakings to accelerate progress toward using atomic energy for peaceful purposes in Europe.

In various stages of planning and negotiation are proposals to build a small homegeneous reactor in England, to base an OEEC study project on the Halden reactor facility in Norway, and to establish a small chemical reprocessing plant in Belgium. OEEC anticipates that early in 1958 the necessary number of its 17 members will have ratified a convention and statute to govern the Belgian project, and another convention to set up security controls.

The OEEC atomic programs are an outgrowth of its experience in dealing with European economic problems for which it was established in 1948 in connection with the administration of the Marshall plan.

The total OEEC program is flexible enough to permit coordination with the work of other international organizations such as Euratom and IAEA. To this end, a working party has been formed to provide liaison with Euratom.

The Commission is following OEEC developments with interest and expects to cooperate fully with the organization.

Organization of American States. Besides providing assistance to the Inter-American Institute of Agricultural Sciences, a research facility under the Organization of American States, the Commission has offered cooperation in other atomic energy programs.

The institute, located at Turrialba, Costa Rica, is establishing a study center for application of atomic energy to agriculture, looking

[46] See pp. 26-27, Twenty-second Semiannual Report to Congress (January-June 1957).

toward development of new types of plants with higher productivity and greater resistance to disease and pests.

In November 1957, the Council formally approved formation of an Inter-American Nuclear Energy Commission within the framework of the OAS organization. Such a commission was among the recommendations approved last April by the Committee of Presidential Representatives which was created in 1956 following the proposal by President Eisenhower that such a group be established at a meeting of the Presidents of the American Republics in Panama in 1956.

The purpose of the proposed commission would be to survey the needs of members for research and training in atomic energy, provide technical bibliographical service, and recommend other services in the field of peaceful uses of atomic energy. The U. S. Atomic Energy Commission would cooperate fully with the proposed organization.

The nuclear center being established for Spanish-speaking students at the University of Puerto Rico, reported on later, is expected to serve some of the training needs of the American Republics.

Asian Nuclear Center. The Commission, in cooperation with the Department of State and the International Cooperation Administration, has under study the reports from the Colombo Plan nations on the scope and method of support of a proposed Asian Nuclear Center to be located at Manila.

These reports resulted from a meeting with United States representatives in Washington in July 1957 of a working group representing most of the nations that would be expected to participate. The goal of the project is to provide a facility for training of nuclear scientists, engineers, and technicians and would be adapted to the needs of the Asian countries.

Special Education Programs

During the last year, 105 students from 36 countries received training at the Commission's international reactor technology school, and 55 students from 21 countries took radioisotope courses.

Schools and Training Courses

International reactor schools. The International School of Nuclear Science and Engineering, inaugurated in March 1955 at the Commission's Argonne National Laboratory, has a curriculum designed to give a broad understanding of the basic principles of reactor science and engineering. (See ch. IV section on Education and Training.)

Students applying to the school are selected by an admissions com-

mittee composed of representatives from the cooperating universities (North Carolina State College and Pennsylvania State University), the Commission, the Department of State, and the International Cooperation Administration. The qualifications of an applicant and the relative need of the sponsoring country for trained personnel are considered. Enrollment of students from any one country is necessarily limited since only about 50 can be accepted in each class.

All students must be recommended and sponsored by their governments and must have a working knowledge of the English language.

The reactor school's program is aimed at training scientists and engineers for responsible roles in developing atomic energy for peaceful uses according to the needs of the countries represented. The school's alumni already hold prominent positions in national atomic energy commissions, in education and research institutions, and in atomic industries in their home countries.

A summary of the plans of the 53 students from 26 nations graduated with the fifth class on November 6, 1957, showed that 19 expected to work with government atomic energy organizations in their own country; 14 were to return to the companies that gave them leave to acquire reactor training; 9 were to teach some phase of nuclear technology in universities at home; and the plans of the other 11 included work in isotope production and basic research.

The speaker at the graduation was Director General Sterling Cole, of the IAEA, who told the students that "the new International Atomic Energy Agency provides a new stage upon which I hope many of you, and those who have preceded you here, will play important peace-serving roles."

Radioisotopes training. Since October 1948, the Oak Ridge Institute of Nuclear Studies has conducted courses in the use of radioisotope tracer techniques in research. A limited number of foreign scientists was admitted to these 4-week courses in earlier years, but in 1954 the Commission approved special training courses for foreign nationals, and approved their admission to regularly scheduled courses. Special sessions were held in May and October of 1955. At present, foreign scientists make up 30 percent of the enrollment in regular courses.

Educational guidance. A rapidly increasing number of American schools now offer graduate work and advanced training in nuclear science and engineering. (See ch. IV.) A number of foreign students is attending these institutions. For example, about 35 have been enrolled in the 1956–57 and 1957–58 sessions of the University of Michigan's atomic science school operated under the name of the Phoenix Project.

The Commission is receiving an increasing number of requests from many sources for guidance as to the types of instruction and training available in the United States. These are handled on an individual basis, and during 1957 guidance had been provided in response to an estimated 375 requests received from some 45 countries. The Commission advises on the type of training most appropriate to the background of the individual and to the needs of the country concerned.

Many foreign nationals have been trained at national laboratories, several industries have been able to provide training, and a large number of the applicants have been accepted by universities for training appropriate to their needs. The policy of the Commission is to provide training only in those areas and to the extent that such training does not duplicate the offerings of universities or industrial groups interested in making their facilities available.

Program participation. At least 100 scientists from other nations, many of them outstanding in their respective fields, are working from periods of a few weeks to a year or more at Commission laboratories and installations. These visitors are making valuable contributions to the world's knowledge of atomic energy.

Puerto Rico Training Center

To facilitate the training of students from the American Republics, as well as to help meet the needs of Puerto Rico, the Commission is establishing a Spanish-language atomic energy training center in conjunction with the University of Puerto Rico.

The proposal for the center was made September 17, 1956, by Dr. Milton S. Eisenhower, United States member of the Inter-American Committee of Presidential Representatives.[47]

In January 1957 a symposium on the peaceful uses of atomic energy was held in Puerto Rico under the auspices of the university and the Commission's Oak Ridge Institute of Nuclear Studies, and attended by 1,200 students, faculty, and government officials. Sessions were held at the Rio Piedras campus near San Juan and at the Mayaguez campus on the west coast of Puerto Rico.

During February and March, Commission and contractor personnel visited the university to study existing programs and to assist in developing the university's proposals for the operation of the center. In March, the Commission made a grant of $155,340 to the university for inauguration of a training program in nuclear science and tech-

[47] See p. 18, Twenty-first Semiannual Report to Congress (July–December 1956).

nology at the university's Mayaguez campus. An additional grant of $61,610 was made for the initiation of a radioisotope techniques training course at the Rio Piedras campus.[48] The first group of isotope trainees was graduated in September.

Before 700 university and government officials, a contract providing $300,000 for initial operation of the center by the university was signed at Rio Piedras on October 2. The Commission, on November 1, announced that the Catalytic Construction Co. had been selected as architect-engineer for part of the $2.5 million construction program which includes a building to house the pool research and training reactor, a laboratory building, and a plant house for agricultural research and training, all on the Mayaguez campus. The contractor for the reactor will be selected later.

During the next few years the center will initiate Spanish-language training courses in the medical applications of atomic energy and other research and training projects.

[48] See pp. 22-23, Twenty-first Semiannual Report to Congress (July–December 1956).

VI

PROGRESS IN PHYSICAL RESEARCH

The Commission's physical research program, conducted in its own installations and through contracts with other institutions, continued to make contributions to fundamental knowledge in the fields of physics, chemistry, metallurgy, mathematics, and computer development, and in controlled thermonuclear reactions.

Research on the transuranic elements has resulted in the discovery of four new elements in the last 3 years.

New methods of extracting materials of interest to the atomic energy program have been developed and exploited.

As a result of the study of the properties of metals and other materials, several new materials have been found to be especially suited for use in the atomic energy program and are now in use.

The study of problems such as oxidation, corrosion, radiation damage, and the effects of high temperatures has been carried on and a more detailed knowledge of these problems has resulted.

The last few years have been especially fruitful in advances in nuclear physics. The existence of several nuclear particles, some of which have been a part of generally accepted nuclear theory for many years, was confirmed through experiments. Knowledge of the properties of the nucleus and the nature of matter has been increased, and several new aspects of nuclear theory have evolved or have been revised and tested.

The effort to use thermonuclear fusion as a source of power for the production of electricity was expanded, and basic information in this field was made available to a broader group of interested scientific and industrial organizations. Work was pressed ahead in the field of digital computers—the "electronic brains"—which assist scientists and engineers in many aspects of atomic energy theory, experiment, and development.

These and other highlights of research accomplishments are summarized and reported in succeeding sections of this chapter. The expansion of the Commission's physical research program from a level of slightly under $43 million a year in fiscal years 1954 and 1955 to nearly $60 million in fiscal year 1957, and a better than 40-percent increase in the number of research contracts between 1954 and 1957 must equally be counted as gains in the Nation's efforts to push back

the frontiers of knowledge in the physical sciences. (See Table I, Operating Costs for Physical Research Program, 1954–58, and Table II, Contracts in Physical Research Program, 1954–57.)

The Commission's broad goal in its physical research program is the fulfillment of its responsibilities under the Atomic Energy Act of 1954, as under the previous act of 1946, "to insure the continued conduct of research and development activities." [49] The importance of research in the fundamental fields covered by the Commission programs is evidenced by the fact that the entire atomic energy program had its origins in a few basic scientific discoveries and theories which, at the time of their development, had no apparent practical applications: the theory of relativity, quantum theory and quantum mechanics, and the long series of transuranic studies and nuclear discoveries that led up to the accomplishment of nuclear fission and nuclear fusion.

TABLE I.—OPERATING COSTS FOR PHYSICAL RESEARCH PROGRAM, 1954–58
(Year Ending June 30)

Fiscal year	*Costs* [1] *(in millions)*
1954	$43.1
1955	43.9
1956	51.3
1957	58.9
1958 (estimated)	69.8

[1] Includes depreciation of plant and equipment.

TABLE II.—CONTRACTS IN PHYSICAL RESEARCH PROGRAM, 1954–57

Fiscal year	*Number of contracts*
1954	259
1955	293
1956	323
1957	369

[49] Ch. 4, Research—Sec. 31, Research Assistance—
a. The Commission is directed to exercise its powers in such manner as to insure the continued conduct of research and development activities in the fields specified below, by private or public institutions or persons, and to assist in the acquisition of an ever-expanding fund of theoretical and practical knowledge in such fields. 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 to—
(1) nuclear processes;
(2) the theory and production of atomic energy, including processes, materials, and devices related to such production;
(3) utilization of special nuclear material and radioactive material for medical, biological, agricultural, health, or military purposes;
(4) utilization of special nuclear material, atomic energy, and radioactive material and processes entailed in the utilization or production of atomic energy or such materials for all other purposes, including industrial uses, the generation of usable energy, and the demonstration of the practical value of utilization or production facilities for industrial or commercial purposes; and
(5) the protection of health and the promotion of safety during research and production activities * * *

Developmental work directly related to the Commission's activities is given continuing support. In addition, the Commission's physical research program sponsors and supports investigations in such fundamental fields as those which produced the earlier notable discoveries—fields that otherwise might be overlooked or explored only on an intermittent and short-range basis in programs directed toward more immediate goals. It is not possible to predict what practical applications will result from this type of research. It is possible, however, to define fields for fundamental investigations where results can be expected to have a high degree of relevance to the practical objectives and problems of the atomic energy program, and this is consistently done.

Thus, the fields of investigation and experiment under the physical research program include physics, chemistry, metallurgy, mathematics and computer development and controlled thermonuclear reactions, and involve: all aspects of nuclear physics; the properties of elementary particles; the techniques, equipment, and machines involved in nuclear research; the physical, chemical, and metallurgical properties of materials interesting in the atomic energy program; the geochemistry and geophysics related to the finding of ore; the chemical and metallurgical effects of radiation on materials; the use of radioisotopes in chemistry and physics; and, finally, the problems related to the developmental processes for producing or using special materials such as those for the treatment of ores, separation of isotopes, and the separation of elements produced in nuclear reactors.

In carrying out this research, the program has three objectives: (*a*) to increase understanding of the fundamental laws governing the nature of matter and the universe, (*b*) to apply this fundamental knowledge to the research and development work of the atomic energy program, and as an important byproduct, (*c*) to train scientists and engineers.

The physical research program is conducted at the Commission's major research centers and in other facilities under contractual arrangements which utilize the scientific manpower located at universities and other private laboratories.

At many of these major research centers and in several larger university laboratories, the Commission, as part of its research effort, finances the unusual devices required for present-day research: high-energy particle accelerators, research reactors, electronic computers, and other research devices. The research devices are located at centers where large segments of the scientific community can best utilize them, and where a close relationship can be maintained between fundamental research and programs of practical development.

Of $60 million for 1957, about 70 percent was allocated to support

approximately 1,200 scientific man-years at the major research centers. The remaining 30 percent was allocated to the headquarters-designated contractual physical research program which provides for research at non-Commission institutions—universities, colleges, research organizations, and other Government installations.

As of December 31, this program had approximately 366 research contracts with some 118 universities and private laboratory contractors and with other Government Agencies. This program cost the Commission approximately $22 million; however, this amount resulted in a total research program of about $31 million, because the universities' contractors share in the costs. At present, the Commission supports 70 percent of the program. A list of the contractors and the type of work performed is given in Appendix 9.

As a supplement to the Commission's research program in its major laboratories, the contractual physical research program has a number of definite advantages:

a) When the amount provided by the Commission is added to the funds of the universities, this adds to the effectiveness of the universities' programs as well as to the basic research effort of the Commission's program.

b) The Commission receives the services it would not otherwise have of highly qualified scientists in basic research activities fundamental to the Commission's future capabilities for achievement.

c) The cost of research conducted in the contractual program is less than the research carried on in the large Commission laboratories.

d) Finally, the program provides for the training of undergraduate and graduate students associated with the research projects. With the present lack of scientific manpower, this is an important byproduct of the university research program.

At the present time, the contractual research program includes approximately 1,200 graduate and undergraduate students. In addition, the Commission cooperates with the Office of Naval Research in a joint program of basic research in nuclear physics, and it is estimated that an additional 400 students receive training in research methods through association with about 30 research projects under this program. The Commission and the Navy share the costs on an equal basis, with an additional contribution in most cases by the university contractors. In the fiscal year ended June 30, 1957, each agency obligated $3.34 million for this program.

Progress Under Physical Research Programs

In each of its semiannual reports, the Commission has summed up for the Congress the major administrative activities and technical

accomplishments of the 6-month period covered by the report. In the following sections, this report gives the highlights of physical research supported by the Commission for the calendar years 1954 through 1957, details of which previously were described in portions of the Sixteenth through the Twenty-second Semiannual Reports to Congress dealing with physical research, or are summarized in later portions of this chapter of the Twenty-third Semiannual Report.

Highlights of 1954

- Two new transuranic elements, einsteinium (element 99) and fermium (element 100) were discovered by a radiochemical analysis of debris from the 1952 "Mike" thermonuclear explosion. The discovery was the result of the joint effort of nuclear chemists from the Argonne National Laboratory, the Los Alamos Scientific Laboratory, and the University of California Radiation Laboratory.
- The CP–5 research reactor at the Argonne National Laboratory went critical on February 10, 1954. Since this date, the reactor has played an important role in the Commission's physical research program. Funds have been appropriated in the current fiscal year to increase its effectiveness by increasing the power of the reactor to 4 megawatts. It was originally designed to operate at 1 megawatt.
- The Commission approved the initiation of design studies leading to the construction of two heavy particle linear accelerators at the University of California Radiation Laboratory and Yale University. The accelerators were expected to operate at approximately 10 million electron volts (Mev) per nucleon. The Commission also approved the design and construction of the 25–35 billion electron volts (Bev) alternating gradient synchrotron at Brookhaven National Laboratory. These accelerators were authorized under the accelerator rider to the Second Independent Offices Appropriations Act, 1954.
- Testing of the bevatron at the University of California Radiation Laboratory began in February 1954, and an energy of 6.1 Bev was attained by April of the same year. Construction of the machine began in 1949.
- An annual award—medal, citation, and $50,000—was established in 1954 for individuals making outstanding contributions in the development of atomic energy. Dr. Enrico Fermi was the first recipient and the award was designated the "Fermi Award" after his untimely death.
- The Commission authorized the design and construction of the Oak Ridge Research Reactor at the Oak Ridge National Laboratory.

Highlights of 1955

- The discovery of mendelevium (element 101) was made by a group of nuclear chemists at the University of California Radiation Laboratory, Berkeley.
- At the International Conference on the Peaceful Uses of Atomic Energy held in August 1955 at Geneva, Switzerland, the United States announced that it was working on a long-range research program to develop the controlled release of energy from thermonuclear fusion. During the conference, scientists from a number of countries combined their results to obtain a set of world's average cross sections of the fissionable isotopes uranium 233, uranium 235, and plutonium 239.
- A new particle, the antiproton, was discovered at the University of California Radiation Laboratory, Berkeley.
- New methods for producing highly concentrated nitrogen 15 were developed at the Ames Laboratory and at Columbia University. Gram quantities of nearly 100 percent purity material were produced at both sites.
- A new semicontinuous method of producing thorium was developed at Oak Ridge National Laboratory.
- Experiments conducted at Oak Ridge National Laboratory showed that an ion of a technetium compound, pertechnetate, inhibits the corrosion of steel.

Highlights of 1956

- The Commission approved construction of two high-energy particle accelerators at two universities. One of the accelerators, under the joint sponsorship of Harvard University and the Massachusetts Institute of Technology, will be built on the Harvard campus, while the other machine, jointly sponsored by Princeton University and the University of Pennsylvania, will be placed on the Princeton campus. The Commission also authorized the Midwestern University Research Association and the Argonne National Laboratory to undertake studies for the design and development of high-energy accelerators of advanced design.
- A team of Los Alamos Scientific Laboratory scientists working on an experiment at the Savannah River plant proved conclusively for the first time the existence of a previously hypothetical nuclear particle, the free neutrino.
- Prof. Donald Glaser, of the University of Michigan, invented a new device for detecting nuclear particles, the bubble chamber, in 1952. Since that time a number of the laboratories have explored

the advantages of bubble chambers, especially in studying reactions of mesons and protons. Professor Glaser continued his work on this technique, and in 1956 developed an improved bubble chamber that uses liquid xenon. This new bubble chamber is expected to be able to show the effects of all particles from high-energy reactions. It will be especially suited to detect gamma rays, and thus will be a unique tool for the study of the decay of neutral mesons.

- A new type of nuclear reaction was discovered in December 1956 as a result of research with the Berkeley bevatron at the University of California Radiation Laboratory. The new phenomenon, described as a catalyzed nuclear reaction, occurs when a proton and a nucleus of heavy hydrogen (a deuteron) are pulled together by a negative mu meson. The two particles combine to form helium 3 with the release of 5.4 million electron volts of energy.
- Research with the cosmotron and the bevatron yielded some new and interesting meson particles.
- The University of California Radiation Laboratory announced the discovery of the antiproton's counterpart—the antineutron.
- A classified meeting of 275 scientists was held in June at Gatlinburg, Tenn., on the controlled thermonuclear program. The purpose of the meeting was to bring the participants up to date on progress of the program.
- During 1956, the Commission authorized the wider dissemination of information on controlled thermonuclear reactions. For the first time, classified information was made available to certain categories of industrial groups which had been permitted access to other types of classified information. Arrangements also were made by the Commission for exchange of classified information and visits between the United States and the United Kingdom. In addition, meetings were held between the two countries to draft a classification guide that would make some previously classified material available to the public.
- The newly established Tripartite Nuclear Cross Section Committee held a conference at Harwell, England, in July, and scientists from Canada, the United Kingdom, and the United States exchanged classified and unclassified information on nuclear cross sections (except weapons data) as permitted by the Atoms-For-Peace agreements for cooperation with Canada and the United Kingdom.
- Plans were approved to expand and modernize the New York University computer facility, for use in connection with Commission contract research. A rented IBM–704 computer was installed and placed in operation by New York University.
- The Commission authorized the purchase and installation of a tandem-style Van de Graaff accelerator at the University of Wis-

consin and a 3-Mev electrostatic generator at Johns Hopkins University.

- Several new processes were developed at the Oak Ridge National Laboratory for extracting metals from their ores and for the recovery of certain fissionable materials from reactor fuels.
- A bent crystal gamma-ray spectrometer was constructed at Argonne National Laboratory. The instrument is especially suited for the study of the energy range below 2 Mev.

Highlights of 1957

- The Commission approved the transfer of a 32-Mev proton linear accelerator from the University of California Radiation Laboratory, Berkeley, to the University of Southern California. Besides releasing some much-needed space at UCRL, transfer of the machine materially assisted USC's training and research program.
- The Commission has authorized construction of a 12.5-billion-electron-volt proton synchrotron at the Argonne National Laboratory.
- Approximately 460 persons attended a controlled thermonuclear meeting at Berkeley, Calif., in February to discuss recent developments in controlled thermonuclear research. For the first time, holders of access permits, scientists for the United Kingdom, and representatives of other Government agencies were invited to attend.
- A second controlled thermonuclear conference, held at Princeton University in October, included 130 persons, among whom were representatives from controlled thermonuclear research facilities in the United States and the United Kingdom. Reports on several essentially distinct experimental approaches in the United States and the United Kingdom indicated appreciable progress in confining a very hot gas and producing substantial numbers of neutrons. Production of thermonuclear neutrons is considered an important step in long-range efforts to develop thermonuclear reactors for producing electric power. The temperatures reached in the experiments suggested that the neutrons resulted from thermonuclear reactions, but more experimental work will be necessary to establish the origin of these neutrons definitely. The neutrons could have other sources.
- The Commission approved the initiation of the design of the next larger experimental model in the Princeton Stellarator Program—Model "C"—to be used in research on controlled thermonuclear reactions.
- The Commission sponsored a conference in New York during April on shielding of high-energy accelerators. The conference afforded scientists and engineers an opportunity to review shielding criteria, and enabled them to incorporate the best and most economical devel-

opments in future machines. A report on the proceedings was published in December.

● The joint research efforts of scientists from the Argonne National Laboratory, Great Britain, and Sweden resulted in the discovery of element 102.

● The new heavy ion linear accelerator at the University of California Radiation Laboratory went into operation on April 11. The machine was used in experiments with elements and isotopes heavier than uranium. It may permit the synthesis of elements heavier than the recently identified element 102. The HILAC also permitted a new type of exploration of nuclear forces.

● One development in the field of physics was the discovery of the violation of what was formerly thought to be a physical law. As a result of the combined efforts of theoretical and experimental physicists, experiments demonstrated that subnuclear particles are not symmetrical in their reaction to nuclear events, but instead show a tendency in certain systems to react in certain directions. This new discovery was inspired by the theoretical work of Tsung Dao Lee, of Columbia University, and Chen Ning Yang, of the Institute for Advanced Study at Princeton University, since awarded the Nobel Prize in physics. Their theory is called the nonconservation of parity. The research was supported, in part, through the Commission's university physical research program.

● The Commission approved a new program in 1957 to encourage training and research in the design, development, and use of high-speed digital computers.

● Research with the bevatron and cosmotron continued to produce new and interesting subnuclear particle discoveries.

● The Commission authorized the purchase of two 3-Mev Van de Graaff accelerators for installation at Case Institute of Technology and the University of Maryland.

● Modification of the 184-inch cyclotron at the University of California Radiation Laboratory, Berkeley, was completed. The energy of the accelerated particles was more than doubled. (The maximum proton energy, formerly 340 Mev, is now about 725 Mev.) A study of the various secondary meson orbits, intensities, and energies is underway in preparation for the many meson experiments that are planned. Characteristics of the various other particle beams will be determined as current experiments require. At present, this machine and a Soviet Union accelerator reported to accelerate protons to 680 Mev are the only ones operating at the intermediate range. A third machine expected to operate in the 600-Mev range now is under construction at Geneva, Switzerland.

● The Commission's laboratories continued their radioactive tracer research in order to obtain more basic information in this field. A new method of labeling organic compounds with tritium was discovered.
● Recognizing the lack of pure materials for important research experiments and developmental programs, the Commission began work in the field of pure materials research.

PHYSICS

Research in basic physics seeks to contribute to knowledge of the nature of matter and the universe. Since it is an accepted concept that knowledge and understanding are major factors in the progress of civilization, investigations in this field extend beyond the scope of "peaceful applications of atomic energy." Though they provide the basis of future developments in both the peaceful and military uses of atomic energy, any direct or immediate connection with "applications" of science, in the accepted sense of the phrase, usually has a retarding effect upon the progress of these investigations into the frontiers of science. Accordingly, only a small portion of the research in physics is related directly to the immediate technological uses of atomic energy.

High-Energy Physics Research

Since a primary aim of physics research is to further theoretical understanding of the structure of matter and its properties, the general goal is to find a valid theory that will describe or explain all phenomena observed in experiments. Though it is an independent science and at times speculative, theoretical physics can develop on a sound basis only in conjunction with experimentation. There is a continuous exchange between advances in theory and the design of new experiments and new discoveries. There is also a steady exchange of information between research workers in these fields throughout the world, much assisted by international meetings on specific topics.

Parity theory. A principal recent advance in theoretical physics is a modification in the prevailing theory of elementary particles suggested by T. D. Lee and C. N. Yang who were awarded a Nobel prize for their work. Lee and Yang suggested that their modification—the so-called "violation of parity conservation" resulting from efforts to explain certain observed phenomena—could be tested by determining that in certain radioactive decays, the radiation is not emitted symmetrically in all directions as previously had been thought.[50]

[50] See pp. 91–92, Twenty-second Semiannual Report to Congress (January–June 1957).

The theory was so tested and confirmed in experimental work done at Columbia University, the National Bureau of Standards, and the University of Chicago. Further important confirmation of the theory was furnished by several Brookhaven experiments. It was found that cosmotron-produced mu-mesons, which decay into electrons, emitted these electrons more frequently backward than forward with respect to their direction of flight. Another experiment showed that electrons from radioactive decays, when stopped in matter, produce gamma rays which are circularly polarized. This proved that these electrons have their spin axis alined parallel to their direction of flight, another expected consequence of the views of Lee and Yang.

Cosmotron contributions. Early work established the fact that protons and neutrons are complex entities which, in high-energy collisions with one another, emit very short-lived particles called mesons and hyperons. More recently, such accelerators as the cosmotron and bevatron with controlled, high intensity beams have added a great deal of information about unstable particles. At Brookhaven, there have been at least four notable investigations, resulting from work with the cosmotron, performed by the laboratory staff and by visiting physicists.

Creation of heavy mesons and hyperons was found to take place only by means of a special process known as associated production. A hyperon cannot be created without the simultaneous creation of a heavy meson. This discovery suggested what is known as the Pais-Gell-Mann scheme, which although in no sense a theory of high-energy phenomena, assigns characteristics to the newly discovered particles so that they form a systematic relationship.[51]

A further important consequence of the new theories was that a neutral K-particle was predicted with a much longer half life than the K-particles observed previously. The more common neutral K-particles decay into a positive and a negative pi-meson almost immediately after creation in a collision; the characteristic V-shaped track of the two pi-mesons in the cloud chamber occurs near the point of collision indicating a half life of about 10^{-10} seconds (one ten-billionth of a second). However, cloud-chamber observations at a greater distance from the point of collision, made by a group of physicists from Columbia University, proved the presence of neutral K-particles which live 1,000 or more times longer, and decay into 3 instead of 2 particles (a pi-meson, mu-meson, and gamma ray, or 3 pi-mesons).

The existence of the neutral sigma hyperon was established. This particle was predicted on theoretical grounds, and its discovery had

[51] See p. 94, Twenty-second Semiannual Report to Congress (January–June 1957).

special importance because it gave support to the concept of isotopic spin. This basic concept relates the electrical charges which a given class of particles may be expected to carry.

The existence of the theta-two heavy meson was established. This is a neutral particle, and has as a companion another somewhat similar neutral particle. The two become mixed in a manner predicted by theory and now confirmed by the discovery of the nonconservation of parity.

During the past 4 years a great deal of information has been obtained at the cosmotron on the interaction cross section of protons, neutrons, pi-mesons, and positive K mesons over the very considerable energy range between 400 Mev and the maximum cosmotron energy of 3 Bev. These data have revealed important characteristics about the various particles, and form the starting point for many theoretical studies.

Bevatron contributions. At the University of California Radiation Laboratory, Berkeley, equally significant progress has been made in high-energy physics. In October 1955, a new particle, the antiproton, was discovered in experiments using the 6.2-billion-electron-volt beam of the bevatron, and radiation counters. In further experimental work the same beam which had been shown to contain antiprotons was used to irradiate a stack of photoemulsion plates. In one of these plates, an antiproton interaction was found.

Following this fundamental work, an intensive search was begun for the antiproton's predicted counterpart—the antineutron. A method of detection, called the charge exchange process, was developed, and as a result of some technical improvements the yield of antiprotons was increased greatly so that the discovery could be made in 1956. In the same year, University of California physicists detected another heretofore unknown interaction which forms a mesic molecule with a subsequent release of energy similar to that which occurs in thermonuclear reactions. The new discovery was called a catalyzed nuclear reaction.

The heavy meson beam facilities at the University of California's bevatron were greatly improved by mid-1956. As a result, significant contributions have been made to understanding the production and properties of heavy mesons.

Photographic emulsion work at the University of California Radiation Laboratory has yielded much information on the masses and other properties of the various types of mesons. Hyperons and unstable nuclear fragments have also been studied in emulsion since they are among the products resulting when negative heavy mesons interact with ordinary nuclei. Counter techniques have been em-

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ployed to study the decay properties of the shorter lived neutral heavy mesons that are detected in the region of the bombarded target.

The investigation of heavy mesons at the University of California Radiation Laboratory led to what is now termed the "tau-theta problem." The tau and theta particles are heavy mesons known to have different modes of decay. The tau meson decays into 3 pions (pi-mesons) and the theta meson into 2 pions. According to investigations carried out at this laboratory, the tau and theta mesons have identical masses within experimental error, and no differences in their production has been observed. The lifetimes of the tau and theta mesons have been measured to an accuracy of 4 percent and were found to be indistinguishable.

When the physical properties of the tau and theta mesons, i. e., mass, production, and lifetimes, appear to be identical, it is nearly impossible theoretically to see how these two modes of decay can occur for the same particle. It was these experimental results that stimulated the physicists Lee and Yang to suggest that perhaps some, if not all, ideas about parity might be wrong.

For a more detailed discussion of the developments in this field at Brookhaven National Laboratory and the University of California Radiation Laboratory: See pages 59–60, Nineteenth Semiannual Report to Congress (July–December 1955); pages 84–87, Twentieth Semiannual Report to Congress (January–June 1956); pages 67–71, Twenty-first Semiannual Report to Congress (July–December 1956); pages 91–95, Twenty-second Semiannual Report to Congress (January–July 1957).

Accelerator Design Studies

Because of its continuing interest in fundamental studies of the interactions of elementary particles and the importance of the technology of particle accelerators, the Commission has continued to work on the development of accelerators of advanced design.

During 1956 the Commission authorized the Argonne National Laboratory and the Midwestern Universities Research Association to conduct studies for the design and development of advanced high-energy accelerators. The Argonne machine, a 12.5-Bev proton synchrotron, was authorized by Congress in fiscal year 1958 at a total estimated cost of $27 million, and $1.5 million was appropriated for design work. In December, the Commission authorized the Argonne National Laboratory to proceed with the machine, including selection of an architect-engineer firm.

Many fundamental design characteristics of the machine have been

settled, and work has progressed on engineering design as well as on basic studies of certain components.

Preliminary model magnet studies substantiated the feasibility of the chosen type of magnet structure, and measurements are commencing on a direct-current, one-seventh-sized model accurately scaled from the final machine. The design of a model magnet for pulsed operation has begun. Methods of fabrication of the final magnet are under study.

A detailed prospectus was prepared to acquaint the architect-engineer with design requirements of the complex of buildings, structures, and shields. A committee of advisers from other institutions was formed to help in this study.

The Midwestern Universities Research Association (MURA) continued its design study on highly original concept that is expected to set design criteria for a large, fixed-field, alternating-gradient accelerator. Procurement of major components was initiated by MURA so that fabrication and assembly of the model may begin early in 1958. The model will be constructed with an injection energy of 100 kilovolts and an output energy of 50 Mev. The primary purpose of this new model is to demonstrate the feasibility of very large currents of the order of 100 amperes of electrons at 50 Mev. Because of the large storage time of electrons in this machine, it will be possible to study more elaborate radiofrequency acceleration schemes comparable to those which might be used in a large accelerator.

The main advantage of the fixed-field, alternating-gradient system (FFAG) is that, by accelerating many successive injected pulses of particles and leaving them coasting at selected radii in the accelerator it may be possible to obtain very high currents of high-energy particles.

Studies of accelerator systems of advanced design also are being conducted at Brookhaven National Laboratory, Oak Ridge National Laboratory, Stanford University, and the University of Rochester.

Bubble Chamber Research

The invention of the bubble chamber by Donald Glaser, of the University of Michigan, provided high-energy physicists with a powerful new observational tool.[52] Like its predecessor, the Wilson cloud chamber, the bubble chamber makes visible the tracks of charged particles which traverse it. In the bubble chamber, tracks are marked by gas bubbles in a liquid medium rather than by liquid droplets in the gaseous medium of the cloud chamber. The most obvious advantage of the bubble chamber is that the number of "target nuclei" is much higher for the charged particles in a given volume than that

[52] See pp. 52–53, Eighteenth Semiannual Report to Congress (January–June 1955).

possible in a cloud chamber, liquids being generally about 1,000 times denser than their corresponding vapors.

A bevatron worker translates this improved means of observation directly into decreases in operating time on the machine—an experiment which required 10 weeks of chamber operation at one density would need only 1 week if the density were increased by 10 times. As employed, bubble chambers increase density about 25 times over the highly pressurized vapors used in cloud chambers. In view of the expense of operating the high-energy accelerators, and of the great demands made on their available operating time, it is clear that the contribution that the bubble chamber makes to high-energy physics is of great importance.

Glaser's first chambers, constructed in 1952, were tiny glass bulbs filled with liquid hydrocarbons, such as ether and propane. The development of large chambers has been a community effort among high-energy laboratories all over the world. Glaser in 1956 developed a bubble chamber that uses liquid xenon.[53] All newly found "tricks of the trade" have been shared immediately with other members of the world scientific community. Ordinary publication is too slow in such a rapidly developing technology, so the exchange of information has been often by letters or phone calls.

The University of California Radiation Laboratory has done a major share of the research and development work leading to the construction of liquid-hydrogen-filled bubble chambers of increased size. Liquid hydrogen is the simplest liquid from the nuclear physicist's point of view—all its nuclei consist of a simple proton, rather than of some combinations of protons and neutrons. This simplicity leads to an ease in the interpretation of the photographs of particle tracks that is not possible with the more convenient hydrocarbon chambers. Those who work with liquid-hydrogen bubble chambers (which operate at 246° below zero centigrade) are convinced that the inconvenience imposed by the low-temperature requirements is more than offset by the clarity of the resulting pictures.

The radiation laboratory bubble chamber group has sent copies of all of its "engineering reports" to an ever-expanding list of laboratories either engaged in building such chambers, or in planning future chambers. There now are about 20 laboratories in the "liquid hydrogen bubble chamber club." The sharing of information, apparent throughout all phases of the bubble-chamber development, has resulted in a large net saving to the Commission. In the absence of this exchange, a great deal of expensive development work would have been repeated many times at various Commission laboratories.

The radiation laboratory now is completing the construction of the

[53] See p. 87, Twentieth Semiannual Report to Congress (January-June 1956).

largest liquid-hydrogen bubble chamber in the world. The chamber holds about 150 gallons of liquid hydrogen, in a container approximately 6 feet by 2 feet by 1 foot. It is surrounded by a large magnet, which in turn is housed in a new building close to the bevatron building. The chamber will become operational in the summer of 1958. Its designers also prepared measuring and analyzing equipment to cope with the flood of pictures which will be issued from its cameras.

With modifications such as the diversion of a small part of the accelerator beam, the so-called wipeoff target, recently installed in the bevatron facilities,[54] coupled with the introduction of new high-speed cameras that have increased greatly the number of pictures that can be taken in a given period, the character of physics research has changed. Instead of one research worker or group of workers setting up an experiment, running it, and analyzing the results, high-energy physics experiments are becoming more specialized. Special crews run the high-energy machines, other specialized crews work with experimental equipment such as the bubble chambers, and, finally, a large group of scientists and technicians analyzes the results. This trend has an important advantage. It now is becoming more possible for college professors and other research scientists throughout the country to take advantage of the capabilities of large research facilities without themselves constructing corresponding expensive facilities on their own campuses.

In addition to important investigations described above, the cosmotron's and bevatron's high-energy programs have contributed in other ways in discovering facts about the nature of elementary particles. As the first accelerators producing particles in the billion-electron-volt range, they helped to establish the fact that research devices of this magnitude and complexity could be maintained at an operating efficiency sufficiently high to make them useful research tools. The Brookhaven National Laboratory and the University of California Radiation Laboratory have provided unique experience in methods and techniques of research to graduate students, postgraduate fellows, and staff members of many universities throughout the United States and the world. Thus, it has been demonstrated that large and expensive facilities such as the cosmotron and the bevatron can be used effectively by a large group of scientists and can provide intellectual stimuli to scientists throughout the world.

Sensitive Neutrino Recoil Experiment

Certain radioactive isotopes in decay emit neutrinos alone, and under these circumstances an observation of the recoil imparted to the

[54] See p. 87, Twenty-second Semiannual Report to Congress (January–June 1957).

atom by the departure of the neutrino is particularly direct and graphic evidence of the existence of a particle that is hard to observe in its free state. The experiments are difficult because the neutrino, being of extremely small mass, gives recoil only by virtue of the energy that it carries off, and the amount of recoil momentum is very small.

At Oak Ridge National Laboratory a sensitive recoil experiment has been carried out using the electron-capturing radioisotope argon 37, a monatomic gas, that was allowed to flow through a vessel under essentially high-vacuum conditions. Under these circumstances there were very few disturbing collisions of the recoils with other gas atoms and molecules, and a few of the recoils could be allowed to emerge, with their energy undisturbed, through a hole at one end of the vessel. The recoils were then deflected by passage through magnetic and electric fields, and the energy could be measured within the limits set by the ordinary heat motion of the original atoms.

The energy of the recoils was found to agree within about 1 percent with that expected from the departure of a neutrino having a mass of less than 1 percent of the mass of an electron (the next lightest particle) departing with an energy that had been determined from independent nuclear data.

Nuclear Cross-Section Studies

If a neutron strikes a nucleus, it may not be captured with the resultant formation of a new isotope. Sometimes the neutron may escape, either exciting the nucleus with the loss of some energy, or undergoing an elastic collision. This scattering of the neutron by a given nucleus varies, often quite sharply, with the energy of the colliding neutron. A comprehensive survey of the angular distribution of the scattered neutrons has been carried out at the Commission's laboratories and in contributing universities. At Argonne National Laboratory studies were made of 39 elements, and results indicated that the angular distributions vary in a quite regular manner, both with the energy of the neutron and with the mass of the target nucleus. These results give validity to the suggestion that a nuclear model exists which, with only a few adjustable parameters, will fit all data on all elements.

Scattering of neutrons. It has been found that neutrons and protons bound in some nuclei are unusually stable (oxygen 16 is such an example), so that for interpreting many phenomena, one can consider this stable core of nuclear matter as behaving as an average attractive force to a neutron or a proton. Thus, at the Oak Ridge National

Laboratory, by studying the scattering of neutrons from oxygen 16 and by use of knowledge of the bound states of oxygen 17, one is able to obtain clues to the size, shape, and effective strength of the interaction of the oxygen 16 core on a neutron. The picture of the nucleus so obtained is consistent with a somewhat similar investigation of other particularly stable nuclei carried out at the University of California and at other places, and indicates that nuclei have a diffuse boundary between 2 and 3×10^{-13} centimeters in thickness.

The fact that neutrons are scattered by various nuclei sometimes hampers research. For example, the scattering of neutrons by equipment in which a particular element is being investigated may lead to a decrease in the experimental precision. Different nuclei, such as those of titanium and zirconium, scatter neutrons in such a way that sometimes their separate effects cancel. At Argonne National Laboratory, a series of alloys of these two metals were prepared and investigated. As predicted, it was possible to prepare a particular alloy in which scattering was eliminated. The use of such "inert" materials as this alloy will be of great benefit in some experiments.

From the viewpoint of reactor technology, it is important to know the cross section or probabilities of nuclei for elastic or inelastic scattering, and for capture of neutrons (simple absorption or fission).

Capture cross sections. For calculating neutron economy in reactors, as well as for predicting the radioactivity of materials subject to neutron bombardment, it is of practical importance to know the capture cross sections, particularly in cases where it is impossible to measure them directly as, for example, in the case of neutron capture in radioactive products produced in a reactor. These cross sections must be known over a wide range of energies, since the kinetic energies of neutrons generated in a reactor may range during their lifetime from several million electron volts to almost zero. From the point of view of understanding the properties of nuclei, the resonances (narrow regions of energy in which interaction of neutrons with specific nuclei is high) are of great importance.

Research apparatus. Since neutrons have no electrical charge, they cannot be controlled by electric and magnetic fields as are electrons or protons. Rather, it is necessary to sort out neutrons with a velocity desired for study from among neutrons with an extremely wide range of energies. For this purpose, instruments called "neutron choppers" are available. They are simply mechanical devices that periodically permit the escape of bursts of neutrons, the bursts having a duration of only a few microseconds. This is accomplished by a

high-speed system of slits in rotating baffles. The neutrons of different velocities that come through in a burst arrive at a distant detecting station at different times. As a result, the neutrons can be sorted out with respect to velocity in accordance with the time of arrival.

Most such devices in use measure total cross sections, that is, the total probability for removing neutrons from the beam by a sample of material, no matter by what type of nuclear interaction. Some equipment has been so developed that it is able to produce high-intensity beams of neutrons able to measure individual cross sections (whether for fission, capture, or scattering) with an accuracy comparable to that found in determination of total cross sections.

One of the most important investigations carried out with the Argonne "chopper" has been a measurement of the resonance of plutonium 239 and of the number of neutrons produced by its fission. These results have cleared up some discrepancies that had arisen as a result of earlier work in this field. Other elements studied with the "chopper" at Argonne, with results that are useful both in reactor design and in testing theories of nuclear structure, have included arsenic, chromium, cobalt, copper, gallium, manganese, niobium (columbium), scandium, uranium, vanadium, and zinc.

The present theory of nuclear structure predicts a somewhat irregular variation of the size of the nucleus with increasing atomic weight. This has been directly observed by measuring the scattering of neutrons, using the Brookhaven fast neutron chopper. The resulting data give a rather good confirmation of the theory, and their analysis may set limits on the shape of nuclei as well as their size.

Another method of studying neutron interactions has recently been developed and is in use at many of the Commission's laboratories. In the new method the neutrons are produced through a reaction with the ion beam of a Van de Graaff accelerator or synchrotron. At Oak Ridge National Laboratory, an instrument has been developed for measuring cross sections of neutrons having velocities around 2 million meters a second. This involves accelerating pulses of charged protons 5 to 10 millimicroseconds in duration (0.000,000,005–0.000,000,010 sec) with a Van de Graaff machine, and measuring the time it requires for neutrons, produced by the protons in the Li^7 (p, n) Be^7 reaction (lithium 7+proton→beryllium 7+neutron), to traverse a distance of a few meters. In obtaining the data on the neutron cross sections, time intervals of a fraction of a millionth of a second in duration are measured to an accuracy of a few percent.[55]

[55] See pp. 90-91, Twenty-second Semiannual Report to Congress (January–June 1957)

Nuclear Structure

Though knowledge of the elementary particles still is very fragmentary, both in experimental data and in theory, knowledge of the structure of the atomic nucleus as a whole is making more rapid progress. A large mass of data on excited states of nuclei is being produced all over the world, and the research conducted as a part of the physical research program has made valuable contributions both in experiments and in the analysis of the systematics of the observed results. Numerous experiments studying the radiations of radioactive nuclei and the excitation of nuclei by bombarding with particles of well-defined energies contribute to this very active field.

Coulomb excitation. Atomic nuclei are usually excited, i. e., elevated to excited states, by the direct collision of a subatomic projectile such as a proton, neutron, or alpha particle. Such collisions result in complicated interactions which involve nuclear forces. It is possible, however, to excite nuclei by a long-range electric interaction which does not involve a direct collision with the nucleus. This process, known as "coulomb excitation," has been developed within the last few years into a powerful tool for the systematic study of nuclei.

Coulomb excitation depends on the well-understood electric interaction rather than the more complicated nuclear interaction associated with direct collision, and for this reason the measured probabilities for producing excited states are more easily and reliably interpreted. One is thus able to extract from the experiments information on some of the finer details of nuclear structure. For example, in addition to the establishment of the location of excited states, it is possible to determine the spins of nuclei in excited states and the gamma-ray transition rates between nuclear states.

It is now evident, partly as the result of coulomb experiments, that many excited states of nuclei result from collective or cooperative motion of the nucleons (protons and neutrons) within the nucleus. Both rotational and vibrational states are observed. On the other hand, it is well known that many properties of other nuclear states are well represented by the shell model which ascribes the properties of the state to a single nucleon moving in the average field of all the other nucleons. In general, an important distinction between collective states and shell-model states is the magnitude of the gamma-ray transition rate. Probably the determination of gamma-ray transition rates is the most important contribution of coulomb excitation experiments, since these transition rates allow sensitive tests of the range of validity of the varous nuclear models.

Radioactive Decay and Atomic or Molecular Structures

Since radioactive isotopes are finding more and more applications in physical research, industry, and medicine, it is very important that their half lives, energies, and the types of radiation be determined. It is also important to know what isotopes are produced in certain reactions. All these studies contribute toward understanding the forces that hold the nucleus together.

New evidence has recently been obtained at Oak Ridge National Laboratory about the structural changes that take place in the electron shells of atoms after a radioactive change in the nucleus. Broadly speaking, two kinds of effects are observed:

The first effect is encountered with atoms that are pure beta emitters or atoms that emit beta-gamma radiation without internal conversion, and in this case there is usually no loss of extranuclear electrons. When electron loss does occur, it is most frequently one of the electrons from the external regions of the atom that is shaken loose.

The second effect is encountered when one or more of the inner atomic electrons is removed, and this effect therefore accompanies radioactive decay by electron capture and decay processes that involve internal conversion.

In the second type of events, the damage to the atomic electron structure can be severe. The loss by internal conversion of a single deep-lying electron in xenon, for example, leads most frequently to a loss of 7 more electrons from the atom, and occasionally as many as 20 electrons may be thrown off as the atom readjusts itself.

If the atom is embodied in a molecular structure, the damage to the molecule may range from the slight to the complex. So far, only pure beta emitters have been examined. Molecular dissociation sometimes occurs, essentially in an unpredictable manner. When more molecules have been surveyed, embodying different kinds of radioactivities, the results promise to be of great interest to basic hot-atom chemistry.

At the Argonne National Laboratory, using activated material provided by the CP–5 research reactor, the emphasis has been on radioactive nuclei of short half lives. The energy differences between possible nuclear energy levels are determined by a study of emitted radiations, in a manner quite similar to that by which the electronic states of an atom are determined by means of optical spectra. The work has been greatly helped by development of complicated electronic equipment which not only surveys the gamma-ray spectra, but also can be used to determine the rapid emission in sequence of electrons and energy quanta. In this way, for example, the decay product of tin 105, known to exist in two energy states having half lives of 9.7 days and 9.4 minutes, was analyzed.

An important advance in these respects was the building and instal-

lation at Argonne of a 7.7-meter, bent-crystal, gamma-ray spectrometer [56] for the detection and analysis of gamma rays emitted as a result of nuclear reactions. With this instrument, for example, many new energy states have been found in the nucleus of gold 198, although this isotope had been studied intensively in the past. Much of the earlier work in this field involved discrepancies between the data of different investigators; such differences can now be resolved.

In the measurement of lifetimes of radioactive nuclei, a variety of techniques is employed. In general, a lower limit to which such measurements has been made is the order of one one-hundred-billionth of a second. A technique has been used at Argonne whereby the lower limit of such measurements has been increased some 100,000 times below that obtained before. This procedure has been based on measurements of the "Doppler shift," related to that phenomenon which makes a train whistle sound differently when the train is approaching or when it is leaving a hearer. The method has been successfully employed in determinations of the energy levels of transitory nuclei which are formed in nuclear reactors.

Properties of the Nucleus

Among the properties of nuclei, two of the most interesting are the closely related spin and magnetic moment. The first property arises because the nucleus apparently rotates in space like a top or gyroscope with a constant angular momentum; the second, as the name implies, is a measure of how strong a magnetic dipole or little "compass needle" the nucleus is. Any comprehensive theory of nuclear structure makes predictions about the values of these quantities for different nuclei, the success in doing this being one of the criteria by which a theory is to be judged. Much basic information on these properties for radioactive nuclei has been obtained by means of an atomic beam apparatus which can be used for measuring magnetic resonances.

Some interesting developments in nuclear physics are manifestations of the fact that most nuclei are not perfect spheres; rather, they possess an "out-of-roundness" making them either oblate spheroids (somewhat flattened, like a doorknob) or prolate spheroids (somewhat elongated, like a cigar). The latter is the more common type. The "liquid-drop" model of a nucleus, which had such success in accounting for the spectacular phenomenon of nuclear fission, has not been able to give a quantitative explanation or accounting for the spheroidicity of nuclei.

Theoretical work at Argonne has led to adoption of a "shell model" to explain the discrepancies. For "closed" shells, the distribution of the nuclear components is spherically symmetrical. In a nucleus with

[56] See pp. 66–67, Twenty-first Semiannual Report to Congress (July–December 1956).

unfilled shells a distortion occurs, and a nucleon moves in an elongated potential bowl similar to an elliptical celery dish. Nuclear moments of inertia calculated with this mode, using approximate potentials, have been closer to the experimental values than those calculatedwith the "liquid drop" model.

Orientation of Nuclei

Many nuclei have been found apparently to rotate about an axis much as the earth does, and nuclear properties depend profoundly on this rotation or spin. Under ordinary circumstances the axes of a group of nuclei are completely random in direction and this randomness complicates the study of the spin-dependent properties of nuclei. Such studies may be considerably facilitated, however, by forcing the axes of nuclei to orient predominantly along a chosen laboratory direction. In experiments at the Oak Ridge National Laboratory, nuclear orientation has been produced through the use of enormous crystalline electric and magnetic fields occurring in suitable solids, and by the direct application of the field of a large magnet. In this work it was necessary to cool the nuclei to very low temperatures, often within a small fraction of a degree of absolute zero.

Using these techniques, studies of the spin dependence of neutron capture by manganese 55, samarium 149, and indium 115 have been made. More recently, these techniques have been applied to the alpha emission of uranium 233 and neptunium 237 and to uranium 233 fission. These experiments help to establish a connection between the "cigarlike" shape of these nuclei and the detailed nature of the alpha particle emission and fission processes.

In the case of alpha emission these experiments demonstrate that the alpha particles emerge predominantly from the sides of the nuclear "cigar," rather than from the ends as had been expected. In fission experiments, the direction of flight of the fission fragments was found to bear almost no relation to the orientation of the nuclear "cigar," again a somewhat unexpected result in that current theory would predict a strong correlation.

Controlled Thermonuclear Research

The Commission has been conducting a program in the field of controlled thermonuclear research since 1951.[57] This program however was small in comparison with the present enterprise. It received its first major acceleration in the summer of 1953. The research

[57] See also pp. 96-105, Twenty-second Semiannual Report to Congress (January-June 1957); pp. 18-56, Twenty-first Semiannual Report to Congress (July-December 1956); pp. 90-92, Twentieth Semiannual Report to Congress (January-June 1956); pp. 62-63, Nineteenth Semiannual Report to Congress (July-December 1955).

effort is carried out at four major laboratories (Los Alamos Scientific Laboratory; Oak Ridge National Laboratory; Princeton University; and the University of California Radiation Laboratory, Berkeley and Livermore), and several other smaller university and industrial sites. At these sites, research is directed through a number of alternate approaches toward the development of a method that will achieve a controlled release of energy from nuclear fusion for the production of electric power.

A number of interesting developments have occurred, but all the work still is very much in the research stage, and it now appears that years of intensive theoretical and experimental effort may be expected to elapse before developing the first prototype of an operating thermonuclear machine that will yield more energy than it will consume.

Information on the technical developments in this field of research has been made available to certain categories of industrial groups in this country who are permitted access to classified information. Much information is completely declassified. In addition, an exchange of classified and unclassified information on research in the field of controlled thermonuclear reactions between the United States and United Kingdom was initiated in 1956 under provisions of the existing agreement of cooperation between the two countries. The two countries have also undertaken to draft a new classification guide that will make available to the public more of the information that is presently classified.

Representatives of both countries have exchanged laboratory visits and a number of meetings have been held both in the United States and at Harwell, England. At a meeting at Princeton University in October 1957, it was announced that recent experiments have indicated that appreciable progress has been made in several approaches being studied in the United States and the United Kingdom. Neutrons have been detected in several of the devices used in experiments; however, it is difficult to distinguish between neutrons produced by thermonuclear reactions from those arising from other processes of no interest to the controlled thermonuclear program. Further experimental work is being conducted to establish the origin of the neutrons. Should the neutrons prove to be thermonuclear in origin, an important step will have been made in the long-range efforts to develop a thermonuclear reactor for the production of economic power.

United States and United Kingdom reports, describing the current status of the work in both countries were made public on January 24, 1958. The Commission announced this publication on January 14 in a press release which quoted a message from Sir Edwin Plowden, Chairman of the U. K. Atomic Energy Authority, to Lewis L. Strauss, Chairman of the Atomic Energy Commission, which referred to

"misinterpretations" in both countries of the joint decision to make simultaneous announcements of the United States and the United Kingdom research on controlled fusion reactions.

On November 22, 1957, the following Joint Statement by Mr. Strauss and Sir Edwin was issued:

The United Kingdom and the United States have a close, cooperative arrangement for exchange of information on research in the field of controlled thermonuclear reactions. The agreement for cooperation between the two countries on civil uses of atomic energy has resulted in three conferences in 1957 for exchange of information on major phases of research into controlled thermonuclear reactions, one in Berkeley, California, in February, a second in Harwell, England, in June, and a third in Princeton, N. J., in October.

As was announced at the conclusion of the Princeton meeting, temperatures have been reached in controlled thermonuclear experiments in the two countries that suggest the achievement of neutrons from thermonuclear reactions, but more experimental work will be necessary to establish this as a fact.

Progress in the various experimental approaches to controlled thermonuclear reactions both in terms of negative findings and positive findings, is promptly communicated between the two nations. Thus, the United States benefits from the research results of the approaches being taken by the British and the results of the work on the half dozen or so approaches in the United States benefit the United Kingdom.

There have been statements in the news recently that have made unfortunate and confusing comparative observations about the U. K. and the U. S. programs in this field. Such observations are not only inappropriate in cooperative programs of this kind, but are seriously misleading.

On December 18, 1957, Mr. Strauss sent to the United States from Paris, where he was attending the NATO Conference, the following statement:

A report to the effect that the United Kingdom Atomic Energy Authority has suppressed announcement of success in the control of the fusion reaction at my request is completely false.

Research on this problem has been carried on in both countries independently for a number of years. In 1953 the United States greatly accelerated its research program on which we had been spending less than a half-million dollars a year and are currently spending an amount many times as large and, indeed, as much as the research teams have called for.

Since 1956 we have shared results and information on the project with the United Kingdom as a means of more rapidly reaching the goal we both seek.

Periodically it occurs that first one laboratory and then another will make a useful and illuminating advance. These advances have resulted in the production and maintenance of quite high temperatures in a plasma of light nuclei and the containment of such a plasma for very brief but nevertheless appreciable lengths of time. Much longer containment, however, must be obtained and much higher temperatures reached.

During these experiments on both sides of the Atlantic the emission of neutrons has been observed. Whether or not these neutrons are produced under thermonuclear conditions will only be ascertainable as a result of elaborate and protracted experiments.

At a joint meeting in the United States in October, attended by scientists from both British and U. S. laboratories, information was freely exchanged. It was

agreed that, although the temperatures reached in both countries suggested the achievement of neutrons from thermonuclear reactions, more work would be required to establish this as a fact.

The realization of the production of thermonuclear neutrons, if definitely established, would be an important step—but only a step—in the long range efforts to develop thermonuclear reactors for the production of economic power.

Dr. Arthur E. Ruark of the U. S. Atomic Energy Commission, who heads up the several projects in the United States, has just returned from meetings at Harwell, England, on the topic and reports that the current situation is substantially the one described above.

Three weeks ago when Sir Edwin Plowden, Chairman of the United Kingdom Atomic Energy Authority, was in the United States we issued a joint statement to the effect that comparative observations which had been published about UK–US progress in this field were seriously misleading. To emphasize the degree of collaboration, we arranged for substantially simultaneous publication of reports from some of the British and U. S. laboratories following the necessary concurrences on a Joint Classification Guide. The date for this publication will be as early in the new year as the papers can be made ready.

It may be important to restate that the development of economic thermonuclear power, although I am confident that it will be realized, is still remote. It will not, therefore, interfere with the necessary development of reactors for the production of electrical energy from the fission of heavy elements."

Chemistry

Transuranic Elements

In the nuclear chemistry program of the Commission, researchers have for many years been investigating the nuclear and chemical properties of transuranic elements, the nuclear decay schemes of the isotopes of representative elements from all regions of the periodic chart, and the mechanisms of high-energy nuclear reactions. The information gathered has been completely fundamental, and was assembled with no thought given to practical applications; nonetheless the data have been of practical importance in nuclear technology.

Measurements of the nuclear properties of the heavy nuclei, for example, are of great importance in determining possible applications in programs of long-term reactor development as well as in testing theories of nuclear structure. Since high-flux nuclear reactors operating for long periods of time convert appreciable fractions of uranium into plutonium, or into even heavier transuranic elements, it is important to know the nuclear characteristics of the isotopes produced. Other branches of science sometimes are aided unexpectedly: Many geochemical problems now are attacked by nuclear techniques based on recent information on the heaviest elements. Astrophysicists recently have suggested that the spontaneous fission disintegration of the isotope californium 254 may account for the 55-day component in the light intensity decrease of supernovae.[58]

[58] See p. 75, Twenty-first Semiannual Report to Congress (July–December 1956).

Four new elements have been discovered. The elements 99 (einsteinium) and 100 (fermium) were discovered in 1954 by a radiochemical analysis of debris from a 1952 thermonuclear explosion in which uranium had been converted to various heavier elements. This work was reported jointly by nuclear chemists from the University of California Radiation Laboratory, from the Argonne National Laboratory, and from the Los Alamos Scientific Laboratory.[59] The element mendelevium (element 101) was first made in 1955 at the University of California Radiation Laboratory by the bombardment of a minute amount of einsteinium (element 99) with helium ions in the Crocker 60-inch cyclotron.[60]

A joint effort by scientists from the United States, Great Britain, and Sweden resulted in discovery of element 102 in 1957. The element was produced by bombarding rare isotopes of curium provided by the Argonne National Laboratory, with carbon 13, provided by Harwell, in the cyclotron of the Nobel Institute in Stockholm. Scientists from the three laboratories participated in the experiment. The isotope of the new element is believed to have an atomic mass number of 253, a half life of 10 to 12 minutes, and is an alpha-particle emitter. The new element was named nobelium, symbol No, in honor of the institute where the bombardments were performed.

The initial discovery of the transuranic elements was followed in each case by systematic production and study of as many isotopes of the element as could be made by available techniques. The nuclear properties of the heavy element isotopes as a group have been thoroughly systematized. The chemical and physical properties of the heaviest elements are under continual study to improve radiochemical separation methods, to measure thermodynamic properties of heavy element compounds or ionic species, to determine electronic structures, to determine crystal habits of heavy element or rare earth compounds, to measure magnetic properties, etc. As part of this thorough study, the radioactive decay scheme of each isotope has been determined. These studies have involved the use of all modern techniques of nuclear spectroscopy, including the measurement of alpha, beta, and gamma radiations.

The new data on the heaviest elements have been compared with predictions of theoretical descriptions of the nuclei. There has been remarkable agreement of many experimental results with the predictions of the so-called unified model of the nucleus recently introduced by the Copenhagen school of theoretical physicists led by A. Bohr. This has stimulated much fruitful exchange of ideas between nuclear chemists in this country (more particularly, the University of California Radiation Laboratory) and the Copenhagen school.

[59] See p. 41, Sixteenth Semiannual Report to Congress (January–June 1954).
[60] See p. 51, Eighteenth Semiannual Report to Congress (January–June 1955).

One interesting experimental result stemming directly from the correlation of theory and experiment was the discovery in 1957 at Argonne National Laboratory of a new form of uranium 235—an isomeric form resulting from alpha decay of plutonium 239 with a half life of 26 minutes. Investigations of the nuclear energy levels of uranium 235 have been made at Argonne, the University of California Radiation Laboratory, and other Commission installations.

Investigation of the nuclear energy levels of uranium 235 resulting from the alpha decay of plutonium 239 have been made at the University of California Radiation Laboratory and in other laboratories. The success with which the nuclear level systems of many other heavy element isotopes could be correlated with the so-called "collective" or "unified" model of the nucleus made certain anomalies in the assignments of spin levels to uranium 235 even more baffling. As a result, a search was made for a low-energy nuclear isomer of uranium 235 and one was found. It has a half life, for isomeric transition, of 26.5 minutes plus or minus 0.2 minute, and a total decay energy of less than 200 electron volts, compared to thousands or millions of electron volts for most known cases of isomeric transitions. This is apparently the lowest energy nuclear transition observed to date. An investigation of the electron spectrum of the isomer has been partially completed.

The chemical properties of the transuranic elements and of the rare-earth group of elements are such that a separation of elements within each group is a much more difficult process than is usual in separating two elements. Many approaches have been made to this problem. Argonne made a successful application on the laboratory scale of the technique of extraction by contact of countercurrent liquids, a procedure economically employed in the petroleum and pharmaceutical industries. A study of the distribution coefficients, a measure of the effective separation between the two counter-flowing liquids, indicates that the system employed is suitable for large-scale applications. Pure berkelium, in the tetravalent state, has been efficiently separated from the trivalent lanthanides and actinides, including berkelium, by this procedure.

In April 1957, a new heavy ion linear accelerator (the HILAC) went into operation at the University of California Radiation Laboratory.[61] A similar accelerator is being constructed at Yale University to be used in the physics program. The University of California Radiation Laboratory accelerator is designed to accelerate heavy particles such as carbon ions, nitrogen ions, oxygen ions, and neon ions to such high energies that they are capable of initiating nuclear reactions with the very heaviest elements. Reactions of this type

[61] See p. 105, Twenty-second Semiannual Report to Congress (January-June 1957).

will aid in the extension of the periodic system to heavier elements than are known at present. The nuclear reactions themselves will include many new types which presently cannot be investigated. Considerable data should be obtained to help in the calibration of ranges of heavy ions in photographic emulsions.

Archeological Applications

A common problem in archeology is to determine whether objects found in a given location of an ancient civilization were manufactured nearby, or whether they were transported from a distant source. It has been possible to obtain information concerning the geographic origin of some objects by studying the nature and amount of radioactivity produced in them by irradiation with neutrons.

After an object has been irradiated by neutrons, some of its elements will emit characteristic radiations. Because the radiations from different elements can be measured separately, the relative amounts of the different elements present in the object can be determined. Ceramic pots made in a region usually show the same relative pattern of concentration of elements; ceramic pots from another region may have the same elements but a different pattern of constituents. Thus it is often possible to differentiate between different regions of origin.

After the test has been made the induced radioactivity will decay, leaving the object unharmed and essentially unchanged. Application of this method has been helpful in tracing transport of objects by ancient trade routes.

Meteorites are important materials for analysis in determining the cosmic abundance of the elements since meteorite materials have undergone less chemical fractionation than terrestrial materials found on the surface of the earth. The abundance of uranium and thorium is particularly interesting since quantities of these elements can be used for estimating age and heat generation.

Measurements of thorium and uranium in stone and iron meteorites have been made by using neutron activation to analyze samples. A special advantage of this analytical method is in determining concentrations of certain elements so minute that, in other techniques, contamination from reagents or dust can introduce appreciable errors.

Typical stone meteorites were found to contain of the order of 10^{-8} gram (one-one hundred millionth) of uranium per gram of sample; the amount of uranium in iron meteorites is at the limit of sensitivity of the method (10^{-11} to 10^{-12} gram), approaching one part in one thousand billion. The thorium content of stone meteorites ranges from about 1 to 50×10^{-12} gram of thorium per gram of sample. Iron meteorites contain far less thorium, averaging about 9×10^{-12} gram

per gram of the sample. These results are lower by factors of 10 to 100 than most previous determinations, which apparently were subject to errors due to contamination.

One deduction from these results is a value for the amount of heat produced by radioactivity in the main part of the earth's interior (thought to be similar in chemical composition to the stone meteorites) and in the central core of the earth (thought to be similar to iron meteorites). The results from stone meteorites, taken in conjunction with measurements on their helium, provide a way of estimating their ages. It has been found that about half of the meteorites studied have ages close to that of the earth 4 billion to 4.5 billion years. Three other kinds of meteorites appear to have been formed, or at least to have been involved in events catastrophic enough to invalidate the method, less than 1 billion years ago.

Rare Earths

Because of unusual similarities and differences, the rare-earth elements are ideal subjects for studies on the properties of metals and for combination in tailormade alloys. The investigation of these will lead to a better understanding of the ways in which the modification of one property affects other properties. In addition, a number of rare earths already have found application in the atomic energy program; i. e., for control rods, radioactive isotopes, portable X-ray units, etc.

The ever-increasing demand for pure rare earths makes it necessary that they be produced in quantity, and that methods be developed to lower the cost of production. The Ames Laboratory has been successful in developing processes for separating pure rare earths and producing rare-earth metals to the point that industry has taken over the processes and is producing the materials on a large scale.

Research is continuing on rare-earth separation in an effort to make the process more continuous and to cut production costs. Considerable amounts of pure rare earths have been made, and are available to research organizations. The Ames Laboratory is performing ion exchange separations with columns up to 30 inches in diameter, and still larger units are being used by industry. At Argonne National Laboratory, it was found that by raising the temperature at which the operation is carried out, easier separation and higher concentrations of rare-earth elements are obtained.

A process has been developed for utilizing xenotine as a source of heavy rare earths and yttrium. Xenotine is more readily available and cheaper than gadolinite, the best previous source, and, in addition, it has a greater rare-earth content. A new ion exchange sepa-

ration process for separating lutetium, yttrebium, thulium, erbium, and holmium from one another was developed.[62]

A semicontinuous process has been developed for preparing the rare-earth metals. A number of rare-earth alloys have been prepared, and their fundamental physical properties measured, including melting point, density, coefficients of thermal and volume expansion, resistivity, low temperature magnetic properties, heat capacity, etc. These data are important to a better understanding of the theories of the solid state.

Neutrino Research

Following the discovery of the free neutrino at the Commission's Savannah River plant by a group of Los Alamos Scientific Laboratory investigators,[63] an experiment was performed at Brookhaven National Laboratory to test the properties of neutrinos emitted by beta-decaying fission products in a nuclear reactor.

Approximately 1,000 gallons of carbon tetrachloride were irradiated by the Brookhaven reactor in an attempt to detect the production of radioactive argon 37 from neutrino capture in chlorine 37. The argon was removed by helium sweeping and was counted in a low-level detector. Results indicate that argon 37 was produced in amounts much larger than ascribable to cosmic radiation and the flux of fast neutron leakage.

With the assumption that all "neutrinos" emitted by the reactor are of the kind which may be captured by chlorine 37 to form argon 37, the experimental interaction cross section is calculated to be 1.1×10^{-45} square centimeters. According to the theory accepted until about 1 year ago and also according to the new, parity nonconserving, two-component neutrino theory of Lee, Yang, and Oehme, reactors should emit antineutrinos which cannot produce argon 37. Thus, the result of this experiment indicates that these theories are incomplete.

Recent modifications of the two-component theory propose that a mixture of neutrinos and antineutrinos is emitted from reactors. With this modification the theoretical cross section for argon 37 production by reactor "neutrinos" on the basis that all are of proper kind would be 5.2×10^{-45} square centimeters. Thus, if the modified theory is correct, the fraction 1.1/5.2, approximately one-fifth of reactor "neutrinos" are of one kind and the remainder different. Further experimental work is being conducted to verify the modified theory.

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[62] See p. 109, Twenty-second Semiannual Report to Congress (January–June 1957).

[63] See pp. 82–83, Twentieth Semiannual Report to Congress (January–June 1956).

Chemical Processing by Solvent Extraction

Basic research has led to development of more efficient, versatile, and economic chemical separations methods. These methods now are being used in various phases of the atomic energy program; for example, in recovery of uranium from ores, purification of uranium feed materials, and processing of irradiated reactor fuels. One method, liquid-liquid solvent extraction, which was unknown 10 years ago, is now widely used for these purposes.

Up to about 1950, much initial research and development emphasized the application of organic phosphate compounds to the separation of uranium and other metals. These early studies were carried out at different Commission laboratories, and resulted in development of processes using tributyl phosphate (TBP) for refining uranium and processing irradiated reactor fuels (e. g., the Purex and TBP processes). During the same period, other organophosphate compounds, such as the mono- and dialkyl-phosphoric acids, were found to be exceedingly efficient extractants for uranium.

Starting in about 1951, the application of solvent extraction techniques to recovery of uranium from ores was actively studied by a number of laboratories.

In that year, workers at Dow Chemical Co., Pittsburg, Calif., reported several mono- and dialkyl-phosphoric acids as suitable for the extraction of uranium from commercial phosphoric acid. The Dow studies led to development of the present solvent extraction process for the recovery of uranium from Florida phosphate liquors. Subsequently, the Dow group continued their studies on alkyl phosphoric acids, and in cooperation with the U. S. Bureau of Mines at Salt Lake City, developed a process employing dodecylphosphoric acid, or DDPA, to extract uranium from sulfuric acid leach liquors.

Also in 1951, an extensive program was initiated at Oak Ridge National Laboratory to study other organic reagents as extractants for uranium. Literally hundreds of reagents were screened and evaluated. This program included organonitrogen compounds as well as organophosphorus compounds. Work with organophosphorus compounds led to the process employing di(2-ethylehexyl)phosphoric acid, or EHPA, to extract uranium from sulfate leach liquors. Work with the organonitrogen compounds led to the process employing amines for similar application. The process employing amines has been termed the Amex process, while that utilizing dialkyl phosphoric acids is known as the Dapex process. Studies of amines as extractants of uranium were also carried out at the Battelle Memorial Institute and at the Rohm & Hass Laboratories.

The practical application of both the organophosphate and organonitrogen compounds to ore recovery processes was investigated in the Commission's Raw Materials Development Laboratory at Winchester, Mass., and also at the Bureau of Mines Experiment Station at Salt Lake City. The advantages of the processes for actual mill application have been demonstrated. Within the last year the processes have been successfully applied in four domestic ore-processing plants and one Canadian plant. Two other plants intending utilization of the processes are in the construction or design stage and at least four more are contemplating utilization of these processes. Interest in the method has spread to foreign countries and work now is being conducted in Argentina, Canada, England, France, and South Africa.

In addition to these specific applications, the process with modifications is applicable to such metals as vanadium, molybdenum, cobalt, nickel, and many others. The solvents also are proving useful as reagents in physiochemical measurements, analytical separations, nuclear fuel processes, and commercial separation and purification of other fine and heavy chemicals.

The Thorex process is another example of the application of basic research. This process now has successfully separated kilogram quantities of uranium 233 from neutron-irradiated thorium metal in the Oak Ridge National Laboratory pilot plant. Separation of uranium 233 and thorium from fission products, from protactinium, and from each other was satisfactory. This process will be important in reprocessing blankets of fertile material in breeder power reactors using thermal-energy neutron irradiation of thorium to produce uranium 233. A fundamental research program is being continued in this field.

In a joint program involving Oak Ridge National Laboratory and Vanderbilt University, a technique has been developed for measuring the rates of transfer of ions from one phase to another in systems containing two immiscible liquids; i. e., liquids that will not blend together. It has been found that the reaction rates for transfer of ions across the liquid-liquid interface are of the order of milliseconds. The two liquid phases are mixed at high speed in a venturi tube, and the phases are separated by filtration through a selective membrane which allows only one phase to pass. This technique is valuable in the study of fundamental solvent extraction operations.

Highly Pure Uranium

The Commission's fundamental research program includes the properties of elements and compounds used in nuclear reactors, such as the fuel itself or substances employed in construction of reactors.

To study the fundamental properties of uranium and its alloys, metal of high purity is needed. Argonne National Laboratory achieved highly pure uranium in crystal form by using a fused salt electrolysis process. A new method of casting had to be developed because considerable impurities were picked up in metallurgical processing. It now is possible to obtain microscopic samples of uranium which is better than 99.993 percent pure (by weight).

Pure single crystals of uranium have been prepared by the new method and these have been utilized in investigating the mechanisms proposed to account for deformation of uranium under compression.

Free Radical Research

Research work on free radicals by F. O. Rice, Catholic University, is an example of projects supported through contracts in universities and colleges.

One of the first to study free radicals, Rice developed the technique of forming free radicals at high temperatures and condensing them at low temperatures for study. This technique led to discovery of many new radical species and started a worldwide research effort in free radical chemistry.

Rice explained the color bands of the planet Jupiter as due to free radicals. The work has practical application in the field of rocket-fuel research. For his work in this field, Rice received the Hildebrand prize of the American Chemical Society in 1956.

The usual approach of the radiation chemist has been to irradiate materials and then to determine by chemical analysis how much of the material was destroyed or what kind and how much new material was formed. Often in the course of such studies, the final products arise from very reactive intermediates which have been postulated to be free radicals.

In addition to development of the high- and low-temperature technique, recent progress has been made in using microwave or magnetic resonance techniques to study some reactive intermediates formed by ionizing radiation.

These intermediates, formed in an early step in the radiation process, are paramagnetic in behavior if they are free radicals. If the materials are cooled to a very low temperature, the free radical intermediates become stably trapped, and may be studied by the way in which they absorb very short radio waves (microwaves) when placed in a strong magnetic field. In this way, atomic hydrogen was unambiguously identified at Oak Ridge National Laboratory as a substance formed when a variety of materials, including sulfuric, phosphoric, and per-

chloric acids, were cooled to a low temperature and irradiated with gamma rays.

Once atomic hydrogen was identified, study was directed toward the way in which the atomic hydrogen disappeared upon warming to form the final chemical products. A final product of irradiating these acids is hydrogen gas. In the one case studied thus far, sulfuric acid, it was found that the amount of hydrogen gas liberated in the warmed acid is directly related to the amount of atomic hydrogen observed in the frozen material.

Thus, for the first time, a radiation-produced intermediate material has been unambiguously identified and its relation to the final chemical product demonstrated. Because studies of this type greatly further a fundamental understanding of what happens when matter is irradiated, the method has been extended to a variety of other substances.

At Argonne National Laboratory a large number of organic gasses and solids have been irradiated and examined at low temperatures by sensitive paramagnetic resonance or microwave techniques.

In the case of the normal paraffins, the results show that a hydrogen atom is knocked off the respective molecule by radiation. It was also found that the reaction is usually specific with respect to the particular hydrogen removed from the molecule in spite of the large amounts of energy introduced. The results also gave information on the spatial distribution of the odd electron in the free radical produced, which has important implications with respect to understanding the way in which atoms are held together in molecules.

Radiochemistry

An important fraction of the Commission's effort in chemistry research is devoted to radioactivity, for example in isolating radioelements from nature, cyclotron targets, reactor fuels, or reactor-irradiated samples. Amounts isolated vary from a few hundred atoms, identifiable in special cases from their decay characteristics, to milligrams, grams, and kilograms for study of chemical properties or for other uses.

The Oak Ridge National Laboratory has special facilities for custom chemical processing of extremely radioactive materials, and has in addition access to rich sources of several long-lived fission products, largely through its pilot scale chemical processing plants. The laboratory recently isolated several tons of milligrams of promethium 147, a long-lived isotope of one of the synthetic elements, and many grams of neptunium 237, and isotope of the lightest transuranic element.[64] Great amounts of neptunium 237 also were re-

[64] See p. 106, Twenty-second Semiannual Report to Congress (January–June 1957).

covered at the Argonne National Laboratory by a solvent extraction process.

In addition, about 9.5 grams of americium, produced by neutron irradiation of plutonium, have been separated from plutonium metallurgical waste. A solvent extraction procedure in the metal recovery pilot plant then was used for the initial separation and this was followed by ion exchange for final purification. These weighable amounts permit ordinary chemical study of these elements, and may be expected to add appreciably to our knowledge of chemistry in an important region of the periodic table.

A radioactive, synthetic element of great interest among fission products is technetium. Since it has been available in relatively large amounts, it has been used for conventional chemical studies. In particular, some thought about the probable properties of the pertechnetate ion TcO_4 in relation to those of the chromate ion CrO_4 and other similar ions, led to the suggestion that it might be a corrosion inhibitor. This proved to be the case to an outstanding degree, very minute amounts of the ion affording corrosion protection to iron in a most dramatic way.[65]

Although the nature of the inhibition is not such as to suggest widespread, practical use, even if the cost problem were eliminated, the combination of extreme inhibition with the possibility of very sensitive analysis by means of the radioactivity of the element, has made possible a most fruitful study of the mechanisms of inhibition and of corrosion itself.

A study of the inhibiting nature of osmium oxide, and the pertechnetate, chromate, molybdate, and tungstate ions, has resulted in a new hypothesis regarding the nature of the inhibition or passivation process. This work and related studies using electrical potential measurements during corrosion have been recognized as one of the outstanding recent contributions to the understanding of corrosion, a problem that is of primary importance to the whole reactor development program of the Commission and a large part of the technological effort of the country.

Radiation Chemistry

Part of a program at Brookhaven National Laboratory for investigating the chemical consequences of absorption of radiation by matter has found that the distribution of radiolysis products as formed when hydrocarbon has been dispersed and adsorbed onto a solid surface is

[65] See p. 64, Nineteenth Semiannual Report to Congress (July–December 1955).

quite different from the distribution that occurs in a pure hydrocarbon phase. In comparison with results for the pure-phase radiolysis, some solids, such as finely divided silica, tend to increase the amount of hydrogen produced; others, such as iron oxide, reduce hydrogen production to very small values. The relative proportions of other hydrocarbons produced also are changed by the presence of the solids. Effects appear to be greatest when the ratio of liquid volume to solid surface area is such that the adsorbed liquid thickness does not exceed that of a unimolecular layer.

These results, which have potential industrial interest, may contribute also to a hypothesis on the origins of petroleum and natural gas. According to this hypothesis, oil and gas were produced in rock and sediment by radiolytic action of naturally radioactive substances on organic matter. The difficulty until now has been that the distribution of products formed in irradiation of organic material derived from rock was dissimilar to that found in natural gas and oil. The new results show that this dissimilarity does not constitute evidence against the validity of the radiation hypothesis but, on the contrary, is to be expected.

Neutron Diffraction Studies

Interesting additions to scientific knowledge have been made recently in research using special facilities or capabilities available at the Commission's laboratories; for example, neutron diffraction studies that require neutrons from a reactor. In relating the properties of a substance to its chemical composition, a detailed description of the atomic arrangement in the material is helpful. A highly successful attack on this problem has been made by X-ray study of crystals which can yield accurate information on the relative positions of atoms and the distances between them. An important limitation of the X-ray technique is that the smallest atom, hydrogen, is not readily located in this way—yet hydrogen is a most abundant constituent and plays an important role in determining the properties of a majority of substances.

The technique of neutron diffraction, as used at Oak Ridge National Laboratory and other national laboratories having neutron sources, does not have this defect, and data obtained in this way yield a detailed picture of the arrangement of all the atoms in a substance, hydrogen.

Among the substances investigated are a series of hydrogen-containing crystals of interest to the communications industry because of unusual electrical properties. Studies made of frozen water, H_2O, and frozen peroxide, H_2O_2, may lead to a better understanding of the

differences in the properties of these compounds. Work is in progress on the structures of amine acids, the building blocks of the proteins which make up a large fraction of all living matter.

Argonne National Laboratory carried out a complete structural analysis of the hydrides and deuterides of titanium and hafnium, and elucidated the effects on structures of these metals caused by introducing hydrogen. It found that the resulting brittleness may be ascribed to the directional nature of the chemical bonds formed, rather than to mechanical defects. These results are being utilized to improve theories of corrosion of these metals.

Stability of Oxides and Metals at High Temperatures

A knowledge of the chemical stabilities of oxides and metals at high temperatures is needed to enable ceramists, chemists, engineers, and metallurgists to fabricate fuel elements, to perform pyrometallurgical processing, and to design high-temperature reactors. Argonne National Laboratories used the Knudsen effusion method at temperatures of 1,700° to 2,500° centigrade to study the reactions of the oxides of aluminum, beryllium, magnesium, thorium, uranium, and zirconium with the metals tantalum and tungsten to produce gaseous products.

All these oxides except uranium dioxide were found to react in a vacuum significantly with tantalum to produce either the suboxides of aluminum (Al_2O), thorium (ThO), and zirconium (ZrO), or the gaseous atoms of beryllium and magnesium and gaseous tantalum monoxide. All except the dioxides of thorium, uranium, and zirconium react with tungsten to produce suboxides, Al_2O, or the atoms of beryllium and magnesium and gaseous tungsten trioxide. Thus oxides were shown to be more easily reduced to the gaseous metal by tantalum than by tungsten, and solid uranium dioxide is one of the most stable oxides at high temperature.[66]

From these data and previously reported measurements, equations have been derived which permit a calculation of whether a surmised oxide-metal reaction is important at elevated temperatures. This study suggests that the Group IV–A elements of the periodic table form stable gaseous dioxides and monoxides, the Group V–A elements form stable gaseous monoxides and dioxides, and the Group VI–A elements form stable gaseous trioxides and dioxides.

Another gaseous molecule, the high-temperature stability of which has been measured quantitatively, is triatomic carbon. This molecule will be important in predicting and establishing the stabilities of carbides at high temperatures.

[66] See p. 95, Twentieth Semiannual Report to Congress (January–June 1956).

Alkali Metal-Uranium Oxide Systems

Use as reactor fuels of compounds of an alkali metal and uranium oxide has received relatively little attention, and the available information in the literature is frequently contradictory, both in regard to the methods of preparations and the properties. The chemistry of the compounds also is of interest in some uranium-processing schemes. An investigation of the alkali metal-uranium oxides was undertaken for these reasons, as well as to further the comprehensive study of uranium-oxygen systems.

Alkali metal uranates were prepared by reaction of uranium oxides with alkali metal salts at high temperatures, and indications are that the diuranates $M_2(metal)U_2O_7$ have the greatest thermal stability.

Properties of these compounds in aqueous media also are under investigation. Extension of the work is planned to include oxide systems of uranium in the fourth and fifth valence-state with alkali metal oxides.

The fudamental physics and chemistry of molten salt systems represent a relatively untouched scientific field capable of many important applications in nuclear technology.

Fused salts may be used as solvents for the fuel in certain types of power reactors. They have the advantages of operating at high temperature and thereby gaining high efficiency, and of being easily processed when fission products reach too high a level. Fused salts also are used for carrying the heat from the reactor to the boiler.

In order for engineers to design reactor systems of this type, it is essential that basic information on fused salts be readily available. Recent studies on fused salts at the Ames Laboratory have yielded useful information on electrical conductivity, solubilities of metals in their molten salts, and water solubility in fused salts. A program of research at Oak Ridge National Laboratory aims at development and application of techniques suitable for the study of high-temperature fused salt systems.

Two techniques that have shown particularly promise: ultraviolet spectrophotometry and nuclear magnetic resonance. These methods ultimately can provide quantitative data concerning the chemical nature and stability of the complex ions which are characteristic of fused salt solutions. Attainment of results of this kind will depend, for example, on the careful analysis of ultraviolet band spectrum shapes, the influence of temperature on the band positions and intensities, and, in nuclear magnetic resonance, the effect of the chemical shift.

Since experiments on fused salts must be performed several hundred degrees above room temperature, a considerable effort in this program

has been directed to the difficult adaptation of spectrophotometry and nuclear magnetic resonance techniques to high temperatures.

At Argonne National Laboratory two techniques have been developed for removing and separating metal ions dissolved in fused salt matrices. The first is chromatography, a classical method wherein solutes are removed by an adsorption medium. This method now has been extended to fused salt systems, thus opening up a new field of investigation in the general area of high temperature separation processes. In the chromatographic procedure, a solution of metal ions such as iron (III), with a valence of three; cobalt (II), with a valence of two; nickel (II); calcium (II); uranium (VI); neptunium (V), etc., in a fused eutectic of lithium nitrate-potassium nitrate ($LiNO_3$–KNO_3)—the solution of these materials having their lowest mutual melting point—is flowed through a column packed with alumina or a similar material. The metal ions are absorbed on the oxide and may be removed preferentially by adding complex-forming anions like chloride (Cl^-) to the used salt solution.

A second technique under development for removing and separating metal ions involves the reaction with graphite of a solution of anhydrous chlorides of transition metals in a lithium chloride-potassium chloride (LiCl–KCl) eutectic, or in some other chloride fused salt, to form graphite-lamellar compounds. The alkali and alkaline earth metal chlorides do not react with graphite, as do other metal chlorides, and especially the chlorides of transition metals—3 groups of 3 metals each which have properties which are transitional between categories of elements in the periodic table of elements.

This reaction carried out in fused salt media is an extension of similar reactions known to take place between graphite and transition metal chlorides in the vapor phase. The application of procedures of this sort may be of some interest to various proposed fused salt fuel processing schemes.

A thorough spectrophotometric study of the chlorocomplexes of cobalt (II) in fused nitrate salts has been completed and has yielded for the first time reliable values for complexity constants, heats, and entropies of formation, of complex ion species in fused salts. Stable oxidation states of actinide ions in fused nitrates have been studied spectrophotometrically.

Metallurgy and Materials Research

Progress in reactor development, controlled thermonuclear research, weapons development, and fundamental physical research depends heavily upon development of materials with particular properties and characteristics. The Commission supports both basic

and applied studies on materials to obtain better understanding of the structure of metals and ceramics of special interest in the atomic energy program. These include fissionable and fertile materials as well as nonfissionable materials of interest as moderators, shielding, control rods, and fuel element cladding. In addition, investigations are made of the nature and properties of materials and the effects of nuclear radiations on these materials.

Studies of Radiation Damage

Bombardments with fast neutrons in a nuclear reactor produce atomic displacements in solids, and important changes in physical and chemical properties result. In many cases, an understanding of these radiation effects in solids is of great practical engineering importance. Research seeks not only an improved understanding of the solid state, but also the means by which undesirable radiation effects in solids can be minimized or avoided.

Although the mechanism by which irradiations affect the structure and properties of solids still is not entirely understood, a great deal of progress has been made recently. Effects have been studied in metals, oxides, metallic halides, and semiconductors bombarded by neutrons as well as by charged particles.

Crystals. Radiation effects also are of interest as new tools for probing the intricate connections between measurable crystal properties and crystalline imperfections. An outstanding problem is the absolute measurement of the number of imperfections introduced into a solid by various irradiations.

Recent work at Brookhaven National Laboratory has shown that neutrons of sufficiently long wavelengths (6–12 angstrom units range [67]) are scattered equally in all directions by isolated point defects in the solid, and that this isotropical scattering can be measured when crystalline effects are absent. The nuclear cross section for this type of scattering is accurately known from other measurements. Thus, if the scattering is experimentally measurable, an absolute method is at hand for determining the concentration of point defects. It is very difficult to measure directly the intensity of scattered neutrons, so the attenuation of a long wavelength neutron beam during its passage through the material is determined by measuring the intensity of the beam before it enters the material and after it leaves the material. From this information the concentration of point defects also can be determined.

[67] An angstrom unit is one-hundred-millionth of a centimeter.

Graphite. Experiments using this technique described above have been carried out on samples of graphite irradiated in the Brookhaven reactor at about 50° centigrade. For an exposure of 1.1×10^{20} fast neutrons per square centimeter, the fraction of displaced atoms in graphite was found to be 0.0263. This value was in good agreement with theoretical estimates. The change in neutron transmission by the graphite as a result of reactor irradiation disappears when the sample is annealed at high temperatures.

Basic work of this type has been of great use in reactor technology. For example, the large-scale annealing of graphite in the graphite-moderated Brookhaven reactor, an engineering experiment which considerably alleviated radiation damage in the reactor, could not have been performed without a sound background of basic information.

A principal difficulty in interpreting radiation damage in solids is due to the large number of different centers of damage produced simultaneously by radiation, since all these contribute to changes in properties. Considerable effort has been devoted at Argonne National Laboratory to devising selective experiments which may help resolve the role played by various specific damage centers. Particular emphasis has been placed on the effects of irradiation of graphite, widely used as a moderator for neutrons in reactors.

The rare isotope carbon 11 has been produced in graphite by fast neutron bombardment with the Argonne 60-inch cyclotron. The carbon 11 atoms were displaced from their lattice positions in a manner similar to the displacement of ordinary carbon atoms by neutron bombardment in reactors. The advantages of the cyclotron method are that carbon 11 atoms serve as radioactive tracers and their fate can be much more easily followed. The experimental results have aided greatly in understanding the radiation damage produced in graphite.

Water. Water, both light and heavy varieties generally used as moderators and coolants, also is subject to radiation damage. Much work has been done at Argonne in exploring and explaining the mechanism of such effects, not only in the pure substances but in aqueous solutions. A new chemical dosimeter, based on the oxidation of iron ions in the presence of copper sulfate, has been developed as a result of these investigations. It is relatively insensitive to the effects of gamma rays and of beta rays, but is quite reactive to neutrons with energies intermediate between fast and thermal ranges.

Graphite canning. The utilization of graphite as a moderator in a sodium-cooled reactor imposes requirements not met in other reactors. The economics of containing units of the moderator dictate using the

largest possible units, and requires accurate knowledge of the changes in thermal conductivity caused in larger units by radiation. The effect of radiation in driving gases out of the contained graphite determines the method of venting the containers. Finally, the consequences of possible failure of graphite containers depend upon the nature of the interaction between sodium and graphite, and upon measures taken to prevent or retard severe effects.

The temperature of graphite during irradiation has a marked effect upon the severity of its damage. Tests made by Atomics International at the Materials Testing Reactor, National Reactor Testing Station, Idaho, have shown that under heavy irradiation at maximum Sodium Reactor Experiment temperatures (1,000° Fahrenheit), graphite loses about a third of its power of thermal conductivity. At lower temperatures the loss was more severe. In order to monitor economically the actual experience in the Sodium Reactor Experiment constructed by Atomic International at Santa Susana, Calif., measured samples of graphite have been placed in test channels throughout the reactor, and are to be examined after various periods of irradiation.

The sizable volumes of carbon monoxide, deuterium (heavy hydrogen), and other gases absorbed in graphite during its manufacture can be readily released by heating graphite in a vacuum to very high temperatures. The degree to which these gases are released by irradiation at lower temperatures is being determined in the Sodium Reactor Experiment. Four graphite-containing facilities were provided in the reactor, each being continuously monitored for volume of gas contained, and two of which will provide gas samples for quantitative analysis. These experiments are expected to provide data for simplifying moderator unit containers.

Graphite coating. Studies of protective coatings applied directly to the surface of machined graphite shapes are being pursued. If a means of laying down a coating completely impervious to liquid sodium can be found, a marked economy in protection may be possible. More probable is the achievement of a degree of retardation of liquid sodium penetration of the graphite surface. Such a measure would permit using a "second line of defense" for graphite used in sodium-cooled reactors, and hence more economical, less stringent requirements upon the primary sodium containers.

In addition to the nuclear effects of absorbed sodium in graphite, erratic mechanical effects are associated with sodium-graphite reactions. Studies underway have associated these potentially troublesome physical dilations and mechanical cracking with unidentified impurities present in the graphite or sodium. Establishment of an understanding of the chemistry of sodium-graphite reactions will

permit a sound approach through the philosophy of a multiple line of defense to protect moderators, rather than an expensive, all-out effort to provide absolute protection.

Solid-state studies. In addition to the materials studies on graphite, certain solid-state physics research has been conducted on graphite.

Prior to reactor applications of graphite, very little detailed knowledge of the electronic characheristics of graphite was required. When graphite was subjected to nuclear radiations, its electronic characteristics became apparent and it was found that it behaved in many ways in a fashion analogous to semiconductors, the materials from which transistors are made. Physicists succeeded in correlating the properties as a function of induced radiation changes. The electronics of graphite now is better understood in many of its aspects than that of the other semiconductors.

Atomically, the electronic changes occur because atoms are knocked from their lattice sites in the graphite by the energetic nuclear radiations, and so the research has proceeded along two main fronts. On one hand, the electronics must be understood in order to interpret the changes that are observed and, on the other hand, the way in which the lattice is disrupted must be identified and described.

This dual attack, fruitful in graphite studies, now is being applied to other materials. Lattice defect studies are proceeding on materials with simple electronic structures in which the lattice defects profoundly affect the mechanical behavior. As a matter of fact, the mechanical behavior of solids is more nearly a function of the imperfection of the lattice than of any other single variable. The electronic properties of thorium and uranium are being studied both because of the importance of these elements to the atomic energy program and because they are scientifically anomalous in the large number of valence or bonding electrons that they contain.

At the present time it is possible to predict with reasonable certainty what will happen to graphite when it is subjected to nuclear radiation, and, from this information determine the suitability of graphite to a particular reactor application. The identification of radiation defects in metals and graphite has progressed reasonably well, but several controversies and uncertainties still remain. The electronic properties of thorium and uranium have just begun to be subjected to the detailed analysis required for complete understanding. In the case of thorium, a hopeful beginning has been made in ascribing the properties to pockets of electrons and holes in the electronic structure that are theoretically well founded, and so far experimental results have supported theory.

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Basic Mechanisms of Radiation Damage in Metals

Basic studies of the effects of nuclear radiations on metals have been conducted for two reasons: to attain an understanding of the mechanisms of changes in properties, and particularly to gain an insight into the fundamental mechanisms governing the plasticity of metals.

It has been found necessary to make nuclear bombardments at very low temperatures so as to "freeze-in" the damage. Otherwise, even at temperatures as low as −243° C. (243° below zero centigrade), an annealing phenomenon occurs. This annealing process has been thought for some time to reflect the return to normal lattice sites of interstitially lodged, displaced atoms. However, recent experiments in the Oak Ridge graphite reactor at temperatures approaching that of liquid hydrogen have shown that this view is probably incorrect. Using changes in electrical resistance of samples to measure radiation damage, it was found that the low-temperature annealing process could be stopped by adding to a metal as little as 1 percent of either oversized or undersized atoms of an impurity.

Reactor radiations are known to cause substantial increases in the elasticity of a metal, and heavy bombardments will sometimes increase the elastic limit as much as one-hundred-fold. A high-purity, single crystal of copper irradiated at −253° C. showed a sizable increase in its elastic limit. A subsequent annealing of the sample at −193° C. did not change the yield stress from that at −253° C., a result which suggests that thermal annealing at low temperatures cannot be explained by displaced interstitial atoms returning to a normal lattice site.

Fundamental information on the nature of the defects responsible for plastic flow in metals has been obtained.

Oxidation of Metals

Lack of resistance to corrosion may severely limit application of many metals with desirable high-temperature strengths and low neutron cross sections in the problems of nuclear technology. If the fundamental mechanism of oxidation reactions on metals could be understood fully, the design of alloys with specific oxidation-resistant properties would become practicable. Thus a program of basic research is being pursued at Commission laboratories. Oak Ridge National Laboratory is conducting studies of reaction kinetics and of the structure and surface topography of oxide films on various metals. Electron and X-ray diffraction, electron microscopy, and interferometry have been applied to the problem to observe in detail the

physical and chemical qualities of a growing oxide film by which it protects the metal or fails to do so.

A study was made first of the oxidation rates of the alkali metals. This work yielded the surprising result that, under certain conditions, protective oxides could be formed by these most reactive metals. The investigation has recently been extended to the important metals of Groups IV–A and V–A of the periodic chart, including zirconium, niobium (columbium), and tantalum. The oxidation characteristics of niobium have been found to be of particular interest, since both a protective, then later, a nonprotective oxide, may be formed at the same temperature. Careful microscopic examinations have revealed changes in surface topography of the oxide which can be correlated with the oxidation rate. These surface phenomena may be further associated with the detailed oxidation mechanism and the results may assist a better understanding of the conditions controlling the degree of protectiveness of an oxide film.

A portion of the effort of the oxidation research program has been devoted to evaluating the effect of reactor radiation on oxidation of metals.

Pure Metal Research

The physical properties of solids are markedly influenced by the presence of impurities. For example, chromium which is ductile in a very pure state becomes glass-brittle when its composition includes nitrogen in only a few parts per million. The electrical properties of some materials also are affected by different impurities. This is particularly true of semiconductors used in electronics, the electrical properties of which are very sensitive to nuclear radiation.

A major deficiency of research in the fields of metallurgy, solid-state physics, ceramics, and ultimately reactor development, has been the lack of high purity materials in the form of single crystals. The materials of interest include metals, oxides, metal halides, and semiconductors, such as germanium and silicon in elemental form and certain intermetallic compounds which are extremely affected by radiation. In recognition of this deficiency, the Commission has initiated a program which includes (*a*) a pure metals research program at the Ames Laboratory, which will include studies and preparation of uranium, thorium, niobium, vanadium, calcium, hafnium, and the rare earths (several pounds of high purity calcium (99.9 percent) have been prepared, a few hundred grams of extremely ductile high purity vanadium metal were also prepared, and sizable quantities of high-purity calcium, vanadium, and the other metals are expected to be made in the next year); (*b*) a survey of the purity and availability of

materials from American suppliers; and (*c*) a survey of the needs of Commission laboratories and of certain university contractors for pure materials.

Because of known and anticipated requirements and in recognition of the problems associated with purification and crystal growth, the Commission entered into the following contracts:

(*a*) With Flow Corp. of Arlington, Mass., for studies on the purification and growth of single crystals of metals; (*b*) with Anderson Physical Laboratory, of Champaign, Ill., for studies on the purification and growth of single crystals of metal halides; and (*c*) with National Carbon Co., of Cleveland, for studies on the purification and growth of single crystals of semiconducting materials.

New Materials

Research on the properties and structure of materials has resulted in the application or the potential application of a number of materials to the developmental programs of the Commission, some of which is reported here.

Uranium oxide. The uranium dioxide UO_2 now appears to be an excellent fuel material for nuclear reactors. Research and development on this material is being carried out under a coordinated Commission program through its divisions of research and reactor development. The chief problems with most nuclear fuels are poor corrosion resistance and dimensional instability when subjected to neutron irradiation. UO_2, however, is a relatively inert material. It is nonreactive, with almost all the materials with which it might come in contact in a reactor, the coolant, cladding materials such as stainless steel and zirconium, and matrix metals used to disperse the fuel in some fuel elements. Other advantages of UO_2 are that it does not change phase between room temperature and its melting point; it is easily fabricated by the usual ceramics techniques; it is adaptable to fabrication by remote-control processes; and it is stable under irradiation.

Basic and applied research on various properties and characteristics of UO_2 have made it possible to use this material as a nuclear fuel. Investigations have been carried out on: methods of preparing UO_2 powder; chemical and physical characteristics of the powders; fabrication of UO_2 into solid bodies; sintering characteristics of the oxide and the effect of additives; physical and mechanical properties of solid UO_2 bodies; reactions of UO_2 with other oxides, metals, steam, and air; and effects of irradiation on UO_2 bodies.

Another interesting new material now being investigated for its possible application to the atomic energy program is the metal niobium (columbium). Niobium has a fairly low neutron cross section, has excellent strength and ductility at high temperatures, resists corrosion, and can be fabricated and welded easily. A number of disadvantages to the use of niobium must be overcome and these are being studied.[68]

Materials for liquid-metal fuel reactor. The Liquid-Metal Fuel Reactor Experiment being developed at Brookhaven National Laboratory by the Babcock & Wilcox Co. is based on uranium dissolved in liquid bismuth as a fuel, with a slurry of thorium bismuthide in liquid bismuth as a breeder blanket. This system eliminates the metallurgical problem of dimensional instability of solid uranium under irradiation, but the liquid-metal fuel reactor intensifies corrosion problems. Metallurgists for some time have been investigating the corrosion and erosion of container materials and graphite by liquid metals. They have established constitution diagrams for the appropriate combinations of bismuth, lead, tin, uranium, thorium, etc., which are of importance in this reactor.

This research, which has been both basic and applied, has shown that: (*a*) a chrome-molybdenum steel appears to be satisfactory as a construction material for the reactor and the heat transport system; (*b*) austenitic stainless steel should be satisfactory for use in the chemical processing system; (*c*) no serious difficulties should develop upon using graphite in the liquid metals; (*d*) there is sufficient uranium solubility in liquid bismuth for use in a reactor; and (*e*) there are effective corrosion inhibitors such as zirconium and titanium.

Considerable progress has been made in using inhibitors to control corrosion in liquid bismuth systems. This corrosion is due to the constituents of the steel container dissolving in the bismuth. Tests show that if zirconium is dissolved in the bismuth solution, little or no corrosion of the steel container takes place. Considerable research has been directed toward obtaining an explanation for this inhibiting effect. Zirconium was found to form a protective coating on the steel by reacting with nitrogen, present as an impurity in the steel, to form a zirconium nitride. This zirconium nitride layer effectively prevents corrosion of the container by the liquid metal solution.[69]

New ceramic fuel element. Research in ceramics led to development of a new fuel element which shows considerable promise, particularly in gas-cooled reactors. The fuel element was prepared at the Oak

[68] See pp. 109–110, Twenty-second Semiannual Report to Congress (January–June 1957).
[69] See pp. 98–99, Twentieth Semiannual Report to Congress (January–June 1956).

Ridge National Laboratory by powder metallurgy techniques whereby uranium dioxide or uranium silicide is dispersed in a compact silicon carbide. The high-temperature properties of the carbide are enhanced by a siliconizing treatment so that the fuel element can operate at higher temperatures than most others currently available.

Corrosion-resistant metals. Basic and applied research on corrosion of structural and fuel materials for reactor applications led not only to an improved understanding of corrosion mechanisms but several materials with improved corrosion resistance. An alloy of aluminum containing 1 percent nickel has been developed which makes it possible to use an aluminum alloy in water at much higher temperatures than possible heretofore.

Studies on uranium alloys have led to new fuel alloys with improved corrosion resistance. Several uranium alloys containing zirconium or niobium or both have been developed and put into application.

Part Two

Major Activities in Selected Atomic Energy Programs

Production of Special Nuclear Materials

Production rates of the various special nuclear materials for the last 6 months of 1957, the period covered by this report, equaled or exceeded the established goals. Production facilities operated satisfactorily, and all scheduled requirements for the military and civilian programs were met.

Heavy Water

In accordance with announcement made on December 4, 1956, that Commission needs no longer required operation of two heavy-water plants, production at the Dana, Ind., plant was reduced gradually and operations were discontinued on May 24, 1957. Work involved in placing the plant in standby condition was completed August 23, and the Commission's Dana Area Office was closed November 1.

Heavy water continues to be produced at a reduced rate at Savannah River, S. C.

Plant Construction

Construction of the feed materials production center at Weldon Spring, Mo., continued on schedule during this reporting period. The refinery, which began startup operation in May, now is operating above design rates. Construction of the laboratory was completed on August 23.

Operation of the feed plant at Portsmouth, Ohio, was scheduled for early next year.

New Production Reactor

After reviewing alternative concepts for a plutonium-producing reactor, the Commission assigned responsibility for design and development work on a new large-scale reactor to General Electric Co. at Hanford, Wash. Considerable information needed for the reactor's engineering design has been developed at Hanford as part of the continuing research and development program there.

A contract for preliminary design of supporting facilities required for operation of the reactor was awarded on November 5 to the firm of Burns & Roe, of New York.

Military Applications

During the July–December period of this report, emphasis continued on research and on development activities designed to improve and increase the United States arsenal of nuclear weapons. Tests were conducted. Development programs continued on small weapons which can be used for defensive purposes, and on weapons so designed as greatly to reduce the radioactivity remaining after detonation.

In accordance with Presidential direction, production continued on a variety of nuclear weapons, including particularly weapons designed for defense against attack.

Weapons Testing

Operation Plumbbob

The Nevada Test Organization detonated 24 nuclear devices and conducted 6 safety experiments at the Nevada Test Site near Las Vegas, Nev., in support of the programs of the Commission, the Department of Defense, and the Federal Civil Defense Administration. The operational period of the series, known as *Plumbbob*, extended from March 15 through October 12.

The tests were held to attain new knowledge important to the defense of the United States and the free world, with a major objective of further developing defensive weapons. Studies of weapons effects were conducted to improve military and civil defense against nuclear attack. Biomedical research programs included expanded projects for evaluating the immediate and the delayed effects of radioactive fallout (see section on Biology and Medicine, following). Some tests contributed to studies on weapons producing greatly reduced residual radioactivity.

Ten tests of full-scale nuclear devices were of primary interest to the weapons development program of Los Alamos Scientific Laboratory, Los Alamos, N. Mex. Twelve tests were of primary interest to the development program of the University of California Radiation Laboratory branch at Livermore, Calif. Two, utilizing Los Alamos devices, were of primary interest to the Department of Defense. One of these was a major study of effects from a relatively low aerial burst of a device suspended from a balloon, and the other was a test of effects from a high-altitude airburst of a nuclear warhead in an air-to-air rocket which was launched by an Air Force plane and detonated at a point in space.

Of the 6 safety experiments, 5 were of Los Alamos devices and one was of a Livermore device, all the tests being related to safe handling and storage of nuclear weapons. Two safety experiments at the

Nevada Test Site were conducted in December by Los Alamos Scientific Laboratory. They were similar to the six experiments conducted earlier as part of Operation *Plumbbob* in order to determine the safety of nuclear weapons in handling and storage.

In the original series of safety tests, 3 were positioned on the surface of the earth, 1 was in a horizontal tunnel dug into a mesa, and 2 were in vertical shafts drilled deep into the earth.

New test methods. Two new methods of placing full-scale nuclear devices for tests—suspended from a balloon and deep underground—were considered satisfactory in application. The use of captive balloons to lift the experimental device to an altitude sufficient to prevent the detonation fireball from reaching the ground appreciably reduced local fallout of radioactive materials. Thirteen of the full-scale nuclear tests utilized this method, and none resulted in significant fallout in the test region.

In the second method, a tunnel was dug horizontally into a mesa and at its end was bent in almost a complete circle. A device of known low yield was placed in the chamber at the tunnel's end. This was done so that the detonation would seal off the nearby main tunnel with rocks before radiation products could escape. The experiment's objective of containing all radiation was achieved.

Both these methods involved developing new instrumentation to obtain diagnostic and effects data. Both proved successful and can replace tower detonations in many, but not all, future tests on the continent.

Features of tests. Most *Plumbbob* tests were used by the Armed Forces for orientation of personnel and for training. One test was used by the Marine Corps for a vertical envelopment troop exercise, and another was used by the Army to test its new pentomic organization of divisions and to test the use of helicopters in tactical situations.

Eleven shots were observed by news representatives of the United States, as well as by Federal, State, and local officials, and personnel of other Federal agencies concerned with civil defense as the guests of the Federal Civil Defense Administration. Through arrangements coordinated by the State Department, newsmen representing newspapers of other countries of the Free World which have special defense arrangements with the United States were invited to view these shots, and 21 foreign newsmen observed four of the detonations.

A small number of analyses and experiments was undertaken during Operation *Plumbbob* in connection with the Fireball Chemistry Project, established to study ways and means of reducing the accessibility of fallout radiostrontium to the biosphere and in particular to the human body.

Silica sand was added to the fireball of certain test shots and samples of fallout debris were analyzed for solubility. Fallout debris from previous tests in which large amounts of steel and aluminum were present in the fireball also were analyzed for solubility. Laboratory studies are being conducted to determine the relative capacity of a wide variety of materials to capture strontium 90 under conditions simulating those of a cooling and condensing fireball. Further experiments on this project are planned for the 1958 test series at Eniwetok Proving Ground.

Peaceful Uses of Weapons

A program of investigation into the possible nonmilitary uses of nuclear explosive devices, known as "Project Plowshare," was established at the University of California Radiation Laboratory at Livermore in July 1957. At present, primary emphasis is being given to the potential excavation application.

The underground test held at the Nevada Test Site, September 19, to determine the feasibility of underground testing is expected to provide information which will be of interest to this project. Drilling and investigation of the underground shot was continuing in December.

Testing Activities at Tonopah

Sandia Laboratory continued its utilization of the Tonopah Ballistics Range, activated in the spring of 1957, to determine the ballistic characteristics of inert weapons shapes dropped from high-speed aircraft.

Sandia also began in July a series of rocket tests intended to develop equipment, instrumentation, and procedures for high-altitude research. Rocket firings were held periodically throughout the 6 months.

1958 Tests at Eniwetok

In the absence of a safeguarded disarmament agreement, preparations are underway by the Atomic Energy Commission and the Department of Defense for a series of nuclear tests to begin in April 1958 at the Eniwetok Proving Ground in the Pacific. The United States repeatedly has stated its willingness to suspend nuclear tests as part of disarmament agreement. Until such an agreement is attained, continued development of nuclear weapons is essential to the defense of the United States and of the free world. The test series was announced on September 15.

The forthcoming series will advance the development of weapons for defense against aggression whether airborne, missile-borne, or otherwise mounted. Information on the effects of weapons will be obtained for military and civilian defense use. Test operations will be governed by the declaration made in the Bermuda comminuqué on March 24, 1957, of the intention of the United States "to conduct nuclear tests only in such manner as will keep world radiation from rising to more than a small fraction of the levels that might be hazardous."

An important objective of the tests will be the further development of nuclear weapons with greatly reduced radioactive fallout so that radiation hazard may be restricted to the military target. This principle was first proved in the Pacific test series of 1956.

As in the past series, a control area surrounding the proving ground will be established to safeguard air and sea traffic and will be defined well in advance of the commencement of operations.

Weapons Facilities

The previously reported expansion of weapons production facilities [1]—at the Rocky Flats plant near Denver, Colo., at the Iowa Ordnance Plant at Burlington, Iowa, and at the Pantex Ordnance Plant near Amarillo, Tex.—were essentially completed and the expanded facilities were put into operation.

The plant located at Buffalo, N. Y., operated by ACF Industries, Inc., has been closed as a production facility. The work formerly done at Buffalo will be performed in other plants. Because of the termination of this contract, the Buffalo Area Office will be closed.

A Clearwater Area Office was established to administer a contract for production of electronic equipment at the Pinellas Peninsula Plant, near Clearwater, Fla., after February 1958. The plant is currently operated by General Electric Co. under a subcontract with the Sandia Corp., prime contractor under the Albuquerque Operations Office.

Biology and Medicine

The Commission expanded its surveys and studies of radioactive fallout from weapons tests during the last 6 months, and describes the work in this report. The Commission also describes the precautions taken to protect residents near the Nevada Test Site and the population generally during the spring and summer series of weapons tests, and includes a table of radiation exposures at 138 localities mostly in Nevada and Utah, but also in Arizona and California.

[1] See p. 10, Twenty-first Semiannual Report to Congress (July–December 1956).

This section also reports highlights of preliminary data from weapons tests in which studies of effects from atomic explosions were studied from the standpoint of civil defense.

Construction of the Brookhaven Medical Research Center, at Brookhaven National Laboratory, Upton, Long Island, N. Y., progressed with the hospital building and laboratory essentially complete, and the reactor wing 75 percent complete. Acceptance testing of the control rod drive has been completed. Fuel element fabrication will be started in February by Sylvania-Dow-Corning, Inc., Bayside, Long Island.

The Commission revised its standards on permissible levels for long-time exposure to radiation.

Plumbbob Precautions and Measurements

The precautions taken to protect people and property in areas near the Nevada Test Site and the general population from adverse effects of Operation Plumbbob were essentially those described in earlier reports.[2] Further improvements were undertaken.

During Operation Plumbbob, the test organization postponed test shots on 76 different occasions because weather conditions were unfavorable for providing maximum protection to inhabited areas from the effects of the detonations. Four postponements were ordered because of predictions that the damage from blast might result—the first time that Nevada shots have been postponed because of forecasts of possible blast damage.

The Commission reviews the precautionary methods in the following pages and gives details on some aspects of the safeguards employed.

Measures Taken To Protect the Public

The Nevada Test Site, an area of about 600 square miles, is located in southwestern Nevada adjacent to an Air Force gunnery range of 4,000 square miles. It is surrounded chiefly by areas which are sparsely populated and this in itself is a major safeguard. The test site was closed to the public. Before a detonation, special surveys from the air assured that no persons had wandered into the area, and test shots were publicly announced in advance. As reported in the section on military applications, steps were taken to reduce fallout by firing devices from high towers and balloons. One nuclear detonation was fired deep underground to eliminate fallout completely.

Following each detonation, aircraft from the test organization

[2] See pp. 207–215, Twenty-first Semiannual Report (July–December 1956), for detailed discussion of this subject.

tracked the cloud of radioactive material until radioactive decay or dispersion made it no longer readily detectable.

Another safeguard was provided by an advisory panel of experts in the fields of biology, medicine, blast, fallout prediction, and meteorology which weighed all factors involving public safety before each nuclear detonation. An adverse decision by this panel would result in canceling any shot.

A large Weather Prediction Unit functioned at the Nevada Test Site. The Air Weather Service of the Air Force had approximately 100 men assigned to primary support duty. They manned 10 weather stations set up for the Nevada tests, and also provided an average of 3 weather flight missions off the Pacific coast every 2 days. These proved invaluable in predicting air movements in the test area.

The U. S. Weather Bureau, in addition to providing to the prediction unit nearly a dozen highly trained forecasters and technicians, maintained an extra weather observation site for the test period and performed special observations.

Weather forecasts of changes that might preclude the firing of a shot were obtained up to 1 hour before the shot. About 2 hours prior to each scheduled shot, local conditions were checked by balloon runs in the firing area to verify that high-altitude winds were conforming to forecast patterns and speeds.

The Fallout Prediction Unit was comprised of 5 to 6 specialists whose sole task was to predict, on the basis of weather data and other factors, the fallout pattern for each shot.

The Blast Prediction Unit manned 8 permanent and 4 mobile microbarograph stations. High explosives were detonated before the regular nuclear test, and the blast waves were measured in surrounding areas. These data were then scaled up to the expected blast from the nuclear detonation. Theoretical calculations of blast effects also were made on the basis of predicted meteorological conditions.

Representatives from the three prediction units briefed the advisory panel of experts each time a detonation was scheduled. The test shot was postponed if last-minute data indicated the prospect of significant fallout or blast damage for any inhabited area. A shot could be canceled at any time up to a few seconds before the scheduled detonation.

The innovation of detonating devices suspended from a balloon 1,500 feet above the ground during predawn hours created a new problem in public protection. To safeguard against possible temporary flash blindness caused by direct viewing of the device's fireball at detonation, and to avoid startling drivers, 6 to 9 roadblocks were established at appropriate places on public highways before each of the 5 high-balloon shots. Local officers and Nevada State Highway

Patrol troopers stopped motor vehicles at the roadblocks, and Commission personnel passed out instruction sheets and distributed a booklet entitled "Atomic Tests in Nevada."

The effectiveness of safety precautions is evidenced by the record of locality radiation exposures (see table I) and the absence of major structural damage in nearby occupied areas.

Of more than 9,000-participants in *Plumbbob*, only 18 received radiation exposure in excess of 5 roentgens. Highest exposure was 10.1 roentgens.[3]

National and Worldwide Monitoring System

The offsite monitoring program during weapons tests was a cooperative effort among the Commission, the U. S. Public Health Service, and the U. S. Weather Bureau. It provided maximum coverage of the country for measuring radioactivity levels resulting from weapons tests.

One system, a joint effort of the Commission and the Public Health Service, provided for monitoring 17 zones close to the test site. Each zone was the responsibility of a team which monitored its assigned territory, and provided liaison with people living within the zone. Mobile support teams at the test site were ready for service if needed in any of the zones.

The test organization had four additional monitoring programs:

One program provided data needed for monitoring radiation as far as 275 miles from the test site.

A second program used automatic measuring instruments placed in 29 communities around the test site and connected to headquarters by commercial telephone lines. By placing an ordinary telephone call, the control point could receive signals translatable in a matter of seconds into gamma-radiation dose rates.

In a third program, 17 automatic instruments located in areas adjacent to the test site made permanent records of gamma-dose rates continuously throughout the test series.

The fourth program was carried out by aerial surveys with special gamma-detection instruments.

Measurements remote from the test area were made by 38 Public Health Service monitoring stations, and 12 Commission installations. Gummed-paper collections of fallout were made by 92 Weather Bureau stations within the United States, and also at 74 locations

[3] The recommendations of the National Committee on Radiation Protection and Measurement for exposures in radiation controlled areas are: "The maximum permissible accumulated dose, in *rems*, at any age, is equal to 5 times the number of years beyond age 18, provided no annual increment exceeds 15 *rems*." A *rem* is a unit of radiation measurement for biological effects roughly equivalent to the effect caused by 1 roentgen of X-rays.

outside the United States through arrangements with the Department of State, Weather Bureau, U. S. Air Force, and U. S. Navy. The list of collection stations is in Appendix 11.

Fallout Measurements in Test Site Area

The Commission reports in this section the highest levels of radiation exposure from external gamma radiation, from airborne radioactivity, and from radioactivity in water, expected to accrue as a result of fallout from *Plumbbob* tests.

External gamma radiation. Before Operation *Plumbbob* began, the Commission established a standard level for total accrued external radiation exposures resulting from test fallout, including *Plumbbob*, that would be considered acceptable for localities near the test site. The *Plumbbob* guide level of 3.9 roentgens was not exceeded at any monitored station; at two, estimated doses were over 3 *r*, and at two over 2 *r*. Most of the localities showed estimated dosages far below even the operational guide established, as shown in Table I on the following pages. In this table, the Commission gives the best estimates of the levels that may eventually accrue as a result of Operation *Plumbbob*.

The table expresses exposures in terms of "estimated dose" because the entire radiation exposure from fallout does not occur instantaneously, but accumulates for many weeks and months during which the radioactivity of the fallout materials gradually decays. It will be necessary to record the radiation levels for longer periods of time to make final estimates, but the final totals would not be expected to differ markedly from the estimates based on current data.

The table also reports estimated total exposures accumulated in the localities cited for all nuclear tests held at the Nevada Test Site, including the Plumbbob series.

Airborne radioactivity. To evaluate the radiation doses to the lungs from inhalation of concentrations of radioactive fallout materials in the air, the Commission estimated not only the amount of activity in the air and the duration of exposure in each locality but also the lapse of time after a detonation. Measurements and calculations of possible radiation exposures to the lungs as a result of *Plumbbob* fallout showed that the highest total accumulated dose (recorded at Eureka, Nev., with a population of about 500) was less than that to be expected from breathing for a period of 2 weeks air which contained only the amount of radioactive materials that occurs naturally.

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TABLE I.—PRELIMINARY ESTIMATES OF RADIATION EXPOSURES IN LOCALITIES, ESTIMATED DOSES

COMMUNITY	POPULATION	EXTERNAL GAMMA RADIATION PLUMBBOB	CUMULATIVE FOR ALL TESTS
		(Roentgens)	*(Roentgens)*
ARIZONA:			
Beaver Dam Lodge (near Littlefield)	6	0.21	2.21
Littlefield	44	.25	[1] 1.25
Mount Trumbull	30	[2] 0	.16
Short Creek	90	0	1.60
Wolf Hole	10	0	1.30
CALIFORNIA: Quincy	1,330	.10	.1
NEVADA:			
A & B Mine (SW. of M & M Mine)	4	.10	.1
Acoma (23 miles SE. of Caliente)	16	0	3.0
Alamo	250	.02	1.32
Apex	15	0	.10
Ash Springs	5	.01	.61
Austin	520	.14	.19
Baker	60	.10	.90
Barclay (22 miles SE. of Caliente)	38	0	2.00
Bardoli Ranch (8 miles E. of Nyala)	4	.28	.28
Basalt	5	.17	.17
Beatty	550	.10	.15
Belew Ranch (old Adaven Post Office)	3	.30	.30
Belmont	6	.70	.70
Buckhorn Ranch	12	.04	.94
Bunkerville	250	0	4.30
Butler Ranch (30 miles S. of Alamo)	2	3.22	3.22
Caliente	970	0	.70
Carp (35 miles S. of Caliente)	Variable to 25	.20	3.80
Charleston Lodge	60	0	.15
Clarke's Station (32 miles E. of Tonopah)	Variable 0 to 5	0	.80
Coaldale	25	.45	.45
Crestline	22	0	.70
Crystal	5	0	4.00
Crystal Springs	5	.08	1.08
Currant	75	.27	.77
Dodge Construction Co	175	2.20	2.20
Dry Lake	20	0	1.00
Duckwater	50	.02	.82
East Ely	1,000	0	.60
Eden Creek Ranch (64 miles SW. of Crystal Springs).	0	0	.70
El Dorado	3	.36	.36
Elgin (transient railmen)	Variable 30 average.	.03	3.53
Ely	3,558	.43	1.03
Eureka	500	.40	.60
Fallini Ranch	15	.78	1.58
Fallon	2,400	.13	.13
Fernly	418	.10	.10
Gault	0	2.86	2.86
Geyser Ranch	5	.37	.37
Glendale	50 average	.08	.78
Goldfield	220	.52	.52
Goldpoint	10	.17	.17
Groom Mine	0	.02	2.02
Hawthorne	1,861	.12	.12
Hiko	55	.05	1.05
Hoya	8	1.40	2.80
Indian Springs	250	.09	.14
Kimberly	120	.05	.55
Las Vegas	47,000	0	.20
Lincoln Mine	250–500	1.25	5.25
Lida	25	.19	.19
Lockes	4	.32	1.62
Logandale	300	.03	.43
Lund	250	.28	.36
Manhattan	42	.14	.14
M & M Mine (10 miles NW. of the Warm Springs on Highway 6).	2	2.34	2.34
Mesquite	590	.08	1.88
McGill	2,300	.05	.45
Millett (ranch)	5	.32	.32
Mina	450	.13	.13
Moapa area	175	.07	.87
Montgomery Pass	3	.15	.15
North Las Vegas	13,000	0	.20

[1] Indicates relatively little fallout prior to Operation Plumbbob.
[2] Zero means no substantial fallout.

TABLE I.—PRELIMINARY ESTIMATES OF RADIATION EXPOSURES IN LOCALITIES, ESTIMATED DOSES—Continued

COMMUNITY	POPULATION	EXTERNAL GAMMA RADIATION PLUMBBOB	CUMULATIVE FOR ALL TESTS
NEVADA—Continued		*(Roentgens)*	*(Roentgens)*
Nyala	6	0.17	1.87
Overton	725	.01	.36
Pahrump	89	0	.20
Panaca	500	.03	.68
Parmans Ranch (10 miles S. of Belmont)	7	.78	.78
Pioche	1,392	.03	.73
Preston	60	.31	1.01
Rattlesnake maintenance station	4	.24	.24
Reed	0	0	4.00
Reveille Mills (10 miles SE. of the Warm Springs on Highway 6).	4	3.40	3.40
Round Mountain	200	.17	.22
Rox	13	.21	3.21
Ruby Hill Mine	50	.40	.40
Ruth	1,244	0	.50
Schurz	100	.13	.13
Sharps (Adaven)	25	0	1.20
Shoshone	250	0	.70
Silver Peak	7	.38	.38
South Paw Mine (5 miles N. of Mount Irish)	3	.41	.41
Stone Cabin Ranch (23 miles E. of Tonopah)	8	.42	.42
Stonehouse Ranch (5 miles N. of Belmont)	4	1.27	1.27
Sunnyside	26	.27	1.47
Tonapah	1,375	.62	.62
Uhaldi Ranch (1 mile S. of Old Adaven Post Office)	5	.29	.29
Ursine	25	0	.69
Walch Pine Creek Ranch	4	.21	.21
Warm Springs (on Highway 6)	55	.25	.75
Warm Springs Ranch (4 miles NW. of Moapa)	58	.04	1.04
UTAH:			
Alton	154	.02	.82
Anderson Junction	17	.4	1.60
Bear Valley Junction (Orton Jct.)	15	0	.40
Beaver	1,685	0	.25
Beryl Junction	8	.03	1.03
Cedar City	6,106	.12	.52
Central	49	.30	.30
Enterprise	800	.05	.75
Garrison	125	.10	.80
Glendale	275	.06	1.26
Gunlock	127	.24	2.24
Hamilton Fort	26	.12	.72
Harrisburg Junction	5	.11	.11
Hurricane	1,375	.08	4.28
Ivins	75	.50	.50
Kanab	1,900	0	1.60
Kanarraville	263	.47	1.67
Leeds	100	.54	3.54
Long Valley	10	.01	.81
Lund	75	0	.50
Milford	1,673	0	.10
Minersville	593	0	.20
Modena	100	.02	.52
Mount Carmel	125	.02	.87
New Castle	115	.04	.64
New Harmony	126	.04	1.24
Orderville	371	.05	1.55
Panguitch	1,501	.36	.56
Paragonah	404	.01	.41
Parowan	1,455	.01	.41
Pintura	50	.62	1.82
Rockville	125	.07	3.07
St. George	5,000	.50	3.50
Santa Clara	319	.46	3.96
Shivwits	95	.54	3.34
Springdale	209	.05	2.65
Toquerville	219	.17	2.17
Veyo	100	.65	2.65
Virgin	135	.08	1.58
Washington	435	.13	3.13
Zane	25	0	.30

Radioactivity in water. The operational guide established by the Commission for Operation *Plumbbob* for concentrations of fallout activity in drinking water is 0.005 microcurie per milliliter of water estimated for 3 days after a detonation. This value is based on the very conservative assumption that a person would continue to use the contaminated water as a sole supply throughout his lifetime. Actually, replenishment of the water by natural processes would greatly dilute activity resulting from fallout.

It was difficult to calculate precisely all the measurements taken of activity in the water to 3 days after each detonation because after succeeding shots the measured activity actually represented fallout from more than one explosion. Collected data show that even the highest activity observed in a drinking water supply—at Fallini Ranch, Nev., population about 15—probably was less than one one-hundredth of the 0.005 microcurie per milliliter established as the operational guide.

Damage Claims After Tests

As a result of the *Plumbbob* test series, one horse grazing on the bombing range received beta burns and was purchased for further study. Of 15 claims of damage received to date, 10 were denied. The claims were mostly for window breakage and minor structural damage. Four claims were for minor glass breakage in Carson City, Nev.

A man from Hiko, Nev., submitted claims for broken windows and for personal injury, medical fees, and lost time from work. The man, 73 years old, alleged that he twisted his neck as a reaction to one detonation and that illness persisted for several weeks thereafter.

Civil Effects Test Group

During Operation *Plumbbob*, the Civil Effects Test Group conducted its most extensive program of biomedical studies since the 1951 tests series at the Eniwetok Proving Ground. There were 58 projects connected with 21 nuclear detonations.

Civil effects technical and scientific investigations are directed toward accumulating data valuable for civil defense activities and concern the consequences of blast, thermal, neutron, and gamma radiation, and fallout on people, food, drink, conventional structures, shelters, utilities, transportation, and community services.

This year's program included a continuation of studies begun in earlier series, and initiated several new, long-range programs related to current problems and designed to furnish the basis for future laboratory and field experiments.

Six general areas were studied: fallout radiation; prompt gamma and neutron radiation; blast effects on structures; blast biology; radiological countermeasures and training; and instrumentation of weapons effects.

Fallout radiation. A group of studies continued work begun on radioactive fallout from the first atomic test, the Trinity detonation in 1945 at Alamogordo, N. Mex. During *Plumbbob,* new methods were used to obtain data on biological accumulations of fallout; physical and chemical characteristics of the fallout particles; the delineation contours of radioactivity levels in the fallout area; and the interaction of fallout with agricultural products. Information developed by this program will help scientists in defining the limits of environmental radiation which may be safely tolerated. It will assist with efforts to devise methods for controlling takeup of fallout by plants, animals, and man. The data also aid in refining safety criteria for weapons tests.

Prompt gamma and neutron radiation. As part of a long-range program to chart the characteristics of bomb radiations and their effects on man, basic measurements were obtained on the distribution on the earth's surface of prompt gamma rays and neutrons from selected nuclear devices. Gamma intensities were measured with chemical dosimeters able to record gamma radiation selectively in the presence of neutrons. Neutron data were collected with detectors containing foils of fissionable materials. Angular paths and intensities of the two radiations from the point of detonation to various locations on the surface of the earth were measured by using specially designed water and lead collimators which allowed only radiations striking within a limited angle to register on the dosimeters.

Exploratory measurements were made of the protection against radiation provided by light frame houses and typical structural materials. The results, when complemented by theoretical and experimental work in the laboratory, are expected to give more accurate knowledge of radiation doses and shielding effects in various types of shelters and conventional structures.

Associated with physical measurements was a series of biomedical tests to determine the acute and chronic effects of massive doses of bomb radiations. Experimental animals were selected so as to provide an evaluation of the related response of various species, and a determination of the relationship between size and response. The experiment was designed to provide data that may be correlated with results from earlier tests.

This work is expected to lead to improved criteria for designing pro-

tective shelters, and to a better understanding of the effects of radiation upon man. Specifically, it is designed to relate various physiological effects with specific quantities of radiation, and to permit a more accurate determination of the amount of radiation received by various Japanese survivors of wartime bombings whose medical histories have been documented by the Atomic Bomb Casualty Commission.

Blast effects on structures. Tests sponsored principally by the Federal Civil Defense Administration were made to determine blast effects on a newly designed family shelter, a shelter designed to serve as an underground garage which also would provide a refuge for a large number of persons, and a dome shelter of reinforced concrete. Antiblast valves, components of a shelter ventilating system, were tested in one event.

With industry cooperation and funding under FCDA sponsorship, blast studies were made of the response of a protective vault for records and valuables and a modular, reinforced-brick, windowless structure. Also through FDCA sponsorship, the first tests were conducted for allies of the United States. Three French and nine German personnel shelters were tested in projects financed by France and the Federal Republic of Germany. Results of these tests also will be made available to the United States.

Blast biology. Work on the biological effects of blast upon man continued in previous weapons tests and in the laboratory. Research was directed toward the effects on biological systems of overpressure from a blast wave, the characteristics and effects of debris and missiles propelled by blasts, and the effects of blast-induced winds. In addition to medical values, the studies are expected to provide guides to improvements in designing protective shelters.

Radiological countermeasures and training. The Commission initiated and financed a new project to determine whether a simple, inexpensive shelter would provide adequate protection for personnel occupying it at the time of a detonation, and also serve as a safe base from which to organize and conduct operations in a fallout-contaminated area. Preliminary evaluation indicates the structure will be useful. Personnel for the project were provided from the staff of the Naval Radiological Defense Laboratory, with assistance by personnel from Commission laboratories, contractors, and FCDA.

The program included several radiological defense training exercises, field testing of monitoring equipment and techniques, and collection of data on radiological defense technology. Proof testing

was carried out in two aerial monitoring instruments developed by the Commission's Health and Safety Laboratory and used for aerial monitoring by civil defense personnel, some with the cooperation of the Civil Air Patrol which furnished aircraft and personnel. Approximately 125 radiological defense personnel from State and community civil defense organizations received training.

Instrumentation and supporting services. Necessary measurements of blast, heat, and nuclear radiation were made to meet the requirements of several programs.

An automatic radiation monitoring system by which readings of radiation intensities at various points near ground zero could be obtained by a telephone hookup was used in conjunction with radio communication with personnel to assist in early postdetonation recovery of instruments.

Fallout Studies

Studies continued during the 6-month reporting period to increase knowledge about the amount of fallout material from weapons tests in man's environment. Samples were collected through a program of worldwide sampling that includes food, soil, air, water, and human and animal bones. Specimens are analyzed particularly for the content of strontium 90, a product in fallout from atomic detonations which behaves much like calcium when taken into the body, being metabolized into the bones.

Additional programs were initiated to collect food and soil, and some expansion in the sampling of human materials is underway. Food samples have been obtained from Turkey and the Philippine Islands through the cooperation of the Interdepartmental Committee on Nutrition.

Expanded Food Collection Program

The foods program was expanded to include determining the strontium 90 content of foods comprising the major sources of calcium in Latin American diets. During July and August, arrangements were made to collect samples in Chile, Argentina, Peru, and Brazil of wheat, flour, potato, and green vegetable foods, which are being analyzed by the Commission's Health and Safety Laboratory, New York. Results will be made available to the participating countries.

A second food collection program was undertaken late this year in Venezuela, Bolivia, Ecuador, and Guatemala. Samples in these countries include primary calcium foods of more primitive populations

from areas where the soil has very low calcium content because of leaching by heavy rains. These results may help to define better the high end of the distribution curve of strontium 90 body burdens among the world population.

Soil Sampling Program—Resurvey

Since 1953, the Commission has sponsored a program of worldwide soil sampling and analysis under a cooperative arrangement with the U. S. Department of Agriculture. This program provides information on the amount of strontium 90 in soils, and the ratio of strontium to calcium which enters the food chain and ultimately finds its way into the skeleton. A Department of Agriculture representative will revisit the sites of earlier surveys to collect new samples in Europe, Africa, South America, Asia, Australia, New Zealand, and the British Isles.

A similar program in the United States this fall extended earlier sampling procedures. In addition to samples collected from sites previously surveyed, samples were taken at different latitudes with similar rainfall patterns. The results may help clarify the effect of latitude on deposition of fallout material.

Improved techniques for anlysis of soil, exchangeable calcium, and cesium 137 have been developed by the Health and Safety Laboratory.

Stratospheric Sampling Program

Collection of particulate material in the upper atmosphere was continued during the reporting period by use of equipment carried by balloons to heights of 50,000 to 90,000 feet. Nuclear Science & Engineering Corp. was awarded a contract for radiochemical analysis of the samples, and first results are being evaluated.

Publications on Fallout

After the hearings on "The Nature of Radioactive Fallout and Its Effects on Man" were held before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy during May and June, the committee published the testimony, exhibits, and statements. The text is available in two volumes from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., for $3.75 (Part One), and $2.75 (Part Two). A summary analysis of the hearings by committee staff is similarly available for 15 cents.

A statement on radioactive fallout submitted to the Commission in October by its Advisory Committee on Biology and Medicine was released and is reproduced in Appendix 13 of this report. Copies are available on request.

Strontium 90 in Soil, Diet, and Bone

Average levels of strontium 90 in the United States in the soil, in the diet, and in the skeleton have increased during the past year, consistent with the limits predicted for fallout from weapons already detonated.

The increase is due in part to continued fallout of material retained in the stratosphere since 1954, and in part to subsequent nuclear tests by this and other countries. The average concentration in milk from Perry, N. Y., during 1956, for example, was 3.3 micromicrocuries of strontium 90 per gram of calcium, with a maximum of 5.6 in November. The average for the first 7 months of 1957 was about 4 micromicrocuries of strontium 90 per gram of calcium.

The average concentrations in the skeletons of children in North America, based on samples of bone from 47 children in the age range from 0 to 9 years, was about 0.8 micromicrocurie of strontium 90 per gram of calcium, as compared to about 0.5 in earlier samples. The highest individual concentration observed among children was between 2 and 3 times the average. The worldwide average was slightly lower than that of the United States, with concentrations in South America less than half those in North America.

The National Research Council-National Academy of Sciences recommended a maximum level for general populations or children of 100 micromicrocuries of strontium 90 per gram of calcium.[4]

Revision of Radiation Standards

The Commission approved for application to all Commission operations a series of revised maximum permissible levels of radiation exposures which are based upon recent recommendations made by the National Committee on Radiation Protection and Measurement.[5] Most of the new standards are contained in a statement issued January 8 entitled, "Maximum Permissible Radiation Exposures to Man."[6] The committee's new recommendations will be included in the revision of several committee handbooks on radiation protection published by

[4] "Biological Effects of Atomic Radiation--Summary Reports," 1956.

[5] See appendix 10.

[6] See pp. 168-170 and 179-184, Twenty-first Semiannual Report (July-December 1956).

the National Bureau of Standards and used as guides in Commission activities.

In issuing its revised recommendations, which lower the permissible levels in some instances for both radiation workers and general populations, the National Committee noted that the changes are not a result of any positive evidence of damage resulting from use of the earlier maximum permissible dose levels. Rather, the committee based its new recommendations on a desire to bring the maximum permissible dose into accord with the trend of scientific opinion, particularly with respect to possible genetic effects and to increasing concern over possible reduction in life expectancy resulting from radiation exposure. Because of expanding national and international uses of atomic energy, the committee suggested that its recommendations be put into effect within 5 years.

Under the new standards, permissible levels of exposure to external radiation for atomic energy workers are little affected. On yearly levels, the new standard provides that the total radiation dose which any individual worker may accumulate beyond the age of 18 shall average not more than 5 rems a year, and no dose of more than 15 rems shall be accumulated in any one year. An average dose of 15 rems a year was the maximum permissible exposure level under the previous standard. This yearly level has not often been reached except by a few persons exposed in radiation incidents. For the individual worker and for the average groups of workers, levels of radiation exposure have been kept well below even the lower levels set by the new standard.

Another basic revision occurs in the permissible radiation levels for internal emitters, radioactive substances that tend to get into and remain in the human body. In controlled areas, the maximum permissible concentrations in air and water of radioactive substances that tend either to be distributed evenly throughout the body or to be concentrated near the gonads has been reduced to one-third of the values previously specified for occupational exposures to such radioactive substances. The maximum permissible concentrations of radioactive substances that tend to be concentrated in single organs other than the gonads, such as strontium 90 in the bones, remain at the previously recommended levels.

In adopting the committee's recommendations, the Commission believes that because in the past its operators have followed conservative radiation protection policies, few contractors will find it necessary to make substantial adjustment in their operations. Such changes in present safety practices as are required will be made as soon as practicable. The Commission has traditionally adhered to the policy

stated in National Bureau of Standards Handbook 59, "that exposure to radiation be kept at the lowest practicable level in all cases." The Commission is continuing this policy.

The Commission action does not affect the operations of Commission licensees. Radiation exposure standards for licensees are set in a Commission regulation (Title 10, Chapter 1, Code of Federal Regulations, Part 20, Standards for Protection against Radiation) which remains in effect. The Commission is currently preparing amendments to this regulation to make it consistent with the new recommendations.

For individuals outside of controlled areas, the maximum permissible concentration continues to be one-tenth of the recommended permissible exposures for radiation workers.

In addition to occupational exposure limits, the NCRPM made the following recommendation regarding exposures to the whole population:

> The maximum permissible dose to the gonads for the population of the United States as a whole from all sources of radiation, including medical and other manmade sources, and background, shall not exceed 14 million rems per million of population over the period from conception up to age 30, and one-third that amount in each decade thereafter. Averaging should be done for the population group in which crossbreeding may be expected.

The Commission is in accord with the philosophy expressed in this recommendation. The Commission exercises control over the exposures resulting from its own operations and those of its licensees, but does not control exposures which the public may receive from other sources of ionizing radiation. Therefore, the Commission has adopted the requirement that its industrial operations must not release any radiation which might be expected to expose members of the populace to an average whole body dosage exceeding 0.5 rem per year or an average concentration of radioactive material exceeding one-tenth of the maximum permissible concentrations for occupational exposure. This requirement will have the effect of limiting exposures to the public from Commission operations to one-tenth of the dosages al owed atomic energy workers.

This exposure limit for the public is in accord with a determinat on of the NCRPM that, if persons outside of controlled areas, but exposed to radiation from a controlled area, are assumed to receive yearly an average per capita dose of 0.5 rem, the total dose to the whole population from manmade radiations is not likely to exceed 10 million rems per million of population up to age 30.

Military Reactor Development

In the Commission's program of developing military reactors of various types for use by the armed services, tests continued during the reporting period on the Army Package Power Reactor, construction was advanced on Navy propulsion reactors, and Air Force experiments looking toward nuclear-powered flight went ahead.

Progress with civilian power reactors, and in advancing reactor and related technologies, are described in Chapter III of the preceding special section of this report, Part One, which deals with "Progress in Peaceful Uses of Atomic Energy."

Army Reactors

Army Package Power Reactor (APPR). After completion of construction and dedication during April, the Army Package Power Reactor at Fort Belvoir, Va., was put through a 700-hour performance test which was successfully concluded in July.

On July 24, a 6-month operating run was initiated. This run is intended to test reliability of plant operation over an extended period of time and to permit accumulation of operating data for planning field units of this type. Upon completion of these tests, called for under the original construction contract, the plant will be operated by Alco Products, Inc., under contract with the Government.

Concurrent research and development was directed toward plant improvement and the complete evaluation of performance characteristics. A new steam generator using bimetallic tubing, one not susceptible to chloride stress corrosion, was designed and ordered for evaluation.

Argonne Low Power Reactor. Twenty-seven percent of the construction of this unclassified reactor prototype had been completed as of the end of December. Completion of construction was scheduled early in 1958. Most Government-furnished items have been delivered to the site at the National Reactor Testing Station, Idaho, and the hazards summary report has been submitted.

Gas-Cooled Reactor Experiment (GCRE). Work on the Gas-Cooled Reactor Experiment proceeded on schedule during the reporting period: detailed design neared completion; a heat transfer loop experiment was put in operation at San Ramon, Calif., by the contractor, Aerojet General Nucleonics Corp.; site surveys resulting in the selec-

tion of a site at the National Reactor Testing Station were completed; and procurement of long-lead items was initiated.

Other research and development activities included evaluation of an engineering mockup of the core; a critical experiment at Battelle Memorial Institute, Columbus, Ohio; materials testing; and advanced fuel element. An inpile reference test loop was placed in operation at Battelle. Related research and development activities consisted of efforts aimed at the design and fabrication of loops for the Oak Ridge Reactor (ORR), the Engineering Test Reactor (ETR), and a reactor at the Hanford Works.

Advanced reactor systems. Three firms were being considered to perform independent investigations of nuclear reactor concepts showing promise for use in military applications demanding a mobile powerplant with a moderate power rating, extreme compactness, and low operating weight. The work under each contract consists of a classified study to select a reactor concept, and the preparation of a preliminary design for an appropriate low power reactor experiment. A contract was negotiated with Consolidated Vultee Aircraft Corp. (Convair) for a survey of lightweight-shield development for such compact reactors.

Naval Reactors Program

As of the end of the reporting period, the Navy had awarded contracts for the nuclear reactor plants for the 18 nuclear-powered ships which the Congress has authorized through the fiscal year ending June 30, 1958. The 18 ships will incorporate 27 reactors. Sixteen ships are submarines (one to utilize two reactors), one is an aircraft carrier (to utilize eight reactors), and one a guided missile cruiser (two reactors). At the request of the Department of Defense, the Commission is procuring the reactor cores for these ships.

During this reporting period, the submarines, USS *Nautilus* and the USS *Seawolf*, continued to operate satisfactorily. A third nuclear powered submarine, USS *Skate*, SSN578, successfully completed her initial sea trials. Construction progressed on prototype reactor plants for a large radar picket submarine, a small submarine and a large naval surface ship. The Commission continued research and development work on other naval nuclear propulsion plants for submarine and surface ship application.

Submarine Thermal Reactor (S1W/S2W). The Naval Reactor Facility (S1W) plant continued to operate for scheduled testing and training

purposes until October. In November the plant was shut down for refueling.

The USS *Nautilus* (SSN571) (S2W) returned to New London from the Pacific in July. During September the *Nautilus* traveled under the Arctic ice to a latitude of 87° North. No ship has ever been so far north. During 5½ days under the ice, the *Nautilus* steamed over 1,000 miles. No submarine is known ever to have gone more than 20 miles under ice before.

Immediately after reaching the open sea, the *Nautilus* headed for NATO exercises. During these exercises she made her longest submerged run, steaming 5,007 miles in 332 hours at an average speed of 15 knots. The *Nautilus* has now steamed some 100,000 miles and was fully submerged more than half this distance.

Submarine Intermediate Reactor (S2G). The USS *Seawolf* (SSN575), powered by the S2G sodium-cooled nuclear propulsion plant, had steamed at the end of December more than 29,000 miles, over 20,000 submerged.

Submarine Advanced Reactor (S3G). Construction of a land-based prototype nuclear propulsion plant for the Submarine Advanced Reactor (S3G) progressed at West Milton, N. Y. Major components continued to be installed in the section of submarine hull which will house the prototype reactor compartment and engine room. The radar picket submarine *Triton* (SSR(N)586), which is under construction at Groton, Conn., will utilize two S3G type of nuclear propulsion plant.

Small Submarine Reactor (S1C). Construction of the Small Submarine Reactor prototype propulsion plant continued at the Nuclear Engineering Laboratory of Combustion Engineering, Inc., at Windsor, Conn. Erection of the submarine hull which will house the prototype has been completed and installation of steam and reactor plant components is underway.

An S1C type of nuclear propulsion plant will be installed in a small submarine authorized by Congress in the Navy's fiscal year 1958 shipbuilding program.

Large ship reactor (A1W). Construction of the A1W land-based prototype two reactor plant of a large ship reactor continued at the National Reactor Testing Station. An aircraft carrier utilizing eight A1W type of nuclear propulsion plant units has been authorized for construction.

High speed submarine project (S5W). Research and development continued at the Commission's Bettis Plant on a nuclear propulsion plant suitable for installation in high speed attack submarines and guided missile launching submarines. This type of nuclear propulsion plant, designated S5W, will be installed in 10 nuclear powered submarines authorized by Congress through Fiscal Year 1958.

Guided missile cruiser project (C1W). Design and development work continued at the Commission's Bettis Plant on a nuclear propulsion plant for the guided missile cruiser, USS *Long Beach* CG(N)9. The keel of the USS *Long Beach* was laid on December 2, 1957, at the Fore River Shipyard of the Bethlehem Steel Co., Quincy, Mass.

Destroyer reactor (D1G). Design and development work continued at the Knolls Atomic Power Laboratory on development of a pressurized water nuclear propulsion reactor for use in a destroyer type of naval ship. The Shipbuilding Division, Bethlehem Steel Co., under contract with KAPL, continued work on the propulsion plant design and machinery arrangements.

Aircraft Reactors Program

The Commission and the Air Force have created an integrated joint Commission-U. S. Air Force project office to manage their joint program leading to the application of nuclear power for the propulsion of aircraft and missiles. The office will have complete executive management responsibility for all aspects of the nuclear propulsion system for manned aircraft as well as for reactors for nuclear missile propulsion and auxiliary nuclear power units.

This arrangement is designed to eliminate areas of coordination required previously, and to expedite communications between the operating contractors and the project director. The office is located in the headquarters of the Commission and is staffed by the Commission, the Air Force, and the Navy, under Maj. Gen. D. J. Keirn, USAF, who is project director within the Commission and the U. S. Air Force. General Keirn continues in his assignment as chief of the Aircraft Reactors Branch in the Commission's Division of Reactor Development, and as assistant deputy chief of staff for Development for Nuclear Systems of the Air Force.

National Reactor Station activities. Experiments connected with testing of reactors in relation to the nuclear operation of turbojet engines continued at the National Reactor Testing Station, performed by General Electric Co., contractor.

Construction of the *Low Power Test Facility* continued at the testing station and was expected to be completed early in 1958.

An expansion is in progress in the assembly and maintenance areas at the station, mainly shop facilities. This work includes some modification to existing buildings, as well as some new construction.

Construction of the *Flight Engine Test Facility* was started and is scheduled for completion late in 1959.

Connecticut Aircraft Nuclear Engine Laboratory (CANEL). Portions of research and small-scale component development facilities were completed and are currently in use at the Connecticut Aircraft Nuclear Engine Laboratory. The presently programed plant is to be completed next year. Realinement of responsibilities between the Commission and the Air Force has placed this work under a Commission contract with Pratt & Whitney Aircraft Division, United Aircraft Corp.

Nuclear-powered rockets and ramjet engines. Feasibility studies which the Commission has initiated relative to applying nuclear power to rockets and ramjet engines were continued at Los Alamos Scientific Laboratory, and at the University of California Radiation Laboratory at Livermore.

Community Operations

Sale of Property, Oak Ridge and Richland

Sales of real estate by the Housing and Home Finance Agency at *Oak Ridge,* Tenn., begun in July 1956, continued during the last half of 1957 at a satisfactory rate. All single-family houses, all but 100 of the duplexes, and a major portion of the commercial properties have been sold. Some of the larger parcels of vacant land were placed on the market in December, and apartments and dormitories will be offered for sale during the coming year.

At *Richland,* Wash., response to the sales program which began when residential lots were offered for sale on March 21 has been favorable. The rate of sales has been increasing rapidly.

Sales at both communities as of December 31 are summarized as follows:

	Oak Ridge		*Richland*	
	Number offered	*Percent sold*	*Number offered*	*Percent sold*
Single and duplex houses	4, 360	98	2, 220	43
Residential lots	1, 422	20	228	19
Commercial properties	102	68	------	-------

Under recent amendments to the Atomic Energy Community Act of 1955, lessees of commercial property in Commission towns are permitted to apply for adjustments in their lease terms on a plea of undue hardship or inequity, and the Commission has established procedures for renegotiation of leases on commercial property. Twenty-one applications are being reviewed at Oak Ridge, and 95 lessees at Richland have requested adjustment.

Self-Government, Oak Ridge and Richland

In July members of the Oak Ridge Town Council met with the Richland Town Council to discuss problems common to both communities, and additional meetings were planned.

The Public Administration Service was engaged to conduct a fiscal and organizational survey of the government of Oak Ridge, similar to one that it performed at Richland last year. The Oak Ridge Town Council helped develop the scope of the proposed survey and the Midwest Research Institute, Kansas City, Mo., was retained to make a similar study of industrial potential.

The Richland Town Council undertook studies of the problems posed by incorporation as indicated by the survey. The council decided to engage a private firm to draft ordinances and regulations to be considered by the municipality.

Los Alamos Activities

The replacement of substandard housing units at Los Alamos which began in the spring of 1956 was completed during the reporting period.

The Commission approved a long-range, land-use plan for Los Alamos and, subject to availability of funds, authorized a start on developing the Barranca Mesa project, north of the town, for building sites for privately owned homes. The initial project would consist of 72 lots.

New Headquarters

The new headquarters building of the Commission, into which the Washington staff will move in January, was dedicated by the President on November 8 before an audience of some 3,000 persons. Besides the five Commissioners, the guests at the dedication ceremony included Members of Congress; Managers of Commission field offices, directors of Commission laboratories, and headquarters staff and their families; officials of the Federal, Maryland State, and local governments; representatives of foreign governments with whom the United

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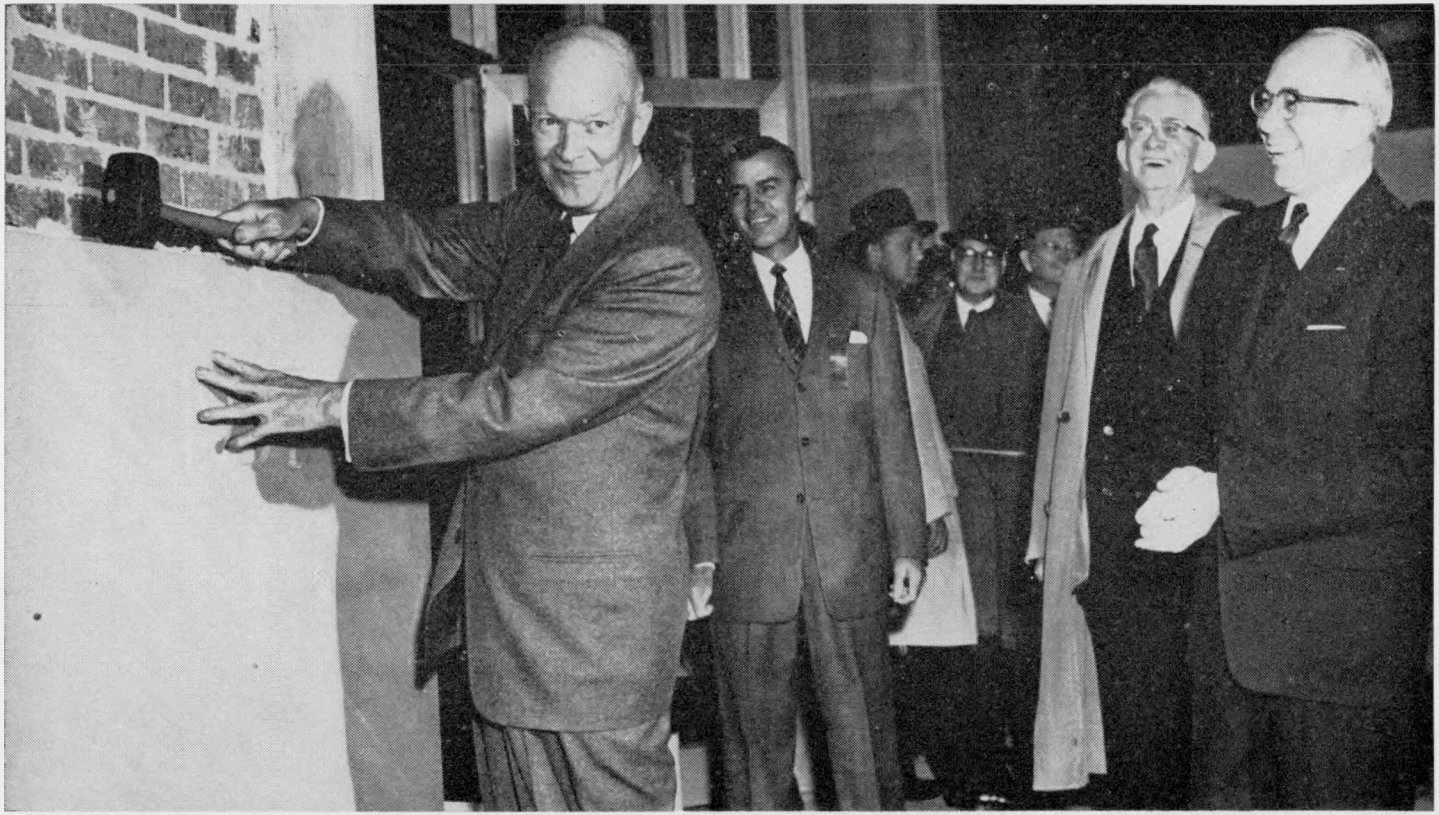

Dedication. The President lays the cornerstone, with Lewis L. Strauss, Commission Chairman (right), and on Mr. Strauss' right, Representative Carl T Durham, Chairman, Joint Committee on Atomic Energy.

Cornerstone. The contents of the cornerstone.

States has atomic energy agreements; and representatives of industry, labor, and professional and scientific societies.

In his short dedicatory remarks, the President said, "I am positive that if this convocation here today could have one wish, it would be that the curse of the atomic explosion may pass from man's knowledge and only the good that results from this great discovery would be with us always."

Earlier he referred to the good and wicked sides of many of man's inventions. "What differentiates it [atomic energy] from all others," the President said, "is the terrible possibilities it opens to wicked men, people who want to use this new discovery for the destruction of mankind now have placed in their hands a power that certainly should give all of us pause. It should awaken man's conscience and appeal to his common sense. Because not only does it bring a sudden possibility of self-destruction but on the other side of that same coin again we have new possibilities for good—the production of power where no power was possible or was known, its usefulness in agriculture, in medicine, biology—everything we can think of * * *. Man's judgment and intelligence must measure up quickly to his inventive genius or mankind's future is bleak indeed."[7]

The President pressed a button, actuating a mechanism powered with batteries charged by eight nuclear power reactors, which uncovered a plaque for the lobby of the building.

The President; Lewis L. Strauss, Chairman of the Commission; and Carl T. Durham, Chairman of the Joint Committee on Atomic Energy of the Congress, joined in the ceremonial laying of the cornerstone, using three engraved silver trowels.

Before the President spoke, Chairman Strauss welcomed the guests and referred to the contents of the sealed box placed in the cornerstone.

"Into this cornerstone," the Chairman said, "go the more important documents tracing the first 15 years of man's control of atomic energy, samples of various nuclear materials and isotopes, and linen wrappings from the Dead Sea Scrolls whose age has been determined by one of the unexpected applications of atomic energy. I refer, of course, to the technique of radiocarbon dating originated by one of our colleagues, Commissioner Libby. And finally, this cornerstone will preserve for future time a record in picture and sound of the most inspiring of the many historic developments that have occurred during the 15 years since controlled atomic fission was achieved—President Eisenhower's memorable 'Atoms for Peace' address of December 8, 1953—a pronouncement which for men and women the world over

[7] Text of the President's remarks, and those of the Chairman, the contents of the program, and a list of contents of the cornerstone box are given in appendix 12.

transformed the atom from an unrelieved symbol of fear and terror to a promise of great blessing."

The microfilmed records included a complete set of semiannual reports to the Congress, Nos. 1 through 22, dated from January 1947 through July 1957.

After the dedication ceremony guests toured wings A, B, and C of the headquarters building, and viewed the mobile "Atoms for Peace" exhibit, brought to the site for the occasion.

Construction of the basic facilities of the new headquarters, contracted for in May 1956, was completed in December.

Public Law 85–107, approved July 17, 1957, authorized construction of an addition to the headquarters building, including a new wing and enlarged service facilities. The new wing—4 stories plus a ground floor—will extend southward, and add about 116,000 gross square feet to the approximately 400,000 square feet contained in the present building. Its completion is scheduled for the fall of 1958.

Nuclear Materials Management

Plans for providing uranium isotopic standards through the joint efforts of the Commission and the National Bureau of Standards, Department of Commerce, are progressing satisfactorily. Materials of very high isotopic purity, known as primary generative materials, have been transferred to the Bureau. These materials will provide the basis for the values on which certified uranium isotopic standards ultimately will be issued. Pending preparation of these standards, arrangements have been made to issue a series of 14 isotopic standards having provisional values.

A set of approved measurement methods is being developed for source and special nuclear materials. These methods are expected to be useful both for routine measurement applications by Commission contractors and licensees, and for umpiring differences in measurements on quantities of materials transferred.

Inspection

Contractor and Direct Commission Activities

At the end of the fiscal year, June 30, 1957, the Director, Division of Inspection, submitted the first annual certification to the General Manager on the adequacy of inspections of Commission and contractor activities to support findings as to the state of compliance with regu-

lations and other Commission requirements. Annual certifications are based on a continuing review of Commission inspection systems.

Commission Foreign Activities

Commission policies and general responsibilities were established for the conduct and coordination of foreign consultations on safeguards and control provisions under international agreements for cooperation.

Construction and Supply

Construction

Capital investment in atomic energy facilities continued to increase steadily during the 6-month reporting period, and as of December 31, was estimated to be about $7.06 billion.

Construction activity during the reporting period ended December 31 continued at about the same level as for the previous 6 months. Costs incurred by the Commission for new plant and equipment during the period amounted to about $150 million. Costs for fiscal year 1958 were expected again to approximate $300 million.

An increasing share of the construction effort was devoted to new reactor and research facilities. During the 1957 fiscal year ended last June 30, plant and equipment costs incurred for reactor and research facilities accounted for $124 million, or 39 percent of the total construction, more than double the $57 million of the previous fiscal year.

Records Management

During fiscal year 1957 the Commission and its cost-reimbursable contractors disposed of 85,000 cubic feet of records having no further value. Emphasis was placed on removing semiactive records from office space to records centers. As of the end of the fiscal year, 42 percent of Commission records was housed in low-cost records centers or storage areas.

Motor Vehicle Management

Average motor vehicle operating and maintenance costs for the Commission fleet dropped from $0.0738 a mile in fiscal year 1956 to

$0.0727 a mile in the 1957 year, to produce a savings of approximately $81,000 on the 74 million miles operated. The fleet was operated almost 3 million miles more in 1957 than in 1956 with little change in the number of vehicles. As a result, vehicle utilization increased from 8,377 miles per vehicle a year in 1956 to 9,183 miles per vehicle in 1957.

Small Business

In a principal address before the President's Conference on Technical and Distribution Research for the Benefit of Small Business, held on September 23–25, Lewis L. Strauss, Chairman of the Commission, pointed to the Commission's role as "wholehearted supporters of small business."

"* * * by the establishment of policies based on a scrupulous regard for the interests of small business," he said, "we have been able to insure that a substantial amount of our contract dollars do go to companies defined as small business."

Referring to research by small businesses, Chairman Strauss cited the need for keeping abreast of developments in their respective fields, even if this could be accomplished only by assigning responsibility among staff for studying current technology.

During the reporting period, the Commission explained its small-business program through testimony before the House Small Business Committee and reports to the Senate Small Business Committee. The Commission continued to participate in numerous conferences on opportunities for small business, by providing contractor exhibits of items used in various programs which small-business concerns could manufacture and supply for atomic energy work.

The Small Business Administration published a paper, "Small Business and the Industrial Applications of Atomic Energy," prepared by the Commission, in the SBA series, "Technical Aids for Small Manufacturers."

A substantial portion of the Commission's subcontract dollars continued to go to small business. During the fiscal year ended in June, $224.3 million, or 39.1 percent of a total of $574.2 million subcontracts, were awarded to small business. This represents an increase in dollar volume over the two preceding fiscal years, and compares favorably with the 39.8-percent average achieved—$1.419 billion in subcontracts to small business out of a total of $3.568 billion, in fiscal years 1951–57, inclusive. Direct contract awards in the 1951–57 period to small business amounted to $337 million, or 3.7 percent, out of a total of $9.104 billion.

Mobilization Planning

The Commission continued to cooperate with the Office of Defense Mobilization (ODM) in the various readiness programs sponsored by that agency. During June and July 1957, headquarters and field offices participated in all phases of Operation Alert 1957 in accordance with the operational guidance of the ODM. The results of this exercise again demonstrated the readiness of the Commission to carry out its responsibilities during an emergency.

Organization and Personnel

Personnel Changes

John F. Floberg, nominated by the President on June 17 for a 5-year term as Commissioner to serve until June 30, 1962, was confirmed by the Senate on August 15, and sworn in October 1.

John S. Graham, nominated by the President on June 17 for an unexpired term as Commissioner to serve until June 30, 1959, was confirmed by the Senate on August 15, and sworn in September 12.

David F. Shaw resigned as Assistant General Manager for Manufacturing to go to Kaiser Engineers.

T. H. Johnson resigned as Director, Division of Research, to go to Raytheon Corp.

Harold L. Price, formerly Director, Division of Civilian Application, was appointed Director, Division of Licensing and Regulation, effective December 18, 1957.

Franklin K. Pittman, formerly Deputy Director, Division of Civilian Application, was appointed Director, Office of Industrial Development, effective December 18, 1957.

John J. Flaherty resigned as Manager of the Chicago Operations Office to go to North American Aviation, Inc.

Kenneth A. Dunbar, formerly Manager, Portsmouth, Ohio, Area Office, was appointed Manager, Chicago Operations Office, effective November 11, 1957.

Robert H. McCulloh, formerly Deputy Manager, Portsmouth Area Office, was appointed Manager, Portsmouth Area Office, effective November 11, 1957.

John I. Thomas, formerly Deputy Manager, Hanford Operations Office, was appointed Manager, Puerto Rico Area Office, effective October 20, 1957.

W. Herbert Pennington was appointed scientific representative, Tokyo Liaison Office, effective August 15, 1957.

Nathan N. Woodruff was appointed scientific representative, Buenos Aires Liaison Office, effective August 18, 1957.

Amasa S. Bishop was appointed scientific representative, Paris Liaison Office, effective October 11, 1956.

Edward L. Brady was appointed scientific representative, London Liaison Office, effective October 16, 1956.

Edward E. Sinclair was appointed Scientific Representative, Chalk River, Canada Liaison Office, effective August 5, 1956.

Organizational Changes

The Division of Civilian Application was abolished December 18 and its functions were reassigned to two new organizational units: the Division of Licensing and Regulation, responsible for regulatory and licensing functions; and the Office of Industrial Development, responsible for developing Commission policy for encouraging and assisting private activities in the civilian applications of atomic energy, exclusive of the reactor program.

The Office for International Conference was established as a temporary organizational unit within the Commission reporting to the Assistant General Manager for International Affairs. It has responsibility on behalf of the Commission for planning, coordinating, and directing the United States technical participation in the Second International Conference on the Peaceful Uses of Atomic Energy to be held in Geneva, Switzerland, September 1–13, 1958. The United States program is a joint undertaking by the Department of State and the Commission.

Supervision of the New York Operations Office has been transferred from the Division of Biology and Medicine to the Division of Reactor Development. This arrangement enables the Division of Biology and Medicine to confine its activities to encouraging research, evaluating research data, and formulating programs for the protection and improvement of health in matters relating to the application of radioactive materials.

The following changes relating to Area Offices have occurred:

The Dana Area Office of the Savannah River Operations Office and the Buffalo Area Office of the Albuquerque Operations Office have been abolished.

The Southern California Office under the San Francisco Operations Office has been abolished. Responsibility for administration of its reactor research and development projects has been transferred to

the Chicago Operations Office. For this purpose the Canoga Park Area Office (Canoga Park, Calif.) has been established.

As a result of program changes, the Salt Lake City and Denver Area Offices have been replaced with smaller units designated Branch Offices. These will report, as the Area Offices had done, directly to the Grand Junction Operations Office.

The Pinellas Area Office (St. Petersburg, Fla.) and Puerto Rico Area Office (College Station, Mayaguez, Puerto Rico) have been established within the Albuquerque and Oak Ridge Operations Offices, respectively. The objective in establishing these Area Offices has been to facilitate administration of AEC contracts.

Commission scientific representatives, reporting to the Division of International Affairs, now are located in Buenos Aires, Chalk River, Canada, London, Paris, and Tokyo.

Scientific and Engineering Requirements

Two parts of the Commission's four-part survey of scientific and engineering manpower requirements for atomic energy activities [8] have been completed, and preliminary figures are available in a third. They indicate a current need for nearly 34,000 scientists and engineers, but no critical shortages.

The survey of private-industry programs undertaken by the Atomic Industrial Forum under Commission contract was published, and copies were distributed to Commission headquarters and field offices, the Joint Committee on Atomic Energy, members of the forum, respondents to the questionnaire, other interested Federal agencies, and the general public.[9]

This survey indicated that in 1956, an estimated 7,000 to 7,500 scientists and engineers were employed either full time or part time in some phase of industrial atomic energy activities. Some shortages were reported, particularly of reactor and metallurgical engineers, but there does not now appear to be a critical shortage for private programs. The current limited shortages may become greater in future years. The survey estimates for 1957 was that 9,000 scientists and engineers were required, and for 1960, approximately 16,000.

A report on the survey of the requirements of the Commission and its contractors was distributed on completion principally for internal use within the Commission and to the Joint Committee. The report is being prepared for publication.

[8] See pp. 65-66, Twenty-first Semiannual Report to the Congress (January-June 1956).

[9] Available on request, Division of Organization and Personnel, Atomic Energy Commission, Washington 25, D. C.

The results of the survey of Commission and contractor needs are summarized in the following table:

CATEGORY	SEPTEMBER 1956	SEPTEMBER 1957	CHANGE
			(percent)
Total	20,515	23,501	+14.6
AEC	1,239	1,474	+19.0
CONTRACTOR	19,276	22,027	+14.3
Research and development	11,649	14,062	+20.7
Production	5,542	6,131	+9.3
Construction	248	180	−27.5
Design	1,837	1,654	−10.0

Shortages of scientific and engineering manpower in contractor organization represented only about 6 percent of total technical staff. The most severe shortages were among electrical, mechanical, and metallurgical engineers. Every effort was made to avoid duplications of requirements as between the two surveys of industrial organizations.

The third part of the total survey effort, dealing with the requirement for scientific and engineering manpower for atomic energy activities in colleges and universities, is presently being completed for the Commission by the American Society for Engineering Education. Preliminary results indicate that 3,800 scientists and engineers were devoting at least part of their time to atomic energy interests in 1957. An increase in 1958 to about 4,300 is anticipated, and by 1960 the total should stand at approximately 5,300.

These surveys indicate that atomic energy activities utilize virtually every area of scientific and engineering knowledge, the largest groups being mechanical engineers, chemists, physicists, electrical engineers, and technically trained administrators and managers. Future demands for technical people apparently will increase for almost all disciplines. The greatest percentage increase is expected for nuclear engineers, metallurgists, and physicists.

The fourth part of the survey dealing with technical manpower needs in atomic energy activities of other Federal agencies has been initiated and results are expected early in 1958.

Commission and Contractor Employment

Total contractor employment rose to 110,731, an increase of 1.6 percent during the first 9 months of 1957. The largest increases occurred under research and development contracts for nuclear propulsion work and weapons development, and in the service category for work connected with weapons tests.

Total employment of construction and design workers continued to decline as in the preceding 2½ years and, as of August, reached a level of some 12,000, the lowest since late 1947 before the Commission launched its first expansion program.

Direct Commission employment rose to 6,774 in September—up 2 percent this year. Operating contractors' employment increased even more proportionately, so that the ratio of operating contractor employees to the total of direct Commission employees has reached 14.5 to 1, as compared with 14.2 to 1 in December 1956 and 8.4 to 1 at the time of the 1952 expansion.

Contractor Work Stoppages

As of August, the year's ratio of time lost through work stoppages to time scheduled in Commission construction activities was the second lowest since 1952, the first year for which complete statistics are available. The 1957 percentage was 1.01, as compared with the 1956 high of 2.69.

The 1957 lost-time rate of 0.47 for Commission operating activities was well below the construction ratio of 1.01, although considerably higher than any annual rate previously recorded. Previous years' rates have ranged from less than 0.05 percent in 1952 to 0.2 percent in 1956.

Earnings of Contractor Employees

Through September 1957, production and other manual workers of Commission production, research and development, and service contractors earned an average of $2.57 gross pay an hour. This represents a 4-percent increase from last year's average.

Rates for the two industries most comparable to atomic energy activities in processes and equipment—products of petroleum and coal and industrial inorganic chemicals—have been used as indices in evaluating the Commission operating contractor data from the beginning of this series of statistics. As in past years, Commission contractor rates for 1957 are close to averages for the private concerns, being 3 percent below petroleum and coal companies, and 5 percent above inorganic chemicals companies.

Fermi Award

Dr. Ernest O. Lawrence, scientist and director of the University of California Radiation Laboratory at Berkeley, Calif., was awarded

the Commission's Enrico Fermi Award on December 2, 1957, "for his invention and development of the cyclotron and for his many other contributions in nuclear physics and atomic energy."

Incentive Awards Program

The Commission held its second Annual Honor Awards Ceremony on December 12, 1957. Distinguished Service Awards were presented to Dr. Charles L. Dunham, Director, Division of Biology and Medicine, and to Samuel R. Sapirie, Manager, Oak Ridge Operations Office. Six present and former employees were presented with Outstanding Service Awards. Six employees received Length of Service Awards for 30 and 40 years of Federal service.

Awards to Employees

The rate at which employees of the Commission are suggesting improvements and economies in Commission activities increased substantially during the year ended June 30, the rate rising from 54 per 1,000 the previous year to 80 per 1,000 in fiscal year 1957.

Awards for suggestions under the Commission's incentives award program also showed an increased rate with 15 per 1,000 accepted during fiscal year 1957 as compared with 7 per 1,000 the previous year.

Twenty-three employees per 1,000 were recognized for job performance beyond that required, as compared with 13 per 1,000 in the previous year.

The following figures show activity in the awards program since its inception:

	Suggestions made	*Suggestions adopted*	*Superior performance awards*	*Special act or service awards*	*Distinguished and outstanding honor awards*
1955 (7 months)	85	4	15	0	4
1956	342	45	77	2	1
1957	528	100	152	3	22

CASH AWARDS
(fiscal years)

	1955	*1956*	*1957*
Suggestions	$665	$2,305	$3,270
Superior performance	1,825	23,260	39,510
Special act or service	-----	900	950

Net first-year dollar benefits from suggestions were $49,824 for 1955; $234,703 for 1956; and $68,973 for 1957.

Award to Brannigan. Francis L. Brannigan, safety engineer in the Safety and Fire Protection Branch, Division of Organization and Personnel, was selected by the Training Officers Conference, an organization of training officers of the Federal Government, as 1 of 5 Federal employees who has made a unique and outstanding contribution in the field of training. Brannigan received the award in recognition of his skill and leadership in training instructors to conduct courses in civic protective measures against atomic hazards.

Safety and Fire Protection

For the second successive year, the Commission's record in safety and fire protection was equivalent in 1956 to second among 42 industries in the United States. The National Safety Council has compiled and published the average injury-frequency rates experienced during 1956 for each of 41 different industries. If the injury experience of the Federal atomic energy program over the previous fiscal year were added to this listing, the Commission would rank as second safest, with a rate of 1.86 lost-time injuries per million man-hours. First, in the Safety Council's calculation, was the communications industry with a record of 0.99; and second was the aircraft manufacturing industry with 1.92.

The Commission showed a reduction in injury rate for 1957 from the 2.40 level as of the end of 1956.

The total decrease of 22 percent is made up of 14-percent decrease in production, research, and services; 37-percent decrease in construction; and 36-percent decrease among Commission employees.

Less average severity in injuries also is reflected in average days lost—192 days per million man-hours worked at the end of September, as compared with 359 days lost per million man-hours in 1956.

Four fatalities occurred in the first 9 months of 1957—2 resulting from electrocutions, 1 a motor vehicle accident, and 1 an airplane crash.

A few more motor vehicle accidents occurred than were experienced in 1956.

Radiation incidents. All radiation incidents reported in the atomic energy program, Federal and private, during calendar year 1956 are summarized in the tables that follow. Most of the incidents were of a minor nature; some involved no exposures of personnel.

TABLE II.—REPORTED INCIDENTS INVOLVING RADIATION
Jan. 1–Dec. 31, 1956 [1]

Date	Location	Number persons involved	Extent of exposure	Nature of incident
Jan. 10, 1956	Milford, Conn [2]	4	1—Estimated whole body gamma dose of 22–26 rads and 2 small skin areas of about 3.600 *r* each. 3—Estimated doses of less than 7 *r*.	Employee on construction job used a piece of string with cobalt 60 source attached; put it in shirt pocket, then in glove compartment of his automobile.
Jan. 16, 1956	Oak Ridge, Tenn.	26	None	Construction area slightly contaminated when radioactive dust was ejected from nearby laboratory. As precautionary measure all employees' clothing were removed for cleaning.
Jan. 17, 1956	Hanford, Wash.	1	Did not exceed 5 percent of maximum permissible.	Operator doing routine work when plutonium-bearing solution caused deterioration of rubber gloves, resulting in contamination to his hands.
Jan. 18, 1956	Las Vegas, Nev.	4	4 *r*, 14 *r*, 19 *r*, and 28 *r*.	It had been prearranged to have a monitor enter a test area, but 4 employees in protective clothing entered the area without the monitor to redeem samples.
Feb. 1, 1956	Oak Ridge	0	None	A critical assembly went prompt critical by an overaddition of fissionable material; the automatic safety system terminated the burst.
Feb. 22, 1956	Hanford	2	Slight skin and clothing contamination.	Inadequate venting of vessel containing plutonium solution forced the solution into the work area.
Mar. 24, 1956	Northern Idaho.	0	None	Train containing carload of uranium metal scrap derailed by rock and snowslide; contents spilled on right-of-way.
Apr. 20, 1956	Western Montana.	0	None	26 cars of freight train derailed as a result of broken rail; car containing uranium compound immersed in river; removed intact.
Apr. 30, 1956	Los Alamos, N. Mex.	1	Beta burn to 1 finger.	While decontaminating a tool used for remote control, employee received skin contamination under his protective gloves.
May 14, 1956	Fort Belvoir, Va.	15 to 25	Possible exposure not more than 6 *r*.	While working near a portable radiographic source, employees exposed to small doses of gamma radiation when cap was knocked off pig containing a 32-curie iridium source.
June 16, 1956	Savannah River.	1	Smear count indicated exposure but employee did not suffer injury nor was he hospitalized.	Employee inserted hand and arm into port of extraction furnace to retrieve plastic bag; employee was wearing protective gloves.
June 18, 1956	Hanford	3	1 employee under observation 4 days; 2d and 3d dismissed after treatment.	Some highly concentrated plutonium solution backed up in the instrument line of an air-operated valve and about a pint escaped into the control room.
June 21, 1956	Los Alamos	8	2 employees received the maximum permissible.	Contaminated blotting paper blew around the room during an experiment.
June 23, 1956	Eniwetok	15	Negligible	Plutonium oxides released when jacket failed on a source stored in house-type trailer.

[1] 10 incidents which occurred during the first 7 months of 1956 were reported in the July–December 1956 Semiannual Report (dated January 1957), pp. 163–164. See also supplement to TID–5360—1956, "A Summary of Incidents Involving Radioactive Material in Atomic Energy Activities," January–December 1956, Office of Technical Services, Department of Commerce, Washington 25, D. C., $1.

[2] Formerly reported at Bridgeport.

TABLE II.—REPORTED INCIDENTS INVOLVING RADIATION
Jan. 1–Dec. 31, 1956 [1]—Continued

Date	Location	Number persons involved	Extent of exposure	Nature of incident
July 2, 1956	Bayside, N. Y.	Unknown.	Except for 4 laboratory workers, all persons associated with the incident (policemen, firemen, etc.) showed no detectable intake of radioactive materials. The 4 men directly involved did not exceed the permissible body burden.	Explosion occurred during burning of thorium metal for conversion to oxide; sympathetic explosions followed. The resulting injuries and 1 death were not caused by radiation.
July 9, 1956	Monterey, Tenn.	0	None	Trailer-truck carrying slightly radioactive material overturned and caught fire; driver hospitalized for minor burns and bruises.
July 23, 1956 [3]	Idaho Falls	8	Exposures ranged from 2.5 *r* to 21.5 *r*; not sufficient to cause illness.	Employees were working on top of reactor which was shut down for scheduled refueling and experimental installation operations. Exposure occurred when a highly radioactive reactor component was placed in a position not adequately shielded because of lowered water level in reactor tank.
Aug. 19, 1956	*Seawolf*	7	Minor; highest was 1.1 *r*.	Exposure occurred during dockside test operations.
Sept. 21, 1956	Hanford	1	Below permissible	In filling a container with plutonium-bearing solution, some of the solution spilled over the mouth of the container and splashed out on to the employee's chest, face, and into his mouth when he applied the container cover.
Sept. 22, 1956	Detroit, Mich.	0	None	Spontaneous ignition occurred in a drum of thorium metal pellets in a railway warehouse.
Dec. 11, 1956	Pleasant Valley, Oreg.	0	None	Tractor-trailer truck carrying 2 casks of radioactive slugs overturned on an icy road; casks remained intact.

[1] 10 incidents which occurred during the first 7 months of 1956 were reported in the July–December 1956 Semiannual Report (dated January 1957), pp. 163–164. See also supplement to TID–5360—1956, "A Summary of Incidents Involving Radioactive Material in Atomic Energy Activities," January–December 1956, Office of Technical Services, Department of Commerce, Washington 25, D. C., $1.

[3] Formerly reported as July 24, 1956.

Labor-Management Relations

Of the total operating contractor work force in atomic energy, about 44 percent is hourly rated production and other manual workers. The majority of these workers is organized for collective bargaining into some 75 units—31 operating production and maintenance units, 16 guard units, and the remainder in various craft unions. Since January 1, some 25 labor agreements and wage reopeners affecting approximately 18,000 workers have been renegotiated between Commission contractors and the unions. All but five of these contracts, involving about 3,688 employees, were negotiated without dispute.

The most significant work stoppages during the past 6 months were the following:

A labor dispute at Portsmouth, Ohio, was settled on August 2 when terms of a new 3-year agreement between the union and Goodyear Atomic Corp. were ratified by members of the Oil, Chemical & Atomic Workers International. The ratification came the day before an 80-day national emergency injunction was scheduled to expire. The new agreement provided for a 13-cent-an-hour increase in 1957, a deferred increase of 9 cents in 1958, and a wage reopener in 1959.

Production and maintenance employees of ACF Industries, Inc., at Buffalo, N. Y., returned to work August 12 after 13 weeks of idleness. The strike was unauthorized and occurred over a grievance resulting from a production flowtime survey being made by the company. Terms of the settlement included a revision of the "no-strike" clause which the contractor considered to be stronger, and reinstatement of the employees who were discharged for violation of the contract.

On July 17, the Atomic Energy Labor-Management Relations Panel took jurisdiction of a strike in Albuquerque, N. Mex., when negotiations broke down over renewal terms of two labor agreements of the Sandia Corp., a subsidiary of Western Electric Co. Involved in the strike which began July 1 were production and maintenance workers represented by Atomic Projects & Production Workers Metal Trades council and office employees represented by the Office Employees International Union, AFL–CIO. Work was resumed on July 18 and final settlement based on the panel's recommendations was reached on August 10 which provided for an average wage adjustment of 11.7 cents an hour for production and maintenance workers, and 10.8 cents for the office and clerical unit.

The panel also was called upon to arbitrate an issue of retroactivity between construction contractors at the National Reactor Testing Station at Arco, Idaho, and the Carpenters Union. Agreement of new contract terms was reached after a 15-day strike, but the contractors and the union were unable to agree on a retroactive date. The parties consented in advance to accept the decision of the panel, which ruled that the 22½ cent-an-hour wage increase should be effective August 5, the date of the agreement between the parties.

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APPENDIX 1

Organization and Principal Staff of U. S. Atomic Energy Commission

Atomic Energy Commission	Lewis L. Strauss, *Chairman.* John F. Floberg. John S. Graham. Willard F. Libby. Harold S. Vance.
General Manager	K. E. Fields.
Special Assistant to General Manager (Congressional).	Bryan F. LaPlante.
Special Assistant to General Manager	Charles Vanden Bulck.
Deputy General Manager	R. W. Cook.
Assistant General Manager	Harry S. Traynor.
Assistant General Manager for Administration.	Robert E. Hollingsworth.
Assistant General Manager for International Activities.	Paul F. Foster.
Assistant General Manager for Manufacturing.	*Vacancy*
Assistant General Manager for Research and Industrial Development.	A. Tammaro.
Controller	Don S. Burrows.
General Counsel	Edward Diamond, *Acting.*
Secretary to Commission	W. B. McCool.
Director, Office of Industrial Development.	Frank K. Pittman.
Director, Office of Operations Analysis and Planning.	Paul C. Fine.
Director, Office of Special Projects	Edward R. Gardner.
Director, Division of Biology and Medicine.	Dr. Charles L. Dunham.
Director, Division of Classification	C. L. Marshall.
Director, Division of Construction and Supply.	John A. Derry.

Director, Division of Information Services.	MORSE SALISBURY.
Director, Division of Inspection	CURTIS A. NELSON.
Director, Division of Intelligence	C. H. REICHARDT.
Director, Division of International Affairs	JOHN A. HALL.
Director, Division of Licensing and Regulation.	HAROLD L. PRICE.
Director, Division of Military Application	Brig. Gen. ALFRED D. STARBIRD.
Director, Division of Nuclear Materials Management.	D. F. MUSSER.
Director, Division of Organization and Personnel.	OSCAR S. SMITH.
Director, Division of Production	E. J. BLOCH.
Director, Division of Raw Materials	JESSE C. JOHNSON.
Director, Division of Reactor Development.	W. KENNETH DAVIS.
Director, Division of Research	PAUL W. MCDANIEL, *Acting*.
Director, Division of Security	JOHN A. WATERS, Jr.

MANAGERS OF OPERATIONS OFFICES AND AREAS

Albuquerque (N. Mex.) Operations Office	KENNER F. HERTFORD.
Burlington (Iowa) Area	E. W. GILES.
Clearwater (Fla.) Area	*Vacancy*
Dayton (Miamisburg, Ohio) Area.	JOHN H. ROBERSON.
Kansas City (Mo.) Area	WALTER C. YOUNGS, Jr.
Los Alamos (N. Mex.) Area	PAUL A. WILSON.
Rocky Flats (Colo.) Area	SETH R. WOODRUFF, Jr.
Sandia (N. Mex.) Area	A. E. UEHLINGER.
South Albuquerque (N. Mex.)	WALTER W. STAGG.
Chicago, (Ill.) Operations Office	KENNETH A. DUNBAR.
Canoga Park (Calif.) Area	A. P. POLLMAN
Hartford (Conn.) Area	ERNEST B. TREMMEL.
Lockland (Ohio) Area	E. M. VELTEN.
Pittsburgh (Pa.) Area	LAWTON D. GEIGER.
Grand Junction (Colo.) Operations Office	ALLAN E. JONES.
Hanford (Wash.) Operations Office	J. E. TRAVIS.
Idaho (Idaho Falls) Operations Office	ALLAN C. JOHNSON.
New York (N. Y.) Operations Office	MERRIL EISENBUD.
Brookhaven (Long Island, N. Y.) Area.	E. L. VAN HORN.

MANAGERS OF OPERATIONS OFFICES AND AREAS—continued

Oak Ridge (Tenn.) Operations Office	S. R. SAPIRIE.
Fernald (Cincinnati, Ohio) Area	CLARENCE L. KARL.
New Brunswick (N. J.) Area	C. J. RODDEN.
Paducah (Ky.) Area	KENNEDY C. BROOKS.
Portsmouth (Ohio) Area	ROBERT H. MCCULLOH.
Puerto Rico (Mayaguez) Area	JOHN I. THOMAS.
St. Louis (Mo.) Area	FRED H. BELCHER.
San Francisco (Calif.) Operations Office	HAROLD A. FIDLER.
Savannah River (Aiken, S. C.) Operations Office	ROBERT C. BLAIR.
Schenectady (N. Y.) Operations Office	JON D. ANDERSON.

APPENDIX 2

MEMBERSHIP OF COMMITTEES

STATUTORY COMMITTEES AND BOARD

Joint Committee on Atomic Energy—Eighty-fifth Congress

This committee was established by the Atomic Energy Act of 1946, and continued under the Atomic Energy Act of 1954, 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 is referred to the committee. The committee's membership is composed of 9 Members of the Senate and 9 Members of the House of Representatives.

Representative CARL T. DURHAM (North Carolina), *Chairman.*
Senator CLINTON P. ANDERSON (New Mexico).
Senator RICHARD B. RUSSELL (Georgia).
Senator JOHN O. PASTORE (Rhode Island).
Senator ALBERT GORE (Tennessee).
Senator HENRY M. JACKSON (Washington).
Senator BOURKE B. HICKENLOOPER (Iowa).
Senator WILLIAM F. KNOWLAND (California).
Senator JOHN W. BRICKER (Ohio).
Senator HENRY C. DWORSHAK (Idaho).
Representative CHET HOLIFIELD (California).
Representative MELVIN PRICE (Illinois).
Representative PAUL J. KILDAY (Texas).
Representative JOHN J. DEMPSEY (New Mexico).
Representative JAMES E. VAN ZANDT (Pennsylvania).
Representative JAMES T. PATTERSON (Connecticut).
Representative THOMAS A. JENKINS (Ohio).
Representative CRAIG HOSMER (California).
JAMES T. RAMEY, *Executive Director.*

Military Liaison Committee

Under section 27 of the Atomic Energy Act of 1954, "there is hereby established a Military Liaison Committee consisting of—*a.* a Chairman, who shall be the head thereof and who shall be appointed by the President, by and with the advice and consent of the Senate, who shall serve at the pleasure of the President, and who shall receive compensation at the rate prescribed for an Assistant Secretary of Defense; and *b.* a representative or representatives from each of the Departments of the Army, Navy, and Air Force, in equal numbers as determined by the Secretary of Defense, to be assigned from each Department by the Secretary thereof, and who will serve without additional compensation. The

Chairman of the Committee may designate one of the members of the Committee as Acting Chairman to act during his absence. The Commission shall advise and consult with the Department of Defense, through the Committee, on all atomic energy matters which the Department of Defense deems to relate to military applications of atomic weapons or atomic energy including the development, manufacture, use, and storage of atomic weapons, the allocation of special nuclear material for military research, and the control of information relating to the manufacture or utilization of atomic weapons; and shall keep the Department of Defense, through the Committee, fully and currently informed of all such matters before the Commission. The Department of Defense, through the Committee, shall keep the Commission fully and currently informed on all matters within the Department of Defense which the Commission deems to relate to the development or application of atomic energy. The Department of Defense, through the Committee, shall have the authority to make written recommendations to the Commission from time to time on matters relating to military applications of atomic energy as the Department of Defense may deem appropriate. If the Department of Defense at any time concludes that any request, action, proposed action, or failure to act on the part of the Commission is adverse to the responsibilities of the Department of Defense, the Secretary of Defense shall refer the matter to the President whose decision shall be final."

Hon. HERBERT B. LOPER, *Chairman.*
Brig. Gen. DWIGHT E. BEACH, United States Army.
Brig. Gen. JOHN P. DALEY, United States Army.
Rear Adm. JAMES H. FLATLEY, Jr., United States Navy.
Rear Adm. G. S. PATRICK, United States Navy.
Maj. Gen. JOHN S. MILLS, United States Air Force.
Brig. Gen. RICHARD T. COINER, United States Air Force.

General Advisory Committee

This committee was established by the Atomic Energy Act of 1946 (Sec. 2 (b)), and is continued by section 26 of the Atomic Energy Act of 1954. 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.

Dr. WARREN C. JOHNSON, *Chairman;* dean of physical sciences, University of Chicago, Chicago, Ill.

Dr. JESSE W. BEAMS, chairman, physics department, University of Virginia, Charlottesville, Va.

Dr. J. B. FISK, executive vice president, Bell Telephone Laboratories, Murray Hill, N. J.

Dr. T. KEITH GLENNAN, president, Case Institute of Technology, Cleveland, Ohio.

Dr. EDWIN M. MCMILLAN, professor of physics, University of California Radiation Laboratory, Berkeley, Calif.

EGER V. MURPHREE, president, ESSO Research & Engineering Co., New York, N. Y.

Dr. EDWARD TELLER, associate director, University of California Radiation Laboratory, Berkeley, Calif.

Dr. J. C. WARNER, president, Carnegie Institute of Technology, Pittsburgh, Pa.

Dr. ROBERT E. WILSON, chairman of board, Standard Oil Co. of Indiana Chicago, Ill.

Dr. JANE H. HALL, secretary; assistant director, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Patent Compensation Board

This board was established in April 1949 pursuant to Section 11 of the Atomic Energy Act of 1946, and is the Board designated under Section 157a of the Atomic Energy Act of 1954. Section 157 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.

CASPER W. OOMS, chairman; firm of Casper W. Ooms, Chicago Ill.

JOHN V. L. HOGAN, consulting engineer, Hogan Laboratories, Inc., New York, N. Y.

LAWRENCE E. KINGSLAND, Kingsland, Rogers & Ezell, St. Louis, Mo.

Advisory Committee on Reactor Safeguards

The committee reviews safety studies and facility license applications referred to it and makes reports thereon, advises the Commission with regard to the hazards of proposed or existing reactor facilities and the adequacy of proposed reactor safety standards, and performs such other duties as the Commission may request. The committee's reports on applications for facility licenses become a part of the record of the application and available to the public, except for security material. Members are appointed by the Commission for a term of 4 years each, and one member is designated by the committee as its chairman. This statutory committee replaced the former Advisory Committee on Reactor Safeguards in 1957.

Dr. C. ROGERS MCCULLOUGH, chairman; project specialist, research and engineering division, Monsanto Chemical Co., Washington, D. C.

Dr. MANSON BENEDICT, professor of chemical engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Dr. HARVEY BROOKS, dean of engineering and applied physics, Harvard University, Cambridge, Mass.

Dr. WILLARD P. CONNER, manager, physical chemical division, research department, Hercules Powder Co., Wilmington, Del.

Dr. R. L. DOAN, manager, atomic energy division, Phillips Petroleum Co., Idaho Falls, Idaho.

Dr. MARK M. MILLS, associate director, Livermore Laboratory, University of California, Livermore, Calif.

K. R. OSBORN, manager of industrial development, general chemical division, Allied Chemical & Dye Corp., New York, N. Y.

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

REUEL C. STRATTON, assistant director, department of research, the Travelers Insurance Cos. of Hartford, Conn.

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

R. H. GRAHAM, technical secretary, Lockheed Aircraft Corp., Palo Alto, Calif.

ATOMIC ENERGY LABOR MANAGEMENT RELATIONS PANEL

The members of this panel were selected by the President to assist in arriving at peaceful adjustments of labor-management disputes which would imperil the Government's atomic energy program when the normal process of collective bargaining and mediation have been fully utilized without constructive results. The panel operates under procedures designed to accomplish this purpose. It reports annually to the President on its activities.

CYRUS S. CHING, chairman; industrial relations consultant and former Director of the Federal Mediation and Conciliation Service, Washington, D. C.

Rev. LEO C. BROWN, S. J., professor of economics and director of the Institute of Social Order, St. Louis University, St. Louis, Mo.

Vice Adm. O. S. COLCLOUGH, USN, Retired, dean of faculties, the George Washington University, Washington, D. C.

THOMAS W. HOLLAND, professor of labor economics, the George Washington University, arbitrator and consultant on labor relations, Washington, D. C.

ARTHUR M. ROSS, professor of industrial relations and director of the Institute of Industrial Relations, University of California, Berkeley, Calif.

RUSSELL A. SMITH, professor of law and secretary of the University of Michigan Law School, Ann Arbor, Mich.

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. The committee reviews the programs in medical and biological research and health and recommends to the Commission general policies in these fields.

Dr. SIMEON T. CANTRIL, chairman; director, Tumor Institute of Swedish Hospital, Seattle, Wash.

Dr. SHIELDS WARREN, vice chairman; pathologist, New England Deaconess Hospital, Boston, Mass.

Dr. JOHN C. BUGHER, director, medical education and public health, Rockefeller Foundation, New York, N. Y.

Dr. CHARLES H. BURNETT, professor of medicine, University of North Carolina, Chapel Hill, N. C.

Dr. H. BENTLEY GLASS, professor of biology, Johns Hopkins University, Baltimore, Md.

Dr. JAMES G. HORSFALL, director, Connecticut Agricultural Experiment Station, New Haven, Conn.

Dr. LEONIDAS D. MARINELLI, associate director, division of radiological physics, Argonne National Laboratory, Lemont, Ill.

Dr. HARLAND G. WOOD, department of biochemistry, school of medicine, Western Reserve University, Cleveland, Ohio.

Dr. HENRY I. KOHN, scientific secretary; clinical professor of experimental radiology, radiological laboratory, school of medicine University of California Medical Center, San Francisco, Calif.

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 Commission contracts and subcontracts and makes recommendations to the General Manager concerning their disposition.

HENRY P. BRANDIS, Jr., dean of the law school, University of North Carolina, Chapel Hill, N. C.

SHELDON D. ELLIOTT, director of institute for judicial administration, New York University, New York, N. Y.

ROBERT KINGSLEY, dean, school of law, University of Southern California, Los Angeles, Calif.

EDMUND R. PURVES, executive director, American Institute of Architects, Washington, D. C.

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

Advisory Committee On Reactor Physics

This committee is appointed to consider the status of the development of reactor physics information required for the development of reactor concepts and the design and construction of reactors. Nuclear physics data and reactor physics studies required for the design and development of reactors is reviewed and evaluated. The committee's recommendations and advice are used in planning the research and development work in the field of reactor physics.

Dr. ROBERT A. CHARPIE, chairman; assistant director, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. IRA F. ZARTMAN, vice chairman; Engineering Development Branch, Division of Reactor Development, Atomic Energy Commission, Washington, D. C.

Dr. E. RICHARD COHEN, research adviser, Atomics International, North American Aviation, Inc., Canoga Park, Calif.

DESLONDE DEBOISBLANC, director, reactor physics and engineering, Phillips Petroleum Co., Idaho Falls, Idaho.

Dr. GERHARD DESSAUER, director, physics section, E. I. du Pont de Nemours & Co., Inc., Aiken, S. C.

Dr. MILTON EDLUND, manager, physics and math department, Babcock & Wilcox, Lynchburg, Va.

Dr. PAUL F. GAST, manager, physics and instrument research and development, General Electric Co., Richland, Wash.

Dr. HENRY HURWITZ, General Electric Research Laboratory, Schenectady, N. Y.

Dr. IRVING KAPLAN, head, Reactor Physics Division, Brookhaven National Laboratory, Upton, Long Island, N. Y.

Dr. HERBERT J. C. KOUTS, experimental reactor physics group leader, Brookhaven National Laboratory, Upton, Long Island, N. Y.

Dr. SIDNEY KRASIK, manager, central physics and math department, Westinghouse Electric Corp., Pittsburgh, Pa.

Dr. THEODORE MERKLE, division leader, "R" division, University of California Radiation Laboratory, Livermore, Calif.

Dr. JOHN W. MORFITT, manager, nuclear development laboratory, General Electric Co., Cincinnati 15, Ohio.

Dr. HUGH PAXTON, group leader, N2, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. THOMA M. SNYDER, manager, physics—APED, General Electric Co., Pleasanton, Calif.

Dr. BERNARD I. SPINRAD, director, reactor engineering division, Argonne National Laboratory, Lemont, Ill.

Dr. PAUL F. ZWEIFEL, consulting physicist, General Electric Co., Schenectady, N. Y.

Dr. ALVIN RADKOWSKY, secretary; naval reactors branch, division of reactor development, Atomic Energy Commission, Washington, D. C.

Advisory Committee of State Officials

This committee was established by the Commission in September 1955 as a means of obtaining the views and advice of State regulatory agencies in connection with the Atomic Energy Commission's regulatory activities in the field of public health and safety.

Dr. DANIEL BERGSMA, commissioner of health, Trenton, N. J.

A. C. BLACKMAN, chief, division of industrial safety, California Department of Industrial Relations, San Francisco, Calif.

Dr. ROY L. CLEERE, executive director, Colorado State Department of Public Health, Denver, Colo.

CURTIS M. EVERTS, Jr., director, division of sanitation and engineering, Oregon State Board of Health, Portland, Oreg.

JAMES G. FROST, deputy attorney general of Maine, Augusta, Maine.

Dr. ALBERT E. HEUSTIS, commissioner of health, Lansing, Mich.

Dr. JAN LIEBEN, director, division of industrial hygiene, Department of Health, Harrisburg, Pa.

WILLIAM T. LINTON, executive director, water pollution control authority, South Carolina State Board of Health, Columbia, S. C.

B. A. POOLE, director, bureau of environmental sanitation, State Board of Health, Indianapolis, Ind.

DONALD P. ROBERTS, chief, industrial hygiene section, Tennessee Department of Health, Nashville, Tenn.

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.

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

FRANCIS C. FRARY, technical adviser, aluminum research laboratory, Aluminum Co. of America, New Kensington, Pa.

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

ERNEST ROSE, metallurgist, Koppers Co., Pittsburgh, Pa.

WALTER O. SNELLING, research chemist, Allentown, Pa.

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

CLYDE WILLIAMS, president and director, Battelle Memorial Institute. Columbus, Ohio.

Committee of Senior Reviewers

The Committee of Senior Reviewers studies the major technical activities of the Atomic Energy Commission program and advises the Commission on classification and declassification matters, making recommendations with respect to the rules and guides for the control of scientific and technical information. The committee consists of six members appointed for a term of 5 years on a rotating basis.

Dr. ALVIN C. GRAVES, chairman; J. division leader, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. JOHN P. HOWE, Atomics International, North American Aviation, Inc., Downey, Calif.

Dr. WARREN C. JOHNSON, dean of physical sciences, University of Chicago, Chicago, Ill.

Dr. WINSTON M. MANNING, director, chemistry division, Argonne National Laboratory, Lemont, Ill.

Dr. J. R. RICHARDSON, professor of physics, University of California at Los Angeles, Calif.

Advisory Committee on Industrial Information

The committee, formed in 1949, advises and assists in the planning and execution of the Atomic Energy Commission's industrial information program.

E. E. THUM, chairman; editor, *Metal Progress*, American Society for Metals, Cleveland, Ohio.

S. A. TUCKER, vice chairman; publications business manager, American Society of Mechanical Engineers, New York, N. Y.

Dr. ALLEN G. GRAY, technical editor, *Steel*, Penton Publishing Co., Cleveland, Ohio.

EUGENE J. HARDY, National Association of Manufacturers, Washington, D. C.

KEITH HENNEY, consulting editor, *Nucleonics and Electronics*, McGraw-Hill Publishing Co., Inc.; American Institute of Radio Engineers, New York, N. Y.

NORMAN H. JACOBSON, *Electric Light and Power*, Haywood Publishing Co., Chicago, Ill.

WALTER E. JESSUP, editor, *Civil Engineering*, The American Society of Civil Engineers, New York, N. Y.

ANDREW W. KRAMER, editor, *Power Engineering*, The Technical Publishing Co., Barrington, Ill.

JOHN W. LANDIS, American Nuclear Society, New York, N. Y.

Dr. WALTER J. MURPHY, editorial director, Applied Publications, American Chemical Society, Washington, D. C.

FREDERIC A. PAWLEY, research secretary, American Institute of Architects, Washington, D. C.

KARL T. SCHWARTZWALDER, The American Ceramic Society, Inc., Columbus, Ohio.

GEORGE F. SULLIVAN, editor, *The Iron Age*, Chilton Publication, Inc., Philadelphia, Pa.

OLIVER H. TOWNSEND, secretary, Atomic Industrial Forum, Inc., New York, N. Y.

BERNARD M. FRY, secretary; assistant director for technical information service, division of information services, Atomic Energy Commission, Washington, D. C.

Advisory Committee on Isotope Distribution

This committee was originally appointed by the Manhattan Engineer 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. REYNOLDS F. BROWN, department of radiology, University of California Medical School, San Francisco, Calif.

Dr. JOHN A. D. COOPER, assistant dean, Northwestern University Medical School, Chicago, Ill.

Dr. DONALD S. CHILDS, Jr., department of radiology, Mayo Clinic, Rochester, Minn.

Dr. JOHN E. CHRISTIAN, associate professor, department of pharmaceutical chemistry, Purdue University, Lafayette, Ind.

Dr. HENRY J. GOMBERG, assistant director, Phoenix Memorial Laboratory, University of Michigan, Ann Arbor, Mich.

Dr. H. R. NELSON, department of physics, Battelle Memorial Institute, Columbus, Ohio.

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

Dr. JOHN E. WILLARD, professor of chemistry, University of Wisconsin, Madison, Wis.

Dr. PAUL C. AEBERSOLD, secretary; assistant director for isotopes and radiations, division of civilian application, Atomic Energy Commission, Washington, D. C.

Committee for Uranium Isotopic Standards

This committee, established by the Commission in March 1956, reviews all recorded evidence supporting standards on the primary generative product (uranium 235 and uranium 238) and depleted materials, evaluates the standards, and recommends any additional action which the Commission should take to establish the Certified Uranium Isotopic Standards.

DONALD F. MUSSER, chairman; director, division of nuclear materials management, Atomic Energy Commission, Washington, D. C.

Dr. MARK INGHRAM, professor of physics, University of Chicago, Chicago, Ill.

Dr. SAMUEL C. T. MCDOWELL, Chief, Chemistry and Physics Branch, Division of Nuclear Materials Management, Atomic Energy Commission, Washington, D. C.

Dr. CHARLES METZ, supervisor, analytical work, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. HORACE W. NORTON, professor of agricultural statistics, Agricultural Experiment Station, University of Illinois, Urbana, Ill.

Dr. EDWIN ORLEMANN, professor of chemistry, University of California, Berkeley, Calif.

Dr. LEONARD PEPKOWITZ, vice president, Nuclear Materials & Equipment Corp., Apollo, Pa.

Dr. C. J. RODDEN, area manager, New Brunswick Area Office, Atomic Energy Commission, New Brunswick, N. J.

CHARLES D. W. THORNTON, assistant to president, Farnsworth Electronics Co., Fort Wayne, Ind.

Dr. EDWARD WICHERS, chief of chemistry, National Bureau of Standards, Department of Commerce, Washington, D. C.

Metallurgy and Materials Advisory Panel

This panel was established in October 1955 to advise on the Commission's research program on metallurgy, solid state physics, and ceramics.

Dr. HARVEY BROOKS, division of engineering sciences, Harvard University, Cambridge, Mass.

Dr. MORRIS COHEN, department of metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

Dr. MAXWELL GENSAMER, professor of metallurgy, Columbia University, New York, N. Y.

Dr. JOHN P. HOWE, Atomics International, a division of North American Aviation, Inc., Downey, Calif.

Dr. ALBERT R. KAUFMAN, vice president, Nuclear Metals, Inc., Cambridge, Mass.

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

Dr. JOHN C. SLATER, department of physics, Massachusetts Institute of Technology, Cambridge, Mass.

Dr. DONALD K. STEVENS, division of research, Atomic Energy Commission, Washington, D. C.

Nuclear Cross Sections Advisory Group

This group is appointed on a yearly basis to make a continuing review of the Commission's program of nuclear cross-section measurements, and to evaluate the needs for cross-section information in the various activities of the Commission. The following members were appointed to serve from July 1957 to July 1958.

Dr. WILLIAM W. HAVENS, Jr., chairman; department of physics, Columbia University, New York, N. Y.

Dr. GEORGE A. KOLSTAD, vice chairman; division of research, Atomic Energy Commission, Washington, D. C.

Dr. LOWELL M. BOLLINGER, Argonne National Laboratory, Lemont, Ill.

Dr. TOM W. BONNER, department of physics, Rice Institute, Houston, Tex.

Dr. BENJAMIN C. DIVEN, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. REX G. FLUHARTY, Phillips Petroleum Co., Idaho Falls, Idaho.

Dr. HERBERT GOLDSTEIN, Nuclear Development Corp. of America, White Plains, N. Y.

Dr. JOHN A. HARVEY, physics division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. BOWEN R. LEONARD, General Electric Co., Richland, Wash.

Dr. HENRY W. NEWSON, department of physics, Duke University, Durham, N. C.

Dr. JACK M. PETERSON, University of California Radiation Laboratory, Livermore, Calif.
Dr. MAX L. YEATOR, Knolls Atomic Power Laboratory, General Electric Co., Schenectady, N. Y.
Dr. IRA F. ZARTMAN, Division of Reactor Development, Atomic Energy Commission, Washington, D. C.
Dr. VANCE L. SAILOR, secretary; Reactor Division, Brookhaven National Laboratory, Upton, Long Island, N. Y.

Patent Advisory Panel

This panel was appointed in January 1947. It makes informal reports and recommendations to the Commission and its staff on various questions of policy and procedure relating to patents and inventions.

JO. BAILY BROWN; Brown, Critchlon, Flick & Peckham, Pittsburgh, Pa.
JOHN A. DIENNER; Brown, Jackson, Boettcher & Dienner, Chicago, Ill.
CASPER W. OOMS; firm of Casper W. Ooms, Chicago, Ill.

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 to make recommendations concerning them to the General Manager. The board 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; Purcell & Nelson, Washington, D. C.
Dr. PAUL E. KLOPSTEG, associate director, National Science Foundation, Washington, D. C.
JOHN J. WILSON, firm of Whiteford, Hart, Carmody & Wilson, Washington, D. C.

Sherwood Steering Committee

This committee was approved by the Commission on January 27, 1954. The committee meets as the need arises to analyze the overall problem, recommend new projects to be undertaken, suggest who might do the work, review progress and proposals, and recommend desirable emphasis and levels of support of research on peaceful uses of controlled thermonuclear reactions.

Dr. PAUL MCDANIEL, chairman; acting director, division of research, Atomic Energy Commission, Washington, D. C.
Dr. ARTHUR E. RUARK, division of research, Atomic Energy Commission, Washington, D. C.
Dr. LYMAN SPITZER, Jr., Forrestal Research Center, Princeton University, Princeton, N. J.
Dr. JAMES L. TUCK, technical director, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
Dr. HERBERT F. YORK, director, University of California Radiation Laboratory, Livermore, Calif.
Dr. HILLIARD RODERICK, secretary; division of research, Atomic Energy Commission, Washington, D. C.

Stack Gas Problem Working Group

The appointment of this group was authorized in May 1948 to advise the Atomic Energy Commission and its contractors on problems in the treatment and control of gaseous effluents. The group meets formally at irregular intervals but renders continuing assistance in the field of air cleaning through specific research and development work directly by individual members and by individual consulting advice to the various Commission installations.

Dr. PHILIP DRINKER, professor of industrial hygiene, Harvard University School of Public Health, Boston, Mass.

Dr. LYLE I. GILBERTSON, director, research and engineering department, Air Reduction Co., Inc., Murray Hill, N. J.

A. E. GORMAN, division of reactor development, Atomic Energy Commission, Washington, D. C.

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

Dr. CHARLES E. LAPPLE, Stanford Research Institute, Menlo Park, Calif.

Dr. J. A. LIEBERMAN, division of reactor development, Atomic Energy Commission, Washington, D. C.

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

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

APPENDIX 3

Major Research and Development Installations 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. Adolph F. Voigt

Argonne Cancer Research Hospital (University of Chicago, contractor), Chicago, Ill.

The participating institutions associated with Argonne National Laboratory (listed immediately below) are also affiliated with the Argonne Cancer Research Hospital.

Director	Dr. Leon O. Jacobson
Associate Director	Dr. Robert J. Hasterlik

Argonne National Laboratory (University of Chicago, contractor), Lemont, Ill.

Director	Dr. Norman Hilberry
Assistant Director	Dr. James R. Gilbreath
Business Manager	John H. McKinley
Manager, Technical Services	John T. Bobbitt

The participating institutions are:

- Battelle Memorial Institute
- Carnegie Institute of Technology
- Case Institute of Technology
- Illinois Institute of Technology
- Indiana University
- Iowa State College of Agriculture & Mechanic Arts
- Kansas State College
- Loyola University (Chicago, Ill.)
- Marquette University
- Mayo Foundation
- Michigan College of Mining and Technology
- Michigan State University of Agriculture & Applied Science
- Northwestern University
- Ohio State University
- Oklahoma Agricultural & Mechanical College
- Purdue University
- St. Louis University
- State University of Iowa
- Washington University (St. Louis, Mo.)
- Wayne University
- 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

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Bettis Plant (Westinghouse Electric Corp., contractor), Pittsburgh, Pa.

Plant Manager, Westinghouse Electric Corp	JOHN W. SIMPSON
Manager, PWR Project	Joseph C. RENGEL
Manager, SFR Project	ALEXANDER SQUIRE
Manager, A1W Project	JOHN T. STIEFEL
Manager, S5W Project	DOUGLAS C. SPENCER
Manager, F1W Project	KARL W. SCHWANEKAMP
Manager, S1W Site, Naval Reactor Test Facility (NRTS), Idaho.	JOHN M. YADON

Brookhaven National Laboratory (Associated Universities, Inc., contractor), Upton, Long Island, N. Y.

Chairman, Board of Trustees	JOSEPH C. ELGIN
President, AUI	LLOYD V. BERKNER
Vice President, AUI and Laboratory Director	Dr. LELAND J. HAWORTH
Deputy Laboratory Director	Dr. GERALD F. TAPE
Associate Director	WILLIAM H. FIELDS
Assistant Director	Dr. ROBERT A. PATTERSON
Assistant Director	Dr. SAMUEL M. TUCKER

The participating institutions are:

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

Knolls Atomic Power Laboratory (General Electric Co., contractor), Schenectady, N. Y.

General Manager	F. E. CREVER
Manager, D1G Project	K. A. KESSELRING
Manager, SAR Project	B. W. CALDWELL, Jr.
Manager, S1R Project	W. N. OBERLY
Manager, Technical Operations	Dr. H. J. PLUMBLEY
Manager, Advanced Development	Dr. W. R. KANNE
Manager, Operational Analysis	W. N. OBERLY
Manager, Auxiliary Operation	S. B. STROM

Los Alamos Scientific Laboratory (University of California, contractor), Los Alamos, N. Mex.

Director	Dr. NORRIS E. BRADBURY
Technical Associate Director	Dr. DAROL K. FROMAN

Oak Ridge Institute of Nuclear Studies (contractor), Oak Ridge, Tenn.

President of Institute	Dr. PAUL M. GROSS
Vice President of Institute	Dr. W. C. JOHNSON
Executive Director of Institute	Dr. WILLIAM G. POLLARD
Chairman of Council	Dr. MARTEN TEN HOOR
Vice Chairman of Council	Dr. F. C. BILBRANDT

The sponsoring universities of the Institute are:

Agricultural and Mechanical College of Texas
Alabama Polytechnic Institute
Catholic University of America
Clemson Agricultural College
Duke University
Emory University
Florida State University
Georgia Institute of Technology
Louisiana State University
Meharry Medical College
Mississippi State College
North Carolina State College
North Texas State College
Rice Institute
Southern Methodist University
Tulane University of Louisiana
Tuskegee Institute
Union College
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 Miami
University of Mississippi
University of North Carolina
University of Oklahoma
University of Puerto Rico
University of South Carolina
University of Tennessee
University of Texas
University of Virginia
University of West Virginia

Oak Ridge National Laboratory (Union Carbide Nuclear Co., Division of Union Carbide Corp., contractor), Oak Ridge, Tenn.

Director	Dr. A. M. WEINBERG
Deputy Director	Dr. J. A. SWARTHOUT
Assistant Laboratory Director	Dr. G. E. BOYD
Assistant Laboratory Director	Dr. R. A. CHARPIE
Assistant Laboratory Director	Dr. A. H. SNELL
Assistant Laboratory Director	Dr. R. W. JOHNSON
Assistant Laboratory Director	Dr. C. E. WINTERS
Assistant Laboratory Director	M. E. RAMSEY

Raw Materials Development Laboratory (National Lead Co., contractor), Winchester, Mass.

Technical Director and Manager	CHARLES K. MCARTHUR

Sandia Laboratory (Sandia Corp., contractor), Sandia Base, Albuquerque, N. Mex.

President	JAMES W. MCRAE
Vice President and General Manager	MAX H. HOWARTH

University of California at Los Angeles, Atomic Energy Project (University of California, contractor), Los Angeles, Calif.

Director	Dr. STAFFORD WARREN
Project Manager	(Vacancy)

University of California, Medical Center, Radiological Laboratory (University of California, contractor), San Francisco, Calif.

Director	Dr. ROBERT S. STONE

University of California Radiation Laboratory (University of California, contractor), Berkeley, Calif.

Director	Dr. ERNEST O. LAWRENCE
Associate Director	Dr. LUIS W. ALVAREZ
Associate Director	Dr. DONALD COOKSEY
Associate Director	Dr. EDWIN M. MCMILLAN
Associate Director	Dr. GLENN T. SEABORG
Associate Director	Dr. EDWARD TELLER
Associate Director	Dr. HERBERT F. YORK
Assistant Director	WILLIAM M. BROBECK
Director, Crocker Laboratory Medical Physics	(Vacancy)
Director, Donner Laboratory of Medical Physics	Dr. J. H. LAWRENCE
Director, Livermore Laboratory	Dr. HERBERT F. YORK
Business Manager and Managing Engineer	WALLACE B. REYNOLDS

University of Rochester Atomic Energy Project (University of Rochester, contractor), Rochester, N. Y.

Director	Dr. HENRY A. BLAIR
Business Manager	C. S. THOMPSON

National Reactor Testing Station (NRTS), Idaho Falls, Idaho

Nevada Test Site, Las Vegas, Nev.

Eniwetok Proving Ground, Marshall Islands

APPENDIX 4

Radioactive Isotope Distribution Data [1]

Radioactive Isotope	Aug. 2, 1946–Nov. 30, 1957		Jan. 1, 1957–Nov. 30, 1957		Total to Nov. 30, 1957	
	Activity (Curies)	Shipments	Activity (Curies)	Shipments	Activity (Curies)	Shipments
Iodine 131	3,975	33,320	814	3,930	4,789	37,250
Phosphorus 32	1,083	19,410	162	2,333	1,245	21,743
Carbon 14	50	2,658	9	234	59	2,892
Tritium	6,948	451	4,767	129	11,715	580
Strontium 89, 90	416	1,084	21	155	437	1,239
Cobalt 60	190,007	1,429	129,029	216	319,036	1,645
Cesium 137	5,272	763	5,085	147	10,357	910
Iridium 192	10,481	318	5,891	133	16,372	451
Others [2]	965	17,649	1,434	4,434	2,399	22,083
Irradiated Units [3]	----------	13,316	----------	1,281	----------	14,597
Total	219,197	90,398	147,212	12,992	366,409	103,390
Shipments to AEC installations	----------	10,623	----------	1,295	----------	11,918

[1] Domestic shipments from Oak Ridge National Laboratory.
[2] Krypton 85 accounts for the large increase in 1957.
[3] Includes irradiated units of Iodine 131 and Phosphorus 32.

LOCATION AND TYPE OF NEW USERS

(Jan. 1, 1957–Nov. 30, 1957)

States and Territories	Medical Institutes and Physicians	Colleges and Universities	Industrial Firms	Federal and State Laboratories	Foundations and Institutes	Other	Total
Alaska	1	1	0	2	0	0	4
Alabama	10	3	8	2	0	0	23
Arizona	2	1	1	0	0	0	4
Arkansas	5	0	3	2	0	0	10
California	71	5	71	17	2	1	168
Colorado	11	3	6	4	0	3	26
Connecticut	6	0	20	5	1	0	32
Delaware	0	0	3	2	0	0	5
District of Columbia	4	1	2	9	0	0	16
Florida	20	1	5	3	0	1	30
Georgia	5	0	4	2	0	0	11
Hawaii	2	0	2	0	1	0	5
Idaho	1	0	0	0	0	0	1
Illinois	36	4	39	11	2	2	94
Indiana	18	2	19	1	0	0	40
Iowa	7	1	5	0	0	0	13
Kansas	5	2	1	2	0	0	10
Kentucky	9	0	6	1	0	2	16
Louisiana	9	1	11	0	0	0	21
Maine	3	0	7	5	1	0	16
Maryland	7	2	7	5	0	1	22
Massachusetts	11	4	42	5	3	2	67
Michigan	23	0	18	8	1	1	51
Minnesota	14	2	10	1	0	1	28
Mississippi	0	0	1	0	0	0	1
Missouri	18	3	12	4	1	3	41
Montana	5	1	0	0	0	0	6
Nebraska	5	0	1	1	0	0	7
Nevada	1	0	0	2	0	0	3
New Hampshire	1	1	3	2	0	0	6
New Jersey	35	0	47	6	2	0	90
New Mexico	5	1	2	2	0	0	11
New York	95	4	63	14	1	1	178
North Carolina	9	1	5	2	0	0	17
North Dakota	1	0	0	0	0	0	1
Ohio	32	1	32	4	0	1	70
Oklahoma	12	1	12	0	0	0	25
Oregon	7	0	1	3	0	0	11
Panama	0	0	0	0	0	0	0
Pennsylvania	24	4	61	18	1	1	109
Puerto Rico	3	2	0	0	0	0	5
Rhode Island	1	0	7	3	0	0	11
South Carolina	5	0	0	1	0	1	7
South Dakota	8	2	0	1	0	0	11
Tennessee	9	1	3	2	0	3	18
Texas	35	0	32	6	0	1	74
Utah	5	3	4	1	0	0	13
Vermont	0	1	1	1	0	0	3
Virginia	9	0	12	2	0	2	25
Washington	8	1	7	5	1	0	22
West Virginia	7	0	2	0	0	0	9
Wisconsin	21	1	14	0	2	0	38
Wyoming	4	0	0	0	0	0	4
Total	643	61	612	167	19	27	1,529

LOCATION AND TYPE OF ALL USERS
(Feb. 10, 1956–Nov. 30, 1957)

States and Territories	Medical Institutes and Physicians	Colleges and Universities	Industrial Firms	Federal and State Laboratories	Foundations and Institutes	Other	Total
Alaska	2	1	0	1	0	0	4
Alabama	16	4	18	3	0	0	41
Arizona	6	2	3	0	0	0	11
Arkansas	14	1	6	2	0	0	23
California	160	9	133	27	3	2	334
Colorado	23	4	10	5	0	3	45
Connecticut	18	4	34	11	2	0	69
Delaware	1	1	7	3	0	0	12
District of Columbia	17	3	2	15	0	0	37
Florida	37	5	10	4	0	1	57
Georgia	17	2	11	3	0	0	33
Hawaii	5	1	2	2	2	0	12
Idaho	3	2	2	0	0	0	7
Illinois	88	18	80	17	4	2	209
Indiana	36	5	33	1	0	0	75
Iowa	22	4	6	0	0	0	32
Kansas	20	2	6	2	0	0	30
Kentucky	16	3	10	2	0	2	33
Louisiana	22	3	23	1	0	1	50
Maine	5	2	14	5	1	1	28
Maryland	19	3	17	12	0	1	52
Massachusetts	41	24	68	7	6	2	148
Michigan	60	7	39	10	3	0	119
Minnesota	27	6	15	1	0	1	50
Mississippi	6	3	4	1	0	0	14
Missouri	51	5	14	11	0	4	85
Montana	9	2	1	0	0	0	11
Nebraska	15	1	2	1	0	0	19
Nevada	4	0	0	2	0	0	6
New Hampshire	4	2	1	4	0	0	11
New Jersey	56	4	97	8	1	0	167
New Mexico	9	2	6	2	0	0	19
New York	233	20	133	26	4	4	420
North Carolina	25	6	12	5	0	1	49
North Dakota	7	1	0	0	0	0	8
Ohio	80	8	60	8	4	0	160
Oklahoma	22	2	29	2	2	1	58
Oregon	14	2	4	4	0	0	24
Panama	0	0	0	0	0	0	0
Pennsylvania	78	15	108	24	2	0	227
Puerto Rico	6	2	0	0	0	0	8
Rhode Island	7	1	12	3	0	0	23
South Carolina	6	2	3	0	0	0	11
South Dakota	11	1	0	1	0	0	13
Tennessee	29	7	13	2	0	2	53
Texas	104	6	78	7	3	1	199
Utah	8	3	4	2	0	1	18
Vermont	2	1	2	1	0	0	6
Virginia	27	4	19	8	0	2	60
Washington	19	4	10	8	0	1	42
West Virginia	18	1	7	1	0	0	27
Wisconsin	42	3	28	2	4	0	79
Wyoming	5	1	1	0	0	0	7
Total	1,572	225	1,197	267	41	33	3,335

NOTE.—From Aug. 2, 1946, to Feb. 10, 1956, radioisotopes were dispensed under a Commission authorization procedure. During that time, 3,100 organizations were authorized to use radioisotopes. On Feb. 10, 1956, the authorization procedure was changed to a licensing procedure to conform to the Atomic Energy Act of 1954 and the task of converting authorizations to licenses was begun.

The Twenty-second Semiannual Report to Congress listed 4,041 organizations authorized (or licensed) to use radioisotopes through May 31, 1957. During the past years, the number of new users has been added to old users to give a summary total.

Because the licensing procedure has been in effect for nearly 2 years and because conversion of authorizations to licenses is about 90 percent completed, it seems desirable to convert to a licensing report. The following table shows 3,335 byproduct material licenses now in existence.

The apparent number of organizations using radioisotopes has dropped for the following reasons:

(1) Large institutions at multiple locations, previously holding several authorizations, have been issued a single basic license.

(2) Because of the effort involved in converting several thousand authorizations to licenses, and keeping current with new applications in an expanding radioisotopes program, several authorizations still await conversion.

(3) During nearly 12 years of radioisotope utilization, some organizations have discontinued using radioisotopes.

(4) Generally licensed quantities of radioisotopes (Code of Federal Regulations, Title 10, Pt. 30, Sec. 30.72) have been increased. Several users now purchase radioisotopes under general license and do not receive a specific license; thus they are not included here.

SHIPMENTS OF RADIOACTIVE ISOTOPES TO FOREIGN COUNTRIES

Country	Jan. 1, 1957–Nov. 30, 1957	Total January 1947 to Nov. 30, 1957	Country	Jan. 1, 1957–Nov. 30, 1957	Total January 1947 to Nov. 30, 1957
Argentina	8	134	Iran	5	6
Australia	11	123	Israel	27	42
Austria	2	4	Italy	31	82
Belgian Congo	0	3	Japan	146	663
Belgium	33	210	Korea	1	1
Bermuda	0	16	Lebanon	0	7
Brazil	137	634	Mexico	122	331
British West Africa	3	4	Netherlands	46	128
Burma	6	6	New Zealand	3	16
Canada	610	1,983	Nicaragua	6	6
Chile	19	175	Norway	14	80
Colombia	24	62	Pakistan	0	10
Costa Rica	1	3	Peru	53	122
Cuba	126	588	Philippines	73	83
Denmark	25	264	Portugal	2	14
Dominican Republic	5	6	Republic of China	11	13
Ecuador	16	17	Russia	1	1
Egypt	9	11	Spain	8	23
El Salvador	0	1	Sweden	80	328
England	33	213	Switzerland	15	100
Federal Republic of Germany	71	122	Syria	0	2
Finland	6	27	Thailand	12	14
France	52	205	Trinidad	9	9
Gold Coast	0	1	Trieste	0	4
Greece	6	7	Turkey	0	5
Guatemala	4	40	Union of South Africa	2	39
Honduras	2	3	Uruguay	2	13
Iceland	0	5	Venezuela	227	308
India	26	67	Yugoslavia	9	11
Indonesia	3	6	Total	2,143	7,401

Kind of Isotope	Jan. 1, 1957–Nov. 30, 1957	Total January 1947 to Nov. 30, 1957	Kind of Isotope	Jan. 1, 1957–Nov. 30, 1957	Total January 1947 to Nov. 30, 1957
Phosphorus 32	92	1,125	Strontium 89, 90	48	199
Iodine 131	916	2,783	Calcium 45	32	169
Carbon 14	115	513	Other	593	1,596
Sulfur 35	16	158	Total	2,143	7,401
Iron 55, 59	118	342			
Cobalt 60	213	516			

APPENDIX 5

COMMISSION-OWNED PATENTS

PATENTS ISSUED TO THE COMMISSION WHICH ARE AVAILABLE FOR LICENSING [1]

The following 126 U. S. Letters Patents owned by the United States Government as represented by the Atomic Energy Commission are in addition to the 118 patents listed in the Twenty-second Semiannual Report. The patents listed have been made available for licensing at periodic intervals. The total number of patents available for licensing is 1,345. Licenses are granted on a nonexclusive, royalty-free basis.

PATENT NO.	TITLE	PATENTEE
2,476,490	Production of Trifluoroacetic Acid	W. N. Haworth and Maurice Stacey, Birmingham, England.
2,480,467	Production of Trifluoroacetic Acid	W. N. Haworth and Maurice Stacey, Birmingham, England.
2,483,610	Bladed Impeller for Turboblowers	K. Baumann, Knutsford, England.
2,535,202	Indicating, Recording, and Controlling Apparatus.	C. H. Gregory, Eaglescliffe, J. Hall, Norton-on-Tees, England.
2,689,629	Reduction of the Momentum of Falling Bodies.	J. W. Kendall, Risley; I. H. Morrison, Sutton Coldfield, England.
2,717,225	Sintered Refractory Mass	A. E. Williams, London, England.
2,728,633	Production of Uranium and Thorium Compounds.	T. V. Arden, F. H. Burstall, R. P. Linstead, and R. A. Wells, Teddington, England.
2,742,085	Timing Apparatus	A. E. Bennett and J. C. H. Geisow, Abingdon, England.
2,742,348	Fluid Contractor Apparatus	R. Spence and R. J. W. Streeton, Harwell, England.
2,753,476	Current Transfer Systems	D. A. Watt, Oxford, England.
2,759,792	Separating Hafnium from Zirconium	B. A. J. Lister, J. F. Duncan, and J. M. Hutcheon, London, England.
2,759,793	Separating Hafnium from Zirconium	B. A. J. Lister and J. F. Duncan, London, England.
2,770,196	Electromagnetic Interaction Pump	D. A. Watt, Oxford, England.
2,794,562	Fuel Element Loading Apparatus for Neutronic Reactors.	G. A. Anderson, Chicago Heights, Ill.
2,794,670	Releasable Holder for Rod	R. L. Menegus, Wilmington, Del.; R. L. Akers, Claymont, Del.
2,794,923	Electromagnetic Apparatus	S. W. Barnes, Rochester, N. Y.
2,795,479	Method for Converting Uranium Ammonium Phosphate to Uranyl Fluoride.	S. Bernstein and H. A. Bernhardt, Oak Ridge, Tenn.
2,795,480	Recovery of Uranium from Aqueous Phosphate Containing Solutions.	E. F. Stephan and G. A. Lutz, Columbus, Ohio.
2,795,481	Solvent Extraction Process for the Separation of Tantalum and Niobium Values.	H. G. Hicks, Danville, W. E. Nervik, Piedmont; and P. C. Stevenson, Livermore, Calif.
2,795,482	Absorption of Iodine Vapor	R. McNabney, Morristown, N. J.
2,795,499	Production of Metals	D. Peterson, Ames, Iowa.
2,795,654	High Impedance Electronic Circuit	J. R. MacDonald, Dallas, Tex.
2,795,703	Apparatus for Counting Fast Neutrons in the Presence of Gamma Rays.	I. B. Berlman and L. D. Marinelli, Chicago, Ill.
2,795,704	Neutron Ion Chamber	H. Bryant, Park Forest; G. F. Erickson, Chicago; and S. G. Kaufmann, Lombard, Ill.
2,796,320	Solvent Extraction Process for Purification of Thorium.	F. H. Spedding, Ames, Iowa; A. Kant, Pittsburgh, Pa.
2,796,323	Conversion of Dimethyl Ether Boron Trifluoride Complex to Potassium Fluoborate.	A. R. Eberle, South Plainfield, N. J.
2,796,330	Method of Separating and Concentrating Isotopes of Boron and Oxygen.	R. H. Crist, Leonia, N. J.; I. Kirshenbaum, New York, N. Y.
2,796,392	Process and Electrolyte for the Electrodeposition of Zirconium.	M. H. Lietzke, Oak Ridge, Tenn.
2,796,393	Process of Recovering Uranium from Calutron Wash Solutions.	R. Q. Boyer, Berkeley, Calif.

[1] Patents listed as of Nov. 26, 1957. Applicants for licenses should apply to Chief, Patent Branch, Office of the General Counsel, U. S. Atomic Energy Commission, Washington 25, D. C., identifying the subject matter by patent number and title.

PATENT No.	TITLE	PATENTEE
2,796,396	Method of Intermittently Operating a Neutronic Reactor.	L. Szilard, Chicago, Ill.
2,796,398	Means for Sustaining a Nuclear Fission Chain Reaction.	E. C. Creutz, Pittsburgh, Pa.; L. A. Ohlinger, Los Angeles, Calif.; E. P. Wigner, Princeton, N. J.; G. J. Young, Hawthorne, N. Y.
2,796,411	Radiation Shield	R. E. Zirkle, Olympia Fields, Ill.; H. J. Curtis, Shoreham, N. Y.
2,796,424	Separation Process by Adsorption	W. W. Schulz, R. A. Watts, Jr., and R. L. Moore, Richland, Wash.
2,796,529	Radiation Shield	P. Morrison, Ithaca, N. Y.
2,797,050	Remote Adjustment of Automatic Control System.	K. G. Macleish, Oak Ridge, Tenn.
2,797,081	Carbon Burner	F. J. Sullivan, Detroit, Mich.; E. J. Blair, Seattle, Wash.; J. H. Allen, Topeka, Kans.
2,797,142	Method of Reducing Heavy Metal Tetrahalides	J. J. Katz, Chicago, Ill.
2,797,143	Uranium-Vanadium Recovery and Separation by Phosphate Precipitation.	W. F. Arendale, Knoxville, and C. F. Coleman, Oak Ridge, Tenn.
2,797,160	Production of Zirconium	F. H. Spedding and H. A. Wilhelm, Ames, Iowa; W. H. Keller, St. Louis, Mo.
2,797,163	Method of Making Filter Media	W. J. Smith, Arlington, and R. W. James, Lexington, Mass.
2,797,319	Trigger Circuit	N. F. Moody, London, England.
2,797,328	*Transistor Oscillator*	E. G. Miller, Jr., Albuquerque, N. Mex.
2,797,983	Method of Determining Small Quantities of Uranium Compounds in a Gas Stream.	J. Greenspan and A. S. Carlson, Brooklyn, N. Y.
2,798,084	Recovery of Uranium from Aqueous Solutions	R. H. Poirier, Columbus, Ohio.
2,798,164	Portable X-ray or Gamma Source	S. Untermyer, Downers Grove, Ill.
2,798,165	Stable Photomultiplier Amplifier	L. K. Neher, Los Alamos, N. Mex.
2,798,178	Accelerator Target Positioner	H. G. Heard, W. W. Salsig, Jr., Berkeley, Calif.
2,798,181	Pumping Ion Source	J. S. Foster, Jr., Livermore, Calif.
2,798,359	Steam Power Plant with Means for Heavy Water Concentration.	J. S. Foster and G. E. Haddeland, Deep River, Ontario, Canada.
2,798,789	Method of Separating Rare Earths	F. H. Spedding, E. J. Wheelwright, and J. E. Powell, Ames, Iowa.
2,798,847	Method of Operating a Neutronic Reactor	E. *Fermi (deceased)*, L. Szilard, Chicago, Ill.
2,798,848	Neutronic Reactor Fuel Element	K. H. Kingdon, Schenectady, N. Y.
2,799,553	Phosphate Method for Separation of Radioactive Elements.	S. G. Thompson and G. T. Seaborg, Chicago, Ill.
2,799,554	Method of Separating Plutonium	F. Morgan, Chalk River, Ontario, Canada.
2,799,555	Method of Separating Plutonium	F. Morgan, Chalk River, Ontario, Canada.
2,799,642	Neutronic Reactor Fuel Element	H. Hurwitz, Jr., C. Mannal, and E. A. Luebke, Schenectady, N. Y.; J. H. Payne Ballston Spa, N. Y.; and H. Brooks, Cambridge, Mass.
2,799,836	Pulse Transformer	R. E. Heller and D. A. Mack, Berkeley; H. M. Owren, Oakland, Calif.
2,800,387	Uranium Recovery from Ores with Hydrochloric Acid and Acetone.	R. B. Kimball, Idaho Falls, Idaho; R. A. Ewing, Worthington, Ohio.
2,800,588	Marking Fluoroscope Head	T. B. Conrey and H. Taylor, Richland, Wash.
2,800,589	Crystal Dosimeter	P. W. Levy, Sayville, N. Y.
2,800,797	Proportional Waste Line Sampler	J. F. Honstead, Richland, Wash.
2,801,302	Compound Action Gain Control	T. H. Quinn, Richland, Wash.
2,801,960	Gold Plating Process	R. Seegmiller, Los Alamos, N. Mex.
2,802,070	Stabilized Feedback Amplifier	H. L. Fishbine and C. Sewell, Jr., Los Alamos, N. Mex.
2,802,108	Method and Apparatus for Collecting Isotopes	W. E. Leyshon, Oak Ridge, Tenn.
2,803,405	Automatic Counting Apparatus	W. D. Howell, Deep River, Ontario, Canada.
2,803,601	Reactor Unloading Means	C. M. Cooper, Newark, Del.
2,803,748	One Shake Gate Former	R. Kalibjian and V. Perez-Mendez, Berkeley, Calif.
2,803,761	Electromagnetic Apparatus for Moving a Rod	J. N. Young, Chicago, Ill.
2,803,885	Gauging Apparatus	C. A. Ruggles, China Lake, Calif.
2,804,165	Arrangement for Replacing Filters	R. A. Blomgren and N. J. G. Bohlin, Chicago, Ill.
2,804,369	Production of Uranium Hexafluoride	R. D. Fowler, Baltimore, Md.
2,804,550	Automatic Light Control	M. Artzt, Princeton, N. J.
2,804,573	Gas Discharge Devices	W. J. Arrol and S. Jefferson, Abingdon, England.
2,805,473	Uranium-Oxide-Containing Fuel Element Composition and Method of Making Same.	J. H. Handwerk, Joliet; R. A. Noland, Chicago; D. E. Walker, Park Forest, Ill.
2,805,916	*Conversion of Plutonium Trifluoride to* Plutonium Tetrafluoride.	S. Fried, Chicago, Ill.; N. R. Davidson, Sierra Madre, Calif.
2,805,985	Electrodeposition of Plutonium	F. J. Wolter, Ames, Iowa.
2,806,161	Coasting Arc Ion Source	J. S. Foster, Jr., Albany, Calif.
2,806,610	Anti-Swing Crane	R. C. Goertz, Downers Grove, Ill.
2,806,764	Uranium Recovery and Purification Process and Production of High Purity Uranium Tetrafluoride.	R. H. Bailes, Walnut Creek; R. S. Long and R. R. Grinstead, Concord, Calif.

PATENT NO.	TITLE	PATENTEE
2,806,819	Light Water Moderated Neutronic Reactor	R. F. Christy, Santa Fe, N. Mex.; A. M. Weinberg, Oak Ridge, Tenn.
2,806,820	Neutronic Reactor	E. P. Wigner, Oak Ridge, Tenn.
2,806,960	Quartz Fibre Electroscope	R. P. Henderson, Abingdon, England.
2,807,082	Welding Process	J. Zambrow, Bayside, and H. H. Hausner, New York, N. Y.
2,807,518	Process for Recovery of Uranium and Vanadium from Carbonate Solutions by Reduction-Precipitation.	D. A. Ellis and R. O. Lindblom, Concord, Calif.
2,807,519	Process for the Production of an Activated Form of UO_3.	M. J. Polissar, San Francisco, Calif.
2,807,580	Thermal Nuclear Reactor	F. W. Fenning and R. F. Jackson, London, England.
2,807,581	Neutronic Reactor	E. Fermi (deceased), L. Szilard, Chicago, Ill.
2,807,722	Pulse Generator	C. W. Roeschke, Cedar Crest, N. Mex.
2,807,723	High Power Pulsed Oscillator	S. Singer, Urbana, Ill.; L. K. Neher, Los Alamos, N. Mex.
2,807,727	Neutronic Reactor Shield	E. Fermi (deceased), W. H. Zinn, Chicago, Ill.
2,807,785	Line-Above-Ground Attenuator	R. B. Wilds and J. R. Ames, Albuquerque, N. Mex.
2,808,986	Electronic Digital Computer	J. J. Stone, Jr., Clinton; E. R. Mann, Oak Ridge; and E. S. Bettis, Fountain City, Tenn.
2,809,091	Solvent Extraction Process	A. A. Jonke, Elmhurst, Ill.
2,809,157	Neutronic Reactor	H. E. Metcalf, Chicago, Ill.
2,809,887	Method of Alloying Reactive Metals with Aluminum or Beryllium.	O. J. C. Runnalls, Deep River, Ontario, Canada.
2,809,931	Neutronic Reactor System	F. Daniels, Chicago, Ill.
2,810,626	Process for Producing Uranium Hexafluoride	R. D. Fowler, Baltimore, Md.
2,810,689	Fluid Moderated Reactor	E. P. Wigner, L. A. Ohlinger, G. J. Young, and A. M. Weinberg, Chicago, Ill.
2,810,828	Pulse Amplitude Analyzer	G. W. Gray, Lambertville, and A. S. Jensen, Princeton, N. J.
2,811,411	Method of Processing Monazite Sand	G. D. Calkins, Worthington, Ohio.
2,811,412	Method of Recovering Uranium Compounds	R. H. Poirier, Columbus, Ohio.
2,811,413	Fluorination Process	T. S. McMillan, Barnwell County, S. C.
2,811,414	Process for Producing Uranium Halides	E. V. Murphree, Summit, N. J.
2,811,415	Extraction Method for Separating Uranium, Plutonium, and Fission Products from Compositions Containing Same.	G. T. Seaborg, Chicago, Ill.
2,811,416	Process of Removing Plutonium Values from Solution with Group IVB Metal Phospho-Silicate Compositions.	E. R. Russell, Chicago, Ill.; A. W. Adamson, J. Schubert, and G. E. Boyd, Oak Ridge, Tenn.
2,811,423	Redistributor for Liquid-Liquid Extraction Columns.	J. G. Bradley, Richland, Wash.
2,811,487	Neutron Reactor Having a Xe^{135} Shield	H. E. Stanton, Chicago, Ill.
2,811,923	Direct Current Electromagnetic Pump	A. H. Barnes, Downers Grove, Ill.
2,812,232	Prevention of Scale Formation in Uranium Solvent Extractor.	J. W. Delaplaine, Philadelphia, Pa.
2,812,233	Metal Extraction Process	G. W. Lewis, Jr., Roxana, and D. E. Rhodes, Urbana, Ill.
2,812,303	Atomic Power Plant	F. Daniels, Chicago, Ill.
2,812,304	Means for Cooling Reactors	J. A. Wheeler, Princeton, N. J.
2,813,001	Uranium Purification Process	J. R. Ruhoff, Webster Groves, Mo.; C. E. Winters, Oak Ridge, Tenn.
2,813,002	Uranium Purification Process	C. E. Winters, Oak Ridge, Tenn.
2,813,003	Alkaline Carbonate Leaching Process for Uranium Extraction.	A. Thunaes, E. A. Brown, and A. T. T. Rabbitts, Ottawa, Ontario, Canada.
2,813,004	Process for Separating Plutonium from Impurities.	A. C. Wahl, University City, Mo.
2,813,018	Production of Uranium	A. E. Ruehle, Kirkwood, and J. W. Stevenson, Webster Groves, Mo.
2,813,022	Method of Conducting a Person between a Safe Region and a Dangerous Region.	H. A. Moulthrop, Richland, Wash.
2,813,064	Isotopic Fractionation Process of Uranium	A. Clark, Falls Church, Va.
2,813,070	Method of Sustaining a Neutronic Chain Reacting System.	E. Fermi (deceased), M. C. Leverett, Oak Ridge, Tenn.
2,813,073	Neutron Reactor Fuel Element Utilizing Zirconium-Base Alloys.	H. A. Saller and E. R. Szumachowski, Columbus; J. R. Keeler, Grandview, Ohio.
2,813,598	Method for Removal of Light Isotope Product from Liquid Thermal Diffusion Units.	J. D. Hoffman, Chevy Chase, Md.; J. K. Ballou, Lakeside, Calif.
2,813,978	Electron Emission Regulating Means	I. R. Brenholdt, Chicago, Ill.
2,813,979	Apparatus for Producing Ions of Vaporizable Materials.	C. Starr, Berkeley, Calif.
2,814,477	Retort Assembly	C. C. Loomis, Stockbridge, Mass.; W. J. Ash, Salisbury, Conn.
2,814,728	Ion Beam Collimator	A. S. Langsdorf, Jr., Roselle, Ill.

APPENDIX 6

REGULATIONS OF THE U. S. ATOMIC ENERGY COMMISSION [1]

PART 2—RULES OF PRACTICE

TIME OF FILING PETITIONS FOR LEAVE TO INTERVENE

This amendment modifies the Commission's rules of practice to specify that petitions for leave to intervene shall be deemed to have been filed with the Commission as of the time they are received in the Office of the Secretary, Atomic Energy Commission, 1901 Constitution Avenue NW., Washington 25, D. C. In the absence of such amendment, in the case of petitions for leave to intervene filed by mail or telegraph, the time of filing would be deemed to be the time the petitions are deposited in the mail or with the telegraph company (§ 2.700). Hence, parties to a proceeding in which hearings are held might not know of the filing of a petition for leave to intervene until several days after the hearing has convened or, if the hearing is brief, until after the hearing has ended.

In view of the foregoing and the procedural nature of these amendments, the Atomic Energy Commission has found that general notice of proposed rule-making and public procedure thereon are unnecessary and would be contrary to the public interest; and that good cause exists why these amendments should be made effective without the customary period of prior notice.

Effective upon publication in the Federal Register, Part 2, Rules of Practice, is amended in the following respects:

1. The last sentence of § 2.700 is amended to read as follows: "Unless otherwise specified, the filing, when by mail or telegraph, shall upon actual receipt be deemed complete as of the date of deposit in the mail or with the telegraph company as provided in paragraph (d) of § 2.703."

2. Paragraph (a) of § 2.705 is amended by adding the following at the end of the paragraph: "Petitions for leave to intervene, whether filed by mail, telegraph or otherwise, shall be deemed to have been filed with the AEC as of the time received in the Office of the Secretary, Atomic Energy Commission, 1901 Constitution Avenue NW., Washington 25, D. C."

(Sec. 161, 68 Stat. 948, 42 U. S. C. 2201)

Dated at Washington, D. C., this 4th day of September 1957.

For the Atomic Energy Commission.

R. W. COOK,
Acting General Manager.

PART 2—RULES OF PRACTICE

INTERVENTION IN PROCEEDINGS ON APPLICATION FOR FACILITY EXPORT LICENSE

Effective 30 days after publication in the Federal Register, § 2.705 is amended by redesignating paragraph (b) as paragraph (c) and adding a new paragraph (b) as follows:

(b) In any case involving an application for an export license under § 50.44 of this chapter, a petition to intervene with

[1] Policies and regulations of the U. S. Atomic Energy Commission announced prior to December 1957 can be found in the Federal Register and in the following semiannual reports: Fifth, Sixth, Ninth through the Seventeenth, and Nineteenth through the Twenty-second.

respect to such application must be served upon the parties and filed with the AEC within 30 days after publication in the Federal Register of a notice of the filing of such application.

(Sec. 161, 68 Stat. 948; 42 U. S. C. 2201)

Dated at Washington, D. C., this 23d day of September 1957.

For the Atomic Energy Commission.

K. E. FIELDS,
General Manager.

PART 25—ACCESS TO RESTRICTED DATA

CONTROLLED THERMONUCLEAR PROCESSES

Since issuance of Part 25, 10 CFR, "Access to Restricted Data," each applicant for access permit authorizing access to Secret Restricted Data in categories designated in Appendix "A" to that part, has been required to demonstrate that he "has a need for such data in such business, trade or profession" (§ 25.15). On August 1, 1956 (21 F. R. 5733), the Atomic Energy Commission amended Part 25 to require that applicants for access to Secret Restricted Data in category C–20, "Controlled Thermonuclear Process" demonstrate also that they are engaged in a substantial effort to develop, design, build or operate a fission power reactor that is planned for construction; or that they are capable of making significant contributions to research and development in the controlled thermonuclear field.

The Commission has concluded that further amendment is appropriate to encourage more widespread participation by private individuals and organizations in research and development activities regarding controlled thermonuclear processes and to facilitate private investment in such activities.

The following amendments include also clarifying changes in the provisions published on August 1, 1956.

Since these amendments are intended to relieve from, rather than to impose restrictions, and are of a clarifying nature, the Atomic Energy Commission has found that general notice of proposed rule making and public procedure thereon are unnecessary and that good cause exists why these amendments should be made effective without the customary period of notice.

Effective upon publication in the Federal Register, subparagraph (2) of § 25.15 (b) is amended to read as follows:

(2) An application for access to Secret Restricted Data in category C–20, Controlled thermonuclear processes, will be approved only if the application demonstrates also that the applicant:

(i) Is directly engaged in a substantial effort to develop, design, build or operate a fission power reactor that is planned for construction and is making or proposes to make, a comparative evaluation of fission and controlled thermonuclear processes for production of power; or

(ii) Possesses qualifications demonstrating that he is capable of making a significant contribution to research and development in the controlled thermonuclear field and is directly engaged in, or proposes to engage in, a substantial study program, or a substantial research and development program, in this field; or

(iii) Is furnishing to a permittee having access to C–20 under subdivision (i) of this subparagraph substantial financial assistance or substantial scientific, engineering, or other professional services to be used by said permittee in carrying out the activities for which said permittee received access to category C–20; or

(iv) Is furnishing to a permittee having access to C–20 under subdivision (ii) of this subparagraph substantial financial assistance or substantial scientific, engineering, or other professional services to be used by said permittee in the study or research and development program for which said permittee received access to category C–20.

(Sec. 161, 68 Stat. 948; 42 U. S. C. 2201)

Dated at Washington, D. C., this 9th day of August 1957.

K. E. FIELDS,
General Manager.

PART 83—WAIVER OF PATENT RIGHTS

INVENTIONS OR DISCOVERIES BY SPONSOR PERSONNEL

Notice is hereby given that the AEC has adopted the following amendment to the "Waiver of Patent Rights" regulation published in Part 83 of Title 10 of the Code of Federal Regulations. This amendment will become effective upon publication.

Amend § 83.1 (b) (3) by adding the following: "The waiver does include inventions or discoveries made by sponsor personnel in the course of their use of the Gamma Irradiation Facility at the National Reactor Testing Station."

Amend § 83.2 (a) by adding the following at the beginning of that paragraph: "Except with regard to the use of the Gamma facility at the National Reactor Testing Station,".

(Sec. 161, 68 Stat. 948; 42 U. S. C. 2201)

Dated at Washington, D. C., this 18th day of July 1957.

K. E. FIELDS,
General Manager.

PART 140—FINANCIAL PROTECTION REQUIREMENTS AND INDEMNITY AGREEMENTS

On September 2, 1957, Public Law 256 (85th Congress) was signed by the President and became effective as an amendment to the Atomic Energy Act of 1954 (68 Stat. 919). Public Law 256 provides a means for protecting the public from financial loss from a nuclear incident.

To implement the indemnity provisions of the law the Atomic Energy Commission is issuing the following regulations which will be effective until definitive regulations are issued. In connection with the development of such more definitive regulations, the Commission intends to solicit the views of representatives of all affected groups and to furnish full opportunity for public comment.

At the present time there are no licenses in effect under section 103 of the act, and a relatively small number under section 104, authorizing operation of facilities. With one exception, all the licenses authorizing operation of facilities were issued under section 104c for the operation of nuclear reactors at relatively low power for research and development, or at nominal power for critical experiments. The exception is a license issued under section 104b for the operation of a reactor in California for the generation of electrical energy.

The regulation requires each licensee authorized to operate a nuclear reactor to maintain financial protection in the amount of $150,000 per thousand kilowatts of thermal capacity authorized by his license. This amount is established as a temporary basis for determining financial protection required. Public Law 256, 85th Congress, requires financial protection equal to the total amount of private liability insurance available (expected to be approximately $60,000,000) for all power reactors with a capacity of 100,000 electrical kilowatts or more. Such a relationship applied to all reactors needs to be expressed in thermal capacity since many reactors will not be used in connection with the generation of electricity. The ratio of thermal to electrical capacity varies somewhat among different types of reactors. For the purpose of this regulation, this ratio has been assumed as four to one. Therefore, a capacity of 400,000 thermal kilowatts would require $60,000,000 of private insurance, or $150,000 per thousand kilowatts of thermal capacity.

While this formula is deemed appropriate during the interim period for power reactors and the larger research and test reactors, it is not meaningful for those operating at very low power which will produce correspondingly small amounts of fission products. The principal hazard and potential public liability arising from such reactors will be the possibility of exposing to radiation persons in the immediate vicinity of the reactor, such as students, trainees, visitors and persons working on cooperative research projects. There is a re-

mote possibility that a number of such persons might be injured resulting in fairly substantial claims. This type of hazard is present in reactors of any size and the extent to which it varies with different reactors is not readily subject to measurement. For the purpose of this temporary regulation, therefore, it has been determined that $250,000 is a minimum reasonable amount in view of the potential liability.

It is particularly important to note that the amounts of financial protection required by this regulation are not necessarily indicative of those that will be required by the more definitive regulations. The provisions of the latter for determination of these amounts will be based on more thorough consideration of such criteria as cost and terms of private insurance; type, size and location of the licensed activity and other factors pertaining to hazard; and the nature and purpose of the licensed activity, as provided by section 4 of Public Law 256. It should be emphasized, therefore, that the amounts of financial protection required by the more definitive regulations may vary substantially from those in this regulation.

Preparation of the form of indemnity agreement which the Commission will enter into under Public Law 256 has not been completed. Section 140.18 of the regulation, however, is intended to make it clear that such agreements will be issued in due course; and that the Government's obligation to indemnity will take effect at the time established in the section and will not be affected by the time of execution or issuance of such agreements. This will assure maximum financial protection to the public and licensees.

Because these regulations are expected to be replaced at an early date by more definitive regulations, and because it is the purpose of these regulations to carry out the requirements of Public Law 256 with respect only to such types of licensees as are presently authorized to operate facilities, this part does not include many types of provisions which will be included in later revisions; and does not apply to certain kinds of licensees who may be subject to such future regulations.

In light of the foregoing, the Atomic Energy Commission has found that general notice of proposed rule-making and public procedure thereon are unnecessary and would be contrary to the public interest; and that good cause exists why these rules should be made effective after less than the customary 30 days' prior notice. These findings are based particularly on the desirability of making the Federal indemnity available on reasonable terms for protection of the public as promptly as is practicable.

The following rules are published as a document subject to codification, effective 15 days after publication in the FEDERAL REGISTER.

Sec.

140.1 Purpose.
140.2 Scope.
140.3 Definitions.
140.4 Interpretations.
140.5 Communications.
140.11 Amount of financial protection required.
140.12 Types of financial protection.
140.13 Proof of financial protection.
140.14 Special provisions applicable to licensees furnishing financial protection in whole or in part in the form of liability insurance.
140.15 Commission review of proof of financial protection.
140.16 Reports by certain licensees asserting immunity from liability.
140.17 Indemnity agreements.
140.18 Specific exemptions.

AUTHORITY: §§ 140.1 to 140.18 issued under sec. 161, 68 Stat. 948; 42 U. S. C. 2201. Interpret or apply sec. 4, Public Law 256, 85th Cong.

§ 140.1 *Purpose.* The regulations in this part are issued to provide appropriate procedures and requirements for determining the financial protection required of licensees and for the indemnification and limitation of liability of certain licensees and other persons pursuant to section 170 of the Atomic Energy Act of 1954 (68 Stat. 919), as amended.

§ 140.2 *Scope.* (a) The regulations in this part apply to each person who has authority under a license issued pursuant to Part 50 of this chapter, to oper-

ate a nuclear reactor. To the extent provided in paragraph (b) of this section, this part applies also to applicants for such licenses.

(b) Each applicant for license under Part 50 authorizing operation of a nuclear reactor shall (prior to issuance of such license) furnish the proof of financial protection specified in § 140.13, and if appropriate shall furnish the information specified in § 140.16.

§ 140.3 *Definitions.* As used in this part,

(a) "Act" means the Atomic Energy Act of 1954 (68 Stat. 919) including any amendments thereto.

(b) "Atomic energy" means all forms of energy released in the course of nuclear fission or nuclear transformation.

(c) "Byproduct material" means any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material.

(d) "Commission" means the Atomic Energy Commission or its duly authorized representatives.

(e) "Financial protection" means the ability to respond in damages for public liability and to meet the costs of investigating and defending claims and settling suits for such damages.

(f) "Government agency" means any executive department, commission, independent establishment, corporation, wholly or partly owned by the United States of America which is an instrumentality of the United States, or any board, bureau, division, service, office, officer, authority, administration, or other establishment in the executive branch of the Government.

(g) "Licensee" means any person who is the holder of a license issued under the regulations in Part 50 of this chapter authorizing such person to operate a nuclear reactor.

(h) "Licensed activity" means an activity authorized by a license described in § 140.2.

(i) "Nuclear incident" means any occurrence within the United States causing bodily injury, sickness, disease, or death, or loss of or damage to property, or for loss of use of property, arising out of or resulting from the radioactive, toxic, explosive, or other hazardous properties of source, special nuclear or byproduct material.

(j) "Nuclear reactor" means an apparatus, other than an atomic weapon, designed or used to sustain nuclear fission in a self-supporting chain reaction.

(k) "Person" means (1) any individual, corporation, partnership, firm, association, trust, estate, public, or private institution, group, Government agency other than the Commission, any State or any political subdivision thereof, or any political entity within a State, any foreign government or nation or any political subdivision of any such government or nation, or other entity; and (2) any legal successor, representative, agent, or agency of the foregoing.

(l) "Person indemnified" means the person with whom an indemnity agreement is executed and any other person who may be liable for public liability.

(m) "Public liability" means any legal liability arising out of or resulting from a nuclear incident, except claims under State or Federal Workmen's Compensation Acts of employees of persons indemnified who are employed at the site of and in connection with the activity where the nuclear incident occurs, and except for claims arising out of an act of war. "Public liability" also includes damage to property of persons indemnified: *Provided,* That such property is covered under the terms of the financial protection required, except property which is located at the site of and used in connection with the activity where the nuclear incident occurs.

(n) "Source material" means source material as defined in the regulations contained in Part 40 of this chapter.

(o) "Special nuclear material" means (1) plutonium, uranium 233, uranium enriched in the isotope 233 or in the iso-

tope 235, and any other material which the Commission, pursuant to the provisions of section 51 of the act, determines to be special nuclear material, but does not include source material; or (2) any material artificially enriched by any of the foregoing, but does not include source material.

(p) "United States" when used in a geographical sense, includes all Territories and Possessions of the United States, the Canal Zone, and Puerto Rico.

§ 140.4 *Interpretations.* Except as specifically authorized by the Commission in writing, no interpretations of the meaning of the regulations in this part by any officer or employee of the Commission other than a written interpretation by the General Counsel will be recognized to be binding upon the Commission.

§ 140.5 *Communications.* All communications concerning the regulations in this part should be addressed to the Atomic Energy Commission, Washington 25, D. C., Attention: Division of Civilian Application.

§ 140.11 *Amount of financial protection required.* Each licensee is required to have and maintain financial protection for each nuclear reactor in the amount of $150,000 per thousand kilowatts of thermal energy capacity authorized by his license: *Provided,* That in no event shall the amount be less than $250,000 for each nuclear reactor.

§ 140.12 *Types of financial protection.* (a) The amounts of financial protection required under this part may, at the option of the licensee, be furnished and maintained in the form of:

(1) An effective policy of liability insurance from private sources for which the premiums have been paid; or

(2) Adequate resources to provide the financial protection required by § 140.11; or

(3) Such other type of financial protection as the Commission may approve. The Commission may permit licensees, such as Government agencies, for whom none of the above means of establishing protection is feasible, to furnish proof of financial protection in some other appropriate form; or

(4) Any combination of the foregoing.

(b) In any case where the Commission has approved proof of financial protection filed by a licensee pursuant to § 140.13, the licensee shall not substitute one type of financial protection for another type without first obtaining the written approval of the Commission.

§ 140.13 *Proof of financial protection.* (a) Each person, who, on the effective date of this part, is the holder of a license described in § 140.2, shall, within 30 days after the effective date of this part, file with the Commission eight copies of proof of financial protection. The Commission may, upon good cause shown, grant extensions of such period.

(b) Proof of financial protection in the case of licensees who maintain financial protection in whole or in part in the form of liability insurance shall (with respect to such insurance) consist of a copy of the liability policy (or policies) together with a certificate by the issuing organization or organizations stating or undertaking:

(1) That said copy is a true copy of a currently effective policy issued to the licensee;

(2) The period of time for which premiums on the policy have been paid;

(3) That the issuing organization or organizations agree that they will not (for any reason whatever, including any act or failure to act of the licensee) modify, amend, terminate, or suspend said policy, or do any other act affecting such organization's or organizations' obligations under said policy, unless they shall have filed with the Commission a written notice thereof prior to the effective date of such act or action: *Provided,* That nothing in such undertaking shall be deemed to require such organization or organizations to furnish notice to the Commission of the expiration of such policy at the end of the period of time specified in the policy as the term thereof.

(c) Proof of financial protection in the case of licensees who maintain financial

protection in whole or in part in the form specified in § 140.12 (a) (2) shall consist of a showing that the licensee has adequate resources to provide the financial protection required under this part.

(d) The Commission may require any licensee to file with the Commission such additional proof of financial protection or other financial information as the Commission determines to be appropriate for the purpose of determining whether the licensee has or is maintaining financial protection as required under this part.

(e) The licensee shall notify the Commission of any material change in proof of financial protection or in other financial information filed with the Commission under this part.

§ 140.14 *Special provisions applicable to licensees furnishing protection in whole or in part in the form of liability insurance.* In any case where a licensee undertakes to maintain financial protection in the form of liability insurance for all or part of the financial protection required by this part,

(a) The Commission may require that the licensee demonstrate that the organization or organizations which have issued such policies are legally authorized to issue them and do business in the United States and have clear ability to meet their obligations; and

(b) The licensee shall notify the Commission, at least 30 days prior to the expiration of any such policy, of the renewal of such policy or of arrangements made by the licensee to maintain financial protection in some other form.

§ 140.15 *Commission review of proof of financial protection.* (a) The Commission will promptly review proof of financial protection filed by any licensee pursuant to § 140.13. If the Commission finds that the licensee is maintaining financial protection in compliance with the requirements of this part, the licensee will be notified that his proof of financial protection has been approved. In the case of licensees maintaining all or part of their financial protection in a form other than liability insurance such notice of approval may designate the times upon which the licensee shall thereafter furnish to the Commission additional financial information for the purpose of determining whether the licensee is maintaining financial protection as required by this part.

(b) In any case where a licensee has not furnished to the Commission satisfactory proof of financial protection within the period allowed by the Commission pursuant to § 140.13, the Commission may suspend or terminate the license in accordance with the procedures provided in Subpart B, Part 2 of this chapter.

§ 140.16 *Reports by certain licensees asserting immunity from liability.* (a) Within 60 days after the effective date of this part, each licensee who believes that he is wholly or partially immune from public liability under any provision of State or Federal law shall file with the Commission eight copies of an opinion of Counsel containing the following information:

(1) The nature and extent of any such immunity possessed by the licensee;

(2) Whether or not employees of the licensee when engaged in the licensed activity are immune from public liability under any provision of State or Federal law and, if so, the nature and extent of such immunity;

(3) Whether or not the licensee has authority to waive such immunity;

(4) Whether or not the licensee has authority to purchase liability insurance.

(b) Reports filed under this section should include appropriate references to legal authorities. The Commission may, upon good cause shown, grant extensions of the period within which reports may be filed under this section.

§ 140.17 *Indemnity agreements.* (a) The Commission will, in due course, execute and issue agreements of indemnity pursuant to the regulations in this part of such other regulations as may be issued by the Commission. Each such agreement shall contain such provisions as are required by law and such additional provisions as may be incor-

porated therein by the Commission pursuant to regulation. Such agreements, as to any licensee, shall be effective on:

(1) The effective date of this part; or

(2) The effective date of the license authorizing the licensee to operate the nuclear reactor involved, whichever is later.

(b) Each licensee shall pay a fee to the Commission at the rate of $30 per year per thousand kilowatts of thermal capacity authorized in its license: *Provided,* That no fee shall be less than $100 per annum for any nuclear reactor. Such fee shall be due for the period beginning with the date on which the applicable indemnity agreement will be effective under paragraph (a) of this section; and shall be paid in accordance with billing instructions received from the Commission.

§ 140.18 *Specific exemptions.* The Commission may, upon application by any interested person, grant such exemptions from the requirements of this part as it determines are authorized by law and are otherwise in the public interest.

Dated at Washington, D. C., this 5th day of September 1957.

For the Atomic Energy Commission.

R. W. Cook,
Acting General Manager.

[F. R. Doc. 57-7451; Filed, Sept. 10, 1957; 8:53 a. m.]

APPENDIX 7

LICENSES AND ACCESS PERMITS APPLICATIONS FILED AND ACTIONS TAKEN [1]

FACILITY LICENSES

APPLICANT AND LOCATION	DESCRIPTION OF FACILITY	DATE FILED	STATUS AS OF DEC. 31, 1957
POWER REACTORS			
General Electric Co., 1 River Rd., Schenectady 5, N. Y., (Location: Vallecitos Atomic Laboratory, Alameda County, Calif.)	3,000 to 5,000-kilowatt developmental boiling water reactor.	Jan. 10, 1956 (date of application).	Licenses issued as critical July 29, 1957; at power Aug. 31, 1957.
Power Reactor Development Co., 1911 1st St., Detroit, Mich. (Location: Lagoona Beach, Monroe County, Mich.)	100,000-kilowatt fast breeder type power reactor.	Jan. 7, 1956	Construction permit issued Aug. 4, 1956.[2]
Yankee Atomic Electric Co., 441 Stuart St., Boston 16, Mass. (Location: Rowe, Mass.)	134,000-kilowatt pressurized light water type power reactor.	July 9, 1956	Construction permit issued Nov. 4, 1957.
RESEARCH AND TEST REACTORS			
Aerojet-General Nucleonics, San Ramon, Calif. (for sale to licensed institutions).	Five 100-milliwatt self-contained research reactors, serials 104 through 108.	Nov. 28, 1956	Licenses issued July 10, 1957, July 10, 1957, July 31, 1957, Aug. 23, 1957, Sept. 20, 1957.
Aerojet-General Nucleonics, San Ramon, Calif. (for sale to licensed institutions).	Twelve 100-milliwatt self-contained research reactors, serials 109 through 120.	Feb. 12, 1957	Construction permit issued July 8, 1957 (12 reactors); 2 Licenses issued Aug. 23, 1957 and Oct. 28, 1957.
Aerojet-General Nucleonics, San Ramon, Calif. (for sale to licensed institutions).	Five 5-watt self-contained research reactors, serials 121 through 125.	Dec. 3, 1957	Pending.
Aerojet-General Nucleonics, San Ramon, Calif. (for sale to licensed institutions).	Fifteen 100-milliwatt self-contained research reactors, serials 126 through 140.	Dec. 2, 1957	Pending.
Aerojet-General Nucleonics, San Ramon, Calif. (for sale to licensed institution).	One 1-watt pool-type research reactor, AGN-211, serial 100.	Nov. 12, 1957	Pending.
American Radiator and Standard Sanitary Corp., Redwood City, Calif. (Location: Mountain View, Calif.)	1-watt (UTR-1) graphite moderated research reactor.	July 12, 1957	Construction permit issued Oct. 31, 1957.
Catholic University of America, Washington, D. C.	AGN-201 100-milliwatt research reactor, serial 101 (purchased from Aerojet-General Nucleonics).	July 10, 1957	License issued Nov. 15 1957.
Colorado State University, Fort Collins, Colo	AGN-201 100-milliwatt research reactor, serial 109 (purchased from Aerojet-General Nucleonics).	July 22, 1957	License issued Sept. 12, 1957.
Daystrom, Inc., Elizabeth, N. J. (Location: West Caldwell N. J.)	10-kilowatt, Argonaut-type research reactor.	Dec. 11, 1956	Construction permit issued Oct. 11, 1957.[3]
The Dow Chemical Co., Midland, Mich.	1,000 to 10,000-kilowatt liquid metal fuel research reactor.	Jan. 31, 1956	Application withdrawn by letter dated Oct. 30, 1957.

[1] During the period July 1, 1957, through Dec. 31, 1957.
[2] Petitions for leave to intervene were granted in October 1956 and hearings were started in January 1957. The record of hearing has been certified by the hearing examiner to the Commission.
[3] The applicant on December 9, 1957, filed a request for withdrawal of its application.

FACILITY LICENSES—continued

APPLICANT AND LOCATION	DESCRIPTION OF FACILITY	DATE FILED	STATUS AS OF DEC. 31, 1957
RESEARCH AND TEST REACTORS—continued			
Ford Motor Co., 3000 Schafer Rd., Dearborn, Mich. (Location: Rotunda Bldg., Dearborn, Mich.)	10 to 100-kilowatt pool-type research reactor.	Jan. 17, 1956	Application withdrawn by letter dated Oct. 10, 1957.
General Dynamics Corp., San Diego, Calif. (Location: Torrey Pines Mesa, San Diego, Calif.)	10 kilowatt tank-type isotope-production reactor.	Nov. 19, 1957	Pending.
General Electric Co., San Jose, Calif. (Location: Alameda County, Calif.)	30,000-kilowatt pressurized water test reactor (GETR).	June 14, 1957	Notice of hearing published Dec. 11, 1957.
General Electric Co., San Jose, Calif. (Location: Alameda County, Calif.)	30-kilowatt research reactor, light water cooled and moderated, graphite reflected (NTR).	July 1, 1957	Construction permit issued Oct. 24, 1957; license issued Oct. 31, 1957.
National Advisory Committee for Aeronautics, 1512 H St., NW., Washington, D. C. (Location: Sandusky, Ohio).	60 - megawatt pressurized water test reactor.	Aug. 20, 1956	Notice of hearing published Sept. 7, 1957. The hearing has been scheduled for Jan. 16, 1958.
North American Aviation, Inc., Canoga Park, Calif.	5-watt solution-type laboratory reactor (Model L-47).	Jan. 24, 1957	Construction permit issued Aug. 2, 1957; license issued Aug. 5, 1957.
Oklahoma State Univ. of Agriculture & Applied Science, Stillwater, Okla.	AGN-201 100-milliwatt research reactor, serial 102 (purchased from AGN).	Mar. 20, 1957	License issued Aug. 26, 1957.
Ordnance Materials Research Office, Watertown Arsenal, Watertown, Mass.	1,000-kilowatt pool-type research reactor.	Jan. 15, 1957	Construction permit issued Oct. 2, 1957.
Texas Agricultural & Mechanical College, College Station, Tex.	AGN-201 100-milliwatt research reactor, serial 106 (purchased from AGN).	Mar. 25, 1957	License issued Aug. 26, 1957.
The Prosperity Co., Inc., Syracuse, N. Y. (Location: Univ. of Miami, Coral Gables, Fla.)	Pool-type research reactor	Mar. 6, 1956	Denied without prejudice to submission of new application—Dec. 20, 1957.
Union Carbide Corp., New York, N. Y. (Location: Sterling Forest, Orange County, N. Y.)	5,000-kilowatt pool-type research reactor.	Feb. 15, 1957	Construction permit issued Oct. 31, 1957.
University of Akron, Akron, Ohio.	AGN-201 100-milliwatt research reactor, serial 104 (purchased from AGN).	Apr. 5, 1957	License issued Sept. 5, 1957.
University of California, Berkeley, Calif.	AGN-201 100-milliwatt research reactor, serial 112 (purchased from AGN).	Aug. 26, 1957	License issued Nov. 19, 1957.
University of Florida, Gainesville, Fla.	10-kilowatt Argonaut-type research reactor.	Aug. 23, 1957	Construction permit issued Dec. 23, 1957.
University of Michigan, Ann Arbor, Mich.	1,000-kilowatt pool-type research reactor.	Jan. 12, 1955, (date of application).	License issued Sept. 13, 1957.
University of Oklahoma, Norman, Okla.	5-watt laboratory reactor (Atomics International Model L-47).	Aug. 30, 1957	Pending.
University of Utah, Salt Lake City, Utah.	AGN-201 100-milliwatt research reactor, serial 107 (purchased from AGN).	June 24, 1957	License issued Sept. 12, 1957.
University of Virginia, Charlottesville, Va.	1-megawatt pool-type research reactor.	Mar. 29, 1957	Construction permit issued Sept. 13, 1957.
University of Wyoming, Laramie, Wyo.	AGN-201 100-milliwatt research reactor, serial 111 (to be purchased from AGN).	Aug. 21, 1957	Pending.
U. S. Naval Hospital, Bethesda, Md.	AGN-201M 5-watt research reactor, serial 105 (purchased from AGN).	Mar. 27, 1957	License issued Sept. 13, 1957.
Westinghouse Electric Corp., Pittsburgh, Pa. (Location: Waltz Mill, Pa.)	20,000-kilowatt test reactor (pressurized water type).	Mar. 12, 1956	Construction permit issued July 3, 1957.

FACILITY LICENSES—continued

APPLICANT AND LOCATION	DESCRIPTION OF FACILITY	DATE FILED	STATUS AS OF DEC. 31, 1957
CRITICAL EXPERIMENT FACILITIES			
The Babcock & Wilcox Co., 161 East 42d St., New York, N. Y. (Location: Lynchburg, Va.)	Consolidated Edison experiment.	Oct. 27, 1955	License issued Mar. 20, 1957; request for license amendment to perform second Con-Ed experiment filed Dec. 9, 1957.
The Babcock & Wilcox Co., 161 East 42d St., New York, N. Y. (Location: Lynchburg, Va.)	New addition to existing facility.	Feb. 1, 1957	Construction permit issued Oct. 2, 1957.
Battelle Memorial Institute, Columbus, Ohio. (Location: West Jefferson, Ohio.)	----------	Oct. 28, 1955	Notice of proposed issuance of facility license published Dec. 31, 1957.
General Atomic Division of General Dynamics Corp., San Diego, Calif. (Location: Torrey Pines Mesa, San Diego, Calif.)	Experiments relating to General Dynamics research reactor.	Oct. 25, 1956	License issued Aug. 13, 1957; request for license amendment to perform additional experiments filed Dec. 2, 1957.
General Electric Co., 1 River Rd., Schenectady, N. Y. (Location: Vallecitos Atomic Laboratory, Alameda County, Calif.)	----------	Mar. 27, 1956	License issued Aug. 30, 1957.
General Electric Co., 2151 South 1st St., San Jose, Calif. (Location: Vallecitos Atomic Laboratory, Alameda County, Calif.)	Nuclear checkout tests for Spanish reactor.	June 14, 1957	Construction permit issued Sept. 20, 1957; license issued Oct. 16, 1957.
The Martin Co., Baltimore, Md. (Location: Middle River, Md.)	Martin power reactor experiments.	Oct. 26, 1956	License issued Dec. 6, 1957.
National Advisory Committee for Aeronautics, Washington, D. C. (Location: Cleveland, Ohio.)	----------	July 8, 1957	Notice of proposed issuance of construction permit published Jan. 1, 1958.
Nuclear Development Corp. of America, White Plains, N. Y. (Location: Pawling, N. Y.)	----------	Mar. 14, 1956	Notice of proposed issuance of facility license published Dec. 27, 1957.
Westinghouse Electric Corp., Pittsburgh, Pa. (Location: Waltz Mill, Pa.)	Yankee Critical experiments.	Sept. 21, 1956	Construction permit issued Oct. 17, 1957; license issued Nov. 25, 1957.
Westinghouse Electric Corp., 3 Gateway Center, Pittsburgh, Pa. (Location: Waltz Mill, Pa.)	Critical Experiment Station (CES) for the WTR experiments.	Oct. 24, 1957	Pending.
EXPORT LICENSES			
ACF Industries, Inc., 30 Church St., New York, N. Y.	5,000-kilowatt tank-type heavy water cooled and moderated research reactor for export to Comitato Nazionale per le Ricerche Nucleari, Milan, Italy.	Dec. 12, 1956	License issued May 16, 1957.
ACF Industries, Inc., New York, N. Y.	20,000-kilowatt tank-type materials testing reactor for export to Reactor Centrum Nederland, Pettin, Netherlands.	Apr. 23, 1957	Notice of proposed issuance of export license published Jan. 1, 1958.
Aerojet-General Nucleonics, San Ramon, Calif.	100-milliwatt self-contained research reactor, Model AGN-201, for export to Laboratoires R. Derveaux, Boulogne, France.	July 9, 1957	Pending.
American Machine & Foundry Co., 261 Madison Ave., New York, N. Y.	1-megawatt pool-type research reactor for export to Hamilton College, McMaster University, Hamilton, Canada.	May 17, 1957	License issued Aug. 27, 1957.

FACILITY LICENSES—continued

APPLICANT AND LOCATION	DESCRIPTION OF FACULTY	DATE FILED	STATUS AS OF DEC. 31, 1957
	EXPORT LICENSES—continued		
American Machine & Foundry Co., 261 Madison Ave., New York, N. Y.	1-megawatt pool-type research reactor for export to Junta de Energia Nuclear, Lisbon, Portugal.	July 22, 1957	License issued Sept. 13, 1957.
American Machine & Foundry Co., 261 Madison Ave., New York, N. Y.	1-megawatt pool-type research reactor for export to Greek Atomic Energy Commission, Athens, Greece.	May 7, 1957	License issued Sept. 25, 1957.
American Machine & Foundry Co., 261 Madison Ave., New York, N. Y.	1-megawatt pool-type research reactor for export to Societa Ricerche Impianti Nucleari, Milan, Italy.	July 3, 1957	License issued Dec. 6, 1957.
General Electric Co., 150 East 42d St., New York, N. Y.	3,000-kilowatt pool-type research reactor for export to Junta de Energia Nuclear, Madrid, Spain.	May 22, 1957	License issued July 29, 1957.
General Electric Co., 150 East 42d St., New York, N. Y.	3-megawatt, pool-type research reactor for export to Instituto Venezolano de Neurologia e Investigaciones Cerebrales, Caracas, Venezuela.	Oct. 3, 1957	Notice of proposed issuance of export license published Jan. 1, 1958.
James Loudon & Co., Inc., 354 Spring St., Los Angeles 13, Calif.	50-kilowatt solution-type research reactor (Atomics International Model L–54) for export to Senate of the Land Berlin, Berlin, Germany.	Mar. 28, 1957	License issued Sept. 7, 1957.
Mitsubishi International Corp., 120 Broadway, New York, N. Y.	10-megawatt tank-type research reactor for export to The Japan Atomic Energy Research Institute, Tokyo, Japan.	Aug. 12, 1957	License issued Oct. 11, 1957.
Aerojet-General Nucleonics, San Ramon, Calif.	100-milliwatt self-contained research reactor, Model AGN–201 *or* 1-watt pool-type research reactor, Model AGN–211, for export to the Government of Belgium for exhibit at the 1958 World's Fair in Brussels, Belgium.	Dec. 9, 1957	Pending.

ACCESS PERMITS

TABLE I.—*Business or Occupation of Access Permit Holders*

	June 30, 1957	Dec. 31, 1957		June 30, 1957	Dec. 31, 1957
Aircraft and/or components	21	28	Petroleum and petroleum products	20	20
Beverage industry [1]		1	Printing and publishing	10	12
Chemical—general	72	80	Professors, teachers, and scientists	65	69
Chemical—pharmaceutical	5	5	Railroads and railway equipment	9	12
Chemical processing equipment	5	9	Research—general	44	51
Coal industry	4	6	Research—medical	4	4
Communications	1	1	Rubber and rubber products	6	6
Consultants	83	93	Scrap and waste disposal	7	7
Educational institutions	22	23	Shipbuilding and/or components	20	21
Electronic industry	24	31	Special carriers and warehousing	4	4
Engineering—construction	51	52	Stone, clay, and glass products	16	13
Engineering—consulting	70	79	Tobacco and tobacco products	1	1
Engineering—design	25	42	Unions, trade associations, chambers of commerce, and manufacturers' representatives	16	15
Federal, State, and city governments or departments	53	56	Utilities	153	169
Financial organizations	22	18	Weapons, explosives, and propellants	10	10
Food companies	4	4	Others (not elsewhere classifiable) [1]	5	6
Information services	16	23	Total [2]	1,327	1,464
Instrument manufacture	64	66			
Insurance companies	79	89			
Lawyers and public accountants	30	39			
Machinery—general	35	39			
Machinery—special	10	11			
Metal products manufacture	158	164			
Mining and refining	71	70			
Motor vehicles and/or components	6	9			
Paper and pulp companies	6	6			

[1] New classification.
[2] Some permittees have been classified in more than 1 category.

TABLE II.—*Access Permit Holders by Principal Fields of Interest*

	June 30, 1957	Dec. 31, 1957		June 30, 1957	Dec. 31, 1957
Batteries (nuclear)		1	Ore refining and production of feed materials	80	83
Chemical processing and equipment	64	74	Radiation hazards and effects		39
Components (except reactor components)		171	Radioactive waste		42
Consultants	215	248	Reactor—central station	162	196
Controlled thermonuclear field		15	Reactor—components	287	2
Design and construction of atomic energy facilities	98	103	Reactor—heating	149	4
Electronic systems		1	Reactor—other		99
Fuel element fabrication		34	Reactor—propulsion		33
General nuclear research and development	66	73	Reactor—research		8
Information services		27	Shield materials		17
Instruments		97	Special materials	149	141
Insurance evaluation	82	91	Surveys for potential use or need		1
Investment and banking	23	19	Training and education		8
Isotope production and utilization	64	65	Transportation and storage		3
Legal assistance and accounting		25	Weapons and components		1
Machinery		11	Others (not elsewhere classifiable)	65	10
			Total	1,504	1,742

NOTE.—Some of the categories have been changed and new ones added to show a more detailed breakdown of principal fields of interest. These figures include permit holders with more than one field of interest, resulting in a total greater than the number of permittees.

TABLE III.—*Access Permit Holders by Geographic Areas* [3]

	June 30, 1957	Dec. 31, 1957		June 30, 1957	Dec. 31, 1957
New England	119	131	Mountain	43	45
Middle Atlantic	467	477	Pacific	118	142
East North Central	281	298	Hawaii, Alaska, and Puerto Rico	5	6
West North Central	79	70			
South Atlantic	132	140	Total	1,327	1,404
East South Central	34	40			
West South Central	49	55			

[3] Standard Department of Commerce areas.

TABLE IV.—*Number of Permittees Having Access to Secret Restricted Data by Categories*

	June 30, 1957	Dec. 31, 1957		June 30, 1957	Dec. 31, 1957
Chemistry—general	397	453	Reactors—production	291	295
Chemistry—radiation and radiochemistry	447	503	Criticality hazards	369	388
Chemistry—separation processes for plutonium and uranium	356	376	Technology—feed materials	278	286
Chemistry—transuranic elements	226	227	Technology—plutonium	236	246
Controlled thermonuclear processes	91	100	Technology—tritium	52	60
Isotope separation	64	78	Hanford—fuel element technology	1	1
Metallurgy and ceramics	506	246	Hanford—reactor technology	1	1
Metallurgy—raw materials	296	320	Hanford—separations process technology	4	4
Particle accelerators and high-voltage machines	130	158	Radioactive waste	470	502
Physics and mathematics	418	445	Savannah River—fuel element technology	1	1
Instrumentation	440	464	Savannah River—reactor technology	1	0
Radiation effects on reactor materials	476	505	Savannah River—separations process technology	4	4
Health and safety	481	515	Reactors—research and testing	454	503
			Reactors—power	515	573

NOTE.—"Experimental Biology and Medicine" and "Geology and Mineralogy" were removed from Appendix "A" of 10 CFR Part 25 when it was published on Feb. 4, 1956, because the information in these categories, available under the civilian application program, is now unclassified. As of Dec. 31, 1957, there were 806 secret permits in effect.

As of December 31, 1957, 793 permittees had 500 employees or less, while 611 had over 500 employees. A year ago permittees with 500 or less employees numbered 616, while 529 had over 500 employees.

APPENDIX 8

Nuclear Reactors Built, Building or Planned in the United States, as of December 31, 1957

The following tabulation is a compilation of facilities built, building, or planned in the United States as of December 31, 1957, which are capable of sustaining a nuclear chain reaction, with the exception of experiments being conducted at Commission laboratories for weapons research. Certain experiments relating to military propulsion systems are included in the statistical summary but are not listed in the tabulation because of their classified nature.

Where cells within critical experiment facilities have housed two or more experiments, only the most recent experiment is listed. Where two or more cellt operate from a single control panel, experiments in both cells may be listed, bus only one count is made in the statistical summary.

Listings in the "principal contractor" column refer to the technical organization assigned primary responsibility for completion of the project. Contractors' names, abbreviated in the column listing, are given in full in the listing on page 355. Also listed are the names of designers, shipbuilders, and facility operators; these are abbreviated in the column listings.

Startup dates refer to the year of first criticality. Startup dates shown for projects not yet in service are estimates based on the best available information. The dates for non-Commission projects are estimates announced by the sponsoring organizations.

Reactors are listed as having "operated" under the following circumstances:

(*a*) Federal Government reactors—when criticality is achieved.

(*b*) Non-Federal Government reactors in the United States—when an operating license is issued by the Commission.

(*c*) Reactors for foreign locations—when criticality is achieved.

Reactors are listed as "being built" under the following circumstances:

(*a*) Federal Government reactors—when ground is broken, components ordered, or contract awarded, whichever is first.

(*b*) Non-Federal Government reactors in the United States—when construction permit is issued by the Commission.

(*c*) Reactors for foreign locations—when an export license is issued by the Commission.

Reactors are listed in the "planned" category under the following circumstances:

(*a*) Federal Government reactors—when publicly announced or when development work is started.

(*b*) Non-Federal Government reactors in the United States—when license application is received by the Commission, or a public announcement which includes principal contractor and reactor type is made, whichever is first.

(*c*) Reactors for foreign locations—when public announcement is made.

LIST OF CONTRACTORS, DESIGNERS, SHIPBUILDERS, AND FACILITY OPERATORS FOR WHICH ABBREVIATIONS APPEAR IN TABLES

Abbreviation	*Name of Organization*
AC	Allis-Chalmers Manufacturing Co.
ACF	ACF Industries, Inc.
AG	Aerojet-General Corp.
AGN	Aerojet-General Nucleonics, Subsidiary of Aerojet-General Corp.
Alco	Alco Products, Inc.
AMF	AMF Atomics, A Division of American Machine & Foundry Co.
ANL	Argonne National Laboratory, operated by the University of Chicago.
ARSS	American Radiator & Standard Sanitary Corp.
B&W	Babcock & Wilcox Co., The.
BAC	Bendix Aviation Corp.
Bethlehem	Bethlehem Shipbuilding Corp., Quincy, Mass.
BNL	Brookhaven National Laboratory, operated by Associated Universities, Inc.
CE	Combustion Engineering, Inc.
CL	Clinton Laboratory of Manhattan Engineer District.
Convair	Consolidated Vultee Aircraft Corp.
Daystrom	Daystrom, Inc.
Du Pont	E. I. du Pont de Nemours & Co.
FW	Foster Wheeler Corp.
Fluor	Fluor Corp., Ltd.
GDC	General Atomic Division of General Dynamics Corp.
GE	General Electric Co.
GNE	General Nuclear Engineering Co.
Elec. Boat	Electric Boat Division of General Dynamics Corp.
HKF	H. K. Ferguson Co., The.
Ingalls	Ingalls Shipbuilding Corp.
KE	Kaiser Engineers, Division of Henry J. Kaiser Co.
LASL	Los Alamos Scientific Laboratory, operated by University of California.
Lockheed	Lockheed Aircraft Corp.
Mare Island	Mare Island Naval Shipyard.
Martin	Martin Co., The.
Met. Lab	Metallurgical Laboratory of Manhattan Engineer District.
NAA	Atomics International, a Division of North American Aviation, Inc.
NACA	National Advisory Committee for Aeronautics.
Newport News	Newport News Shipbuilding & Drydock Co.
NRL	Naval Research Laboratory.
NDA	Nuclear Development Corp. of America.
ORNL	Oak Ridge National Laboratory, operated by Union Carbide Nuclear Co., a division of Union Carbide Corp.
Portsmouth	Portsmouth Naval Shipyard.
PPC	Phillips Petroleum Co.
P&W	Pratt & Whitney Aircraft Division, United Aircraft Corp.
West	Westinghouse Electric Corp.
Vitro	Vitro Engineering Co., a subsidiary of Vitro Corp.

NUCLEAR REACTORS BUILT, BUILDING, OR PLANNED IN THE UNITED STATES AS OF DECEMBER 31, 1957

Statistical Summary

	Operated, Later Dismantled	Operated	Being Built	Planned	Total
A. *High-temperature power producing reactors:*					
1. Full-scale civilian power reactors, United States locations		2	5	12	19
2. Full-scale civilian power reactors, foreign locations			1	5	6
3. Civilian power reactor experiments	6	6	4	1	17
4. Full-scale military power reactors		3	28		31
5. Military prototypes and experiments, unclassified	3	2	6	1	12
6. Military prototypes and experiments, classified (not listed)		1	2		3
Total, power producing reactors	9	14	46	19	88
B. *Low-temperature reactors (not useful for power generation):*					
1. Research and training reactors, United States locations	6	28	20	29	83
2. Research and training reactors, foreign locations		7	11	5	23
3. Reactors for general testing		2	1	2	5
4. Reactors for specialized testing		13	4	6	23
5. Production reactors		13		1	14
Total low temperature reactors	6	63	36	43	148
C. *Critical experiment facilities:*					
1. Critical experiment facilities, unclassified	9	40	7	4	60
2. Critical experiment facilities, classified (not listed)	4	4		1	9
Total, critical experiment facilities	13	44	7	5	69
Grand total	28	121	89	67	305

NUCLEAR REACTORS BUILT, BUILDING, OR PLANNED IN THE UNITED STATES AS OF DEC. 31, 1957

A. High Temperature Power Producing Reactors

A.1. *Full-Scale Civilian Power Reactors, U. S. Locations*

Name and/or owner	Location	Principal contractor	Type	Power (electric kilowatts)	Startup
Operated:					
Vallecitos Boiling Water Reactor (GE)	Pleasanton, Calif	GE	Boiling water	5,000	1957
Pressurized Water Reactor (AEC)	Shippingport, Pa	West	Pressurized water	60,000	1957
Being built:					
Commonwealth Edison Co. Dresden Station	Near Joliet, Ill	GE	Boiling water	180,000	1960
Consolidated Edison Co. of New York [1]	Indian Point, N. Y	B&W	Pressurized water	275,000	1960
Power Reactor Development Co., Inc., Enrico Fermi Plant [2]	Monroe, Mich	Owner	Fast breeder	100,000	1960
Yankee Atomic Electric Co.	Rowe, Mass	West	Pressurized water	134,000	1960
Nuclear ship *Savannah*	New York Shipbuilding Corp	B&W	Pressurized water	16,400	1960
Planned: [3]					
Rural Cooperative Power Association (AEC) [4 5]	Elk River, Minn		Boiling water	22,000	
Wolverine Electric Cooperative (AEC) [4 5]	Hersey, Mich		Aqueous homogeneous	10,000	
Consumers Public Power District (AEC) [5]	Hallam, Nebr	NAA	Sodium graphite	75,000	1962
Chugach Electric Association, Inc. (AEC) [6]	Anchorage, Alaska	NDA	Sodium, heavy water	10,000	1962
East Central and Florida West Coast Nuclear Groups [7]	Florida	GNE	Gas cooled, heavy water moderated.	50,000	1963
Northern States Power Co. [3]	Near Sioux City, S. Dak	AC	Boiling water	66,000	1962
Pennsylvania Power & Light Co. [7]	Northeastern Pennsylvania	West	Aqueous homogeneous	70–150,000	1963
Carolinas-Virginia Nuclear Power Associates, Inc. [7]	Parr Shoals, S. C	West	Pressurized heavy water	17,000	1963
Gas-Cooled Power Reactor (AEC) [8]	NRTS, Idaho	KE	Gas cooled	40,000	
Large Scale Heavy Water Reactor (AEC)			Pressurized heavy water	100,000	1962
City of Piqua, Ohio (AEC) [4]	Piqua, Ohio	NAA	Organic moderated	12,500	1961
Maritime Gas Cooled Reactor			Gas cooled	14,800	

A.2. *Full-Scale Civilian Power Reactors, Foreign Locations*

Being built:					
Belgium (Syndicat d'Etude del'Energie Nucleaire-SEEN)	Mol	West	Pressurized water	11,500	1959
Planned:					
Brazil (American & Foreign Power Co.) [9]	Jurumirim, Sao Paulo	GE	Boiling water	12,500	1960
Cuba (American & Foreign Power Co.) [9]		GE	Boiling water	12,500	1960
Italy (Edisonvolta.) [9]	Milan	West	Pressurized water	134,000	1961
Mexico (American & Foreign Power Co.) [9]		NAA	Organic moderated	12,500	
Italy, Government of (Societa Italiana Meridionale Energia Atomica) [9]	Rome	Vitro	Pressurized water	134,000	1962

See footnotes at end of table.

A.3. *Civilian Power Reactor Experiments*

Name (all owned by AEC)	Designation	Location	Principal contractor	Type	Power (electric kilowatts)	Start-up	Dismantled
Operated, later dismantled:							
Boiling Reactor Experiment No. 1	BORAX-1	NRTS, Idaho	ANL	Boiling water	No. elec.	1953	1954
Boiling Reactor Experiment No. 2 (modified to BORAX-3).	BORAX-2	NRTS, Idaho	ANL	Boiling water	No. elec.	1954	1955
Los Alamos Fast Breeder	Clementine	Los Alamos, N. Mex.	LASL	Fast	No. elec.	1946	1953
Homogeneous Reactor Experiment No. 1	HRE-1	Oak Ridge, Tenn.	ORNL	Aqueous homogeneous	140	1952	1954
Boiling Reactor Experiment No. 3 (modified to BORAX-4).	BORAX-3	NRTS, Idaho	ANL	Boiling water	1,700	1955	1955
Los Alamos Power Reactor Experiment No. 1	LAPRE-1	Los Alamos, N. Mex.	LASL	Aqueous homogeneous	No. elec.	1956	1957
Operated:							
Experimental Breeder Reactor No. 1 [10]	EBR-1	NRTS, Idaho	ANL	Fast breeder	200	1951	
Experimental Boiling Water Reactor	EBWR	Lemont, Ill.	ANL	Boiling water	5,000	1956	
Boiling Reactor Experiment No. 4	BORAX-4	NRTS, Idaho	ANL	Boiling water	2,400	1956	
Sodium Reactor Experiment	SRE	Santa Susana, Calif.	NAA	Sodium graphite	6,000	1957	
Organic Moderated Reactor Experiment	OMRE	NRTS, Idaho	NAA	Organic moderated	No. elec.	1957	
Homogeneous Reactor Experiment No. 2	HRE-2	Oak Ridge, Tenn.	ORNL	Aqueous homogeneous	300	1957	
Being built:							
Los Alamos Power Reactor Experiment No. 2	LAPRE-2	Los Alamos, N. Mex.	LASL	Aqueous homogeneous	No. elec.	1958	
Los Alamos Molten Plutonium Reactor Experiment No. 1	LAMPRE-1	Los Alamos, N. Mex.	LASL	Fast molten plutonium	No. elec.	1960	
Argonne Boiling Reactor Facility	ARBOR	NRTS, Idaho	ANL	Boiling water	No. elec.	1960	
Experimental Breeder Reactor No. 2							
Planned:	EBR-2	NRTS, Idaho	ANL	Fast breeder	20,000	1960	
Liquid Metal Fuel Reactor Experiment	LMFRE		B&W	Liquid metal	No. elec.		

A.4. *Full-Scale Military Power Reactors*

Name and/or owner	Designation	Designer	Shipbuilder	Type	Start-up
Operated:					
Submarine USS Nautilus (USN)	SSN571	West	Elec. Boat	Pressurized water	1955
Submarine USS Seawolf (USN)	SSN575	GE	Elec. Boat	Sodium	1956
Submarine USS Skate (USN)	SSN578	West	Elec. Boat	Pressurized water	1957

Being built:						
Submarine Swordfish (USN)	SSN579	West	Portsmouth	Pressurized water		
Submarine Sargo (USN)	SSN583	West	Mare Island	Pressurized water		
Submarine Seadragon (USN)	SSN584	West	Portsmouth	Pressurized water		
Submarine Skipjack (USN)	SSN585	West	Elec. Boat	Pressurized water		
Submarine Triton, 2 reactors (USN)	SS(R)N586	GE	Elec. Boat	Pressurized water		
Submarine Halibut (USN)	SS(G)N587	West	Mare Island	Pressurized water		
Submarine Seamp (USN)	SSN588	West	Mare Island	Pressurized water		
Submarine Scorpion (USN)	SSN589	West	Elec. Boat	Pressurized water		
Submarine Sculpin (USN)	SSN590	West	Ingalls	Pressurized water		
Submarine Shark (USN)	SSN591	West	Newport News	Pressurized water		
Submarine Snook (USN)	SSN592	West	Ingalls	Pressurized water		
Submarine Thresher (USN)	SSN593	West	Portsmouth	Pressurized water		
Guided Missile Cruiser, Long Beach (2 reactors) (USN)	CG(N)160	West	Bethlehem	Pressurized water		
Aircraft Carrier, 8 reactors (USN)	CVA(N)65	West	Newport News	Pressurized water		
Submarine Permit (USN)	SS(G)N594	West	Not assigned	Pressurized water		
Submarine Pollack (USN)	SS(G)N595	West	Not assigned	Pressurized water		
Submarine Plunger (USN)	SS(G)N596	West	Not assigned	Pressurized water		
Submarine Tullibee (USN)	SSN597	GE	Not assigned	Pressurized water		
Army Package Power Reactor No. 1a (USA) [11]	APPR-1a	Alco	[illegible]	Pressurized water		1960

A.5. *Military Prototypes and Experiments*

Operated, later dismantled:							
Aircraft Reactor Experiment (AEC)	ARE	Oak Ridge, Tenn	ORNL	Fused salt	No elec	1954	1954
Submarine Intermediate Reactor Mark A (AEC)	S1G	West Milton, N. Y	GE	Sodium		1955	1957
Heat Transfer Reactor Experiment No. 1 (AEC)	HTRE-1	NRTS, Idaho	GE	Direct air cycle	No elec	1956	1957
Operated:							
Naval Reactor Facility (AEC)	S1W	NRTS, Idaho	West	Pressurized water		1953	
Army Package Power Reactor No. 1 (AEC)	APPR-1	Fort Belvoir, Va	Alco	Pressurized water	1,855	1957	
Being built:							
Large Ship Reactor Prototype, 2 reactors (AEC)	A1W	NRTS, Idaho	West	Pressurized water		1958	
Submarine Advanced Reactor Prototype (AEC)	S3G	West Milton, N. Y	GE	Pressurized water			
Small Submarine Reactor Prototype (AEC)	S1C	Windsor, Conn	CE	Pressurized water			
Argonne Low Power Reactor (AEC)	ALPR	NRTS, Idaho	ANL	Boiling water	200	1958	
Gas-Cooled Reactor Experiment (AEC)	GCRE	NRTS, Idaho	AG	Gas cooled	No elec	1959	
Planned:							
Destroyer Reactor Prototype (AEC)	D1G	Schenectady N. Y	GE	Pressurized water			

See footnotes at end of table.

B. Low Temperature Reactors (Not Useful for Power Generation)

B.1. *Research and Training Reactors, U. S. Locations*

Name and/or owner	Designation	Location	Principal contractor	Type	Start-up	Dismantled
Operated, later dismantled:						
Chicago Pile 1 (Manhattan Engineering District)	CP-1	Chicago, Ill	Met. Lab	Graphite	1942	1943
Chicago Pile 2 (AEC)	CP-2	Lemont, Ill	Met. Lab	Graphite	1943	1954
Argonne CP-3, rebuilt as CP-3′ (AEC)	CP-3	Lemont, Ill	Met. Lab	Heavy water	1944	1950
Argonne CP-3′ (AEC)	CP-3′	Lemont, Ill	ANL	Heavy water	1950	1955
Low Power Water Boiler, rebuilt as HYPO (AEC)	LOPO	Los Alamos, N. Mex	LASL	Homogeneous	1944	1944
High Power Water Boiler, rebuilt as SUPO (AEC)	HYPO	Los Alamos, N. Mex	LASL	Homogeneous	1944	1950
Operated:						
Oak Ridge X-10 Area Reactor (AEC)	X-10-100	Oak Ridge, Tenn	CL	Graphite	1943	
Brookhaven Research Reactor (AEC)		Brookhaven Lab	HKF	Graphite	1950	
Low Intensity Test Reactor (AEC)	LITR	Oak Ridge, Tenn	ORNL	Tank	1950	
Super Power Water Boiler (AEC)	SUPO	Los Alamos, N. Mex	LASL	Homogeneous	1951	
North American Aviation Water Boiler Neutron Source (AEC).[12]	WBNS	Van Nuys, Calif	NAA	Homogeneous	1952	
Livermore Water Boiler (AEC)	LIWB	Livermore, Calif	NAA	Homogeneous	1953	
North Carolina State College (Raleigh Research Reactor).[13]	RRR	Raleigh, N. C	Owner	Homogeneous	1957	
Argonne Research Reactor (AEC)	CP-5	Lemont, Ill	ANL	Heavy water	1954	
Pennsylvania State University		University Park, Pa	Owner	Pool	1955	
Armour Research Foundation	ARR	Chicago, Ill	NAA	Homogeneous	1956	
Battelle Memorial Institute		West Jefferson, Ohio	AMF	Pool	1956	
Naval Research Reactor (USN)		Washington, D. C	NRL	Pool	1956	
Omega West Reactor (AEC)	OWR	Los Alamos, N. Mex	LASL	Tank	1957	
U. S. Naval Post Graduate School	AGN-201-100	Monterey, Calif	AGN	Homogeneous solid	1956	
Catholic University of America	AGN-201-101	Washington, D. C	AGN	Homogeneous solid	1957	
Oklahoma A&M College	AGN-201-102	Stillwater, Okla	AGN	Homogeneous solid	1957	
Aerojet-General Nucleonics	AGN-201M-103	San Ramon, Calif	AGN	Homogeneous solid	1957	
University of Akron	AGN-201-104	Akron, Ohio	AGN	Homogeneous solid	1957	
National Naval Medical Center	AGN-201M-105	Bethesda, Md	AGN	Homogeneous solid	1957	
Texas A&M College	AGN-201-106	College Station, Tex	AGN	Homogeneous solid	1957	
University of Utah	AGN-201-107	Salt Lake City, Utah	AGN	Homogeneous solid	1957	
Aerojet-General Nucleonics	AGN-201-108	Lemont, Ill	AGN	Homogeneous solid	1957	
Colorado State University	AGN-201-109	Fort Collins, Colo	AGN	Homogeneous solid	1957	
University of California	AGN-201-112	Berkeley, Calif	AGN	Homogeneous solid	1957	
Argonne Naught Power Reactor	Argonaut	Lemont, Ill	ANL	Graphite/water	1957	
Atomics International	L-47	Canoga Park, Calif	NAA	Homogeneous	1957	
University of Michigan		Ann Arbor Mich	B&W	Pool	1957	
Livermore Pool Type Reactor (AEC)	LPTR	Livermore, Calif	FW	Pool	1958	
Being built:						
Oak Ridge Research Reactor (AEC)	ORR	Oak Ridge, Tenn	ORNL	Tank	1958	
Brookhaven Medical Reactor (AEC)		Upton, N. Y	Daystrom	Tank	1958	
Massachusetts Institute of Technology	MITR	Cambridge, Mass	ACF	Heavy water	1958	
Industrial Research Laboratories, Inc		Plainsboro, N. J	AMF	Pool	1958	
Curtiss-Wright Corp		Quehanna, Pa	Owner	Pool	1958	
Aerojet-General Nucleonics (8 reactors)	AGN201 (113-120)	San Ramon, Calif	AGN	Homogeneous solid	1958	
University of Wyoming	AGN201-111	Laramie, Wyo	AGN	Homogeneous solid	1958	
University of Virginia		Charlottesville, Va	Owner	Pool	1958	

Watertown Arsenal		Watertown, Mass	BAC	Pool	1958	
Union Carbide Nuclear Co		Sterling Forest, N. Y	AMF	Pool	1958	
American Radiator & Standard Sanitary Corp	UTR-1	Mountain View, Calif	ARSS	Graphite/water	1958	
Neutron Source Reactor (AEC)		Upton, N. Y	BNL	Tank	1958	
University of Florida		Gainesville, Fla	GNE	Graphite/water	1958	
Planned:						
University of California at Los Angeles Medical Reactor		Los Angeles, Calif	NAA	Homogeneous		
State College of Washington		Pullman, Wash	GE	Pool	1958	
University of Buffalo		Buffalo, N. Y	AMF	Pool	1958	
University of Oklahoma	L-47	Norman, Okla	NAA	Homogeneous		
Rice Institute	L-47	Houston, Tex	NAA	Homogeneous	1958	
Puerto Rico Nuclear Center	San Ramon, Calif	Mayaguez		Pool	1960	
General Atomic Division of General Dynamics	TRIGA	San Diego, Calif	GDC	Homogeneous solid	1958	
Aerojet-General Nucleonics [14]	AGN-211-100	San Ramon, Calif	AGN	Homogeneous solid pool.	1958	
Isotope Production Reactor	IRGA	San Diego, Calif	GDC	Homogeneous solid	1958	
Aerojet-General Nucleonics (5 reactors)	AGN-201M-(121-125)	San Ramon, Calif	AGN	Homogeneous solid	1958-59	
Aerojet-General Nucleonics (15 reactors)	AGN 201 (126-140)	San Ramon, Calif	AGN	Homogeneous solid	1958-59	

B.2. *Research and Training Reactors, Foreign Locations*

Owner	Location	Principal contractor	Type	Startup
Operated:				
Brazil, Government of (University of Sao Paulo)	Sao Paulo	B&W	Pool	1957
Denmark, Government of (Atomic Energy Commission)	Risoe	NAA	Homogeneous	1957
Japan, Government of (Atomic Energy Research Institute)	Tokai-mura	NAA	Homogeneous	1957
Netherlands, Government of (International Exhibit)	Amsterdam	AMF	Pool	1957
Switzerland, Government of [15]	Wuerenlingen	ORNL	Pool	1955
Germany, Federal Republic of (Technische Hochschule Muenchen)	Munich	AMF	Pool	1957
Germany, Federal Republic of (Farbwerke Hoechst, AG)	Frankfurt	NAA	Homogeneous	1957
Being built:				
Canada (McMaster University)	Hamilton, Ontario	AMF	Pool	1958
Denmark, Government of (Atomic Energy Commission)	Risoe	FW	Tank	1958
France (Laboratories R. Derveaux)	Boulogne	AG	AGN-201-110	1958
Germany, Federal Republic of (Society for the Utilization of Nuclear Energy in Shipbuilding and Navigation, Inc.).	Hamburg	B&W	Pool	1958
Greece, Government of (Atomic Energy Commission)	Near Athens	AMF	Pool	1958
Italy, Government of (National Committee for Nuclear Research)	Ispra	ACF	Heavy water, Tank	1958
Japan, Government of (Atomic Energy Research Institute)	Tokai-mura	AMF	Heavy water	1959
Spain, Government of (Spanish Atomic Energy Commission)	Near Madrid	GE	Pool	1958
Portugal, Government of (Portuguese Atomic Energy Commission)	Near Lisbon	AMF	Pool	1959
West Berlin, Senate of the Land (Institute for Nuclear Research)	West Berlin	NAA	Homogeneous	1958
Italy (Societa Richerche Impianti Nucleari)	Milan	AMF	Pool	1958
Planned:				
Israel		AMF	Pool	
Italy (Enrico Fermi Nuclear Study Center of Politechnico)	Milan	NAA	Homogeneous	1958
Netherlands, Government of (Reactor Center)	Petten	ACF	Tank	1958
Sweden (Aktiebolaget Atomenergi)	Studsvik	ACF	Tank	
Venezuela, Government of (Institute for Neurology and Brain Research)	Near Caracas	GE	Tank	1958

See footnotes at end of table.

B–3. *Reactors for General Testing*

Name and/or owner	Designation	Location	Principal contractor	Type	Start-up
Operated:					
Materials Testing Reactor (AEC)	MTR	NRTS, Idaho	Fluor	Tank	1952
Engineering Test Reactor (AEC)	ETR	NRTS, Idaho	KE	Tank	1957
Being built:					
Westinghouse Testing Reactor	WTR	Waltz Mill, Pa.	Owner	Tank	1959
Planned:					
National Advisory Committee for Aeronautics	NACA-TR	Sandusky, Ohio	NACA	Tank	1959
General Electric Co. Materials Testing Reactor	GETR	Pleasanton, Calif.	Owner	Tank	1958

B–4. *Reactors for Specialized Testing*

Operated:					
Savannah River Test Pile 305 (AEC)	SR-305	Savannah River	Du Pont	Graphite	1953
Hanford 305 Test Reactor (AEC)	HEW-305	Hanford, Wash.	Du Pont	Graphite	1944
Process Development Pile (AEC)	PDP	Savannah River	Du Pont	Heavy water	1953
Thermal Test Reactor (AEC)	SP	Savannah River	Du Pont	Graphite	1953
Thermal Test Reactor No. 1 (AEC)	TTR-1	Schenectady, N. Y.	GE	Graphite	1951
Thermal Test Reactor No. 2 (AEC)	TTR-2	Hanford, Wash.	GE	Graphite	1955
Bulk Shield Test Facility (AEC)	BSTF	Oak Ridge, Tenn.	ORNL	Pool	1950
Tower Shielding Facility Reactor No. 1 (AEC)	TSFR-1	Oak Ridge, Tenn.	ORNL	Tank	1954
Special Power Excursion Reactor Test No. 1 (AEC)	SPERT-1	NRTS, Idaho	PPC	Tank	1955
Kinetic Experiment on Water Boilers No. 1 (AEC)	KEWB-1	Santa Susana, Calif.	NAA	Homogeneous	1956
Ground Test Reactor (USAF)	GTR	Fort Worth, Tex.	Convair	Pool	1953
Aircraft Shield Test Reactor (USAF)	ASTR	Fort Worth, Tex.	Convair	Light water	1954
General Electric Research Reactor	NTR	Pleasanton, Calif.	GE	Graphite/water	1957
Being built:					
Special Power Excursion Reactor Test No. 2 (AEC)	SPERT-2	NRTS, Idaho	PPC	Pressurized water	1958
Special Power Excursion Reactor Test No. 3 (AEC)	SPERT-3	NRTS, Idaho	PPC	Pressurized water	1958
Nuclear Engineering Test Reactor (USAF)	NETR	Dayton, Ohio	ACF	Pool	1958
Radiation Effects Reactor (USAF)	RER	Marietta, Ga.	Lockheed	Pool	1958
Planned:					
Shielding Experiment Facility Reactor (AEC)	SEFR	NRTS, Idaho	GE	Pool	
Tower Shielding Facility Reactor No. 2 (AEC)[16]	TSFR-2	Oak Ridge, Tenn.	ORNL	Tank	1958
Advanced Engineering Test Reactor (AEC)[16]	AETR				1961
Plutonium Recycle Test Reactor (AEC)	PRTR	Hanford, Wash.	GE	Heavy water	1960
Transient Reactor Test (AEC)	TREAT	NRTS, Idaho	ANL	Graphite	1959
Food Irradiation Reactor (AEC)[17]	FIR	Stockton, Calif.		Pressurized water	

B–5. *Production Reactors*

Designation	Designer	Type	Location
Operated:			
B Reactor	Du Pont	Graphite	Hanford, Wash.
D Reactor	Du Pont	Graphite	Hanford, Wash.
F Reactor	Du Pont	Graphite	Hanford, Wash.
C Reactor	GE	Graphite	Hanford, Wash.
DR Reactor	GE	Graphite	Hanford, Wash.
H Reactor	GE	Graphite	Hanford, Wash.
KE Reactor	GE	Graphite	Hanford, Wash.
KW Reactor	GE	Graphite	Hanford, Wash.
R Reactor	Du Pont	Heavy water	Savannah River, S. C.
P Reactor	Du Pont	Heavy water	Savannah River, S. C.
K Reactor	Du Pont	Heavy water	Savannah River, S. C.
L Reactor	Du Pont	Heavy water	Savannah River, S. C.
C Reactor	Du Pont	Heavy water	Savannah River, S. C.
Planned:			
Improved Production Reactor [8]	GE		

C. List of Critical Experiment Facilities Abbreviated in Table C.1

Abbreviation	Name and location of facility	Operator	Number of cells	Number of control panels
Alco	Alco Products, Inc., Schenectady, N. Y	Owner	1	1
ANL	Argonne National Laboratory (AEC), Lemont, Ill	ANL	3	3
ANL-ID	Argonne National Laboratory, Idaho Div. (AEC), NRTS, Idaho	ANL	1	1
Bettis	*Bettis Plant (AEC), Pittsburgh, Pa*	West	12	10
B&W	The Babcock & Wilcox Co., Lynchburg, Va	Owner	3	2
BMI	Battelle Memorial Institute, West Jefferson, Ohio	Owner	1	1
VNL	Brookhaven National Laboratory (AEC), Upton, N. Y	ANL	2	2
CANEL	Connecticut Aircraft Nuclear Engine Laboratory (AEC), Middletown, Conn	P&W	2	2
CE	Nuclear Engine Laboratory of Combustion Engineering, Inc., Windsor, Conn	Owner	3	3
ETRC	Engineering Test Reactor Critical Facility (AEC), NRTS Idaho	PPC	1	1
GE	General Electric Co. Vallecitor Laboratory Experimental Physics Facility, Pleasanton, Calif	Owner	2	2
GEANP	Evendale Critical Experiment Facility (AEC), Evendale, Ohio	GE	2	2
GDC	General Dynamics Corp., San Diego, Calif	Owner	1	1
KAPL	Knolls Atomic Power Laboratory (AEC), Schenectady, N. Y	GE	6	5
Lockheed	Lockheed Aircraft Co., Missile Systems Div., Palo Alto, Calif	Owner	1	1
LPTF	Low Power Test Facility (AEC), NRTS, Idaho	GE	2	2
Martin	The Martin Co., Middle River, Md	Owner	2	2
NACA	Lewis Flight Propulsion Laboratory (AEC), Sandusky, Ohio	Owner	1	5
NDA	Nuclear Development Corp. of America, Pawling, N. Y	Owner	1	1
ORNL-CF	Oak Ridge National Laboratory Critical Facility (AEC), Oak Ridge, Tenn	ORNL	3	1
ORNL-PTCA	Pool Type Critical Facility, Bulk Shield Test Facility Pool (AEC), Oak Ridge, Tenn	ORNL	1	1
PCTR	Physical Constants Test Reactor Facility (AEC), Hanford, Wash	GE	1	1
RMF	Reactivity Measurements Facility, MTR Canal (AEC), NRTS, Idaho	PPC	1	1
West	Westinghouse Reactor Evaluation Center Critical Experiment Station, Waltz Mill, Pa	Owner	1	1

See footnotes at end of table.

C.1. *Critical Experiment Facilities* [18]

Abbreviation of facility and location within facility	Subject of experiment or study	Designation of experiment	Startup of experiment	Experiment dismantled
Operated, later dismantled: [19]				
ANL—Bldg. 316, Cell A	Nautilus core design	ZPR–1	1950	1953
ANL—Bldg. 316, Cell B	Savannah River reactor design	ZPR–2	1952	1953
ANL—Bldg. 316, Cell C	Fast neutron study (modified to ZPR–4')	ZPR–4	1953	1956
GEANP	Test reactor assembly No. 2	TRA–2	1954	1955
GEANP	Test reactor assembly No. 3	TRA–3	1955	1955
ORNL—Bldg. 205	Nuclear safety and reactor design studies	X–10–200	1945	1948
ORNL—Bldg. K–25	Nuclear physics and nuclear safety with uranium solutions	K–25	1946	1950
ORNL—MTR	Materials test reactor mockup		1950	1950
ORNL—Y12 area	Test reactor assembly No. 1	TRA–1	1954	1954
Operated:				
Alco	APPR core design	APPR–s	1956	
ANL–ID	Coupled fast thermal reactor	ZPR–3	1955	
ANL—Bldg. 316, Cell A	Nuclear constants with fast exponential source	ZPR–4	1957	
ANL—Bldg. 316, Cell B	Interactions between two basic systems	ZPR–5	1956	
ANL—Bldg. 316, Cell C	Boiling water concept	ZPR–7	1957	
Bettis	2 region physics	TRX	1953	
Bettis	Reactivity measurements	PTF	1956	
Bettis	S5W core design	S5W–FA	1956	
Bettis	A1W core 1 physics [20]	A1W–FA–1	1956	
Bettis	A1W core 1 mockup (A1W–M–1) [20]	A1W–M–1	1956	
Bettis	A1W core 2 physics [20]	A1W–FA–2	1957	
Bettis	A1W core 2 mockup [20]	A1W–M–2	1957	
Bettis	PWR core 1 physics	PWR–FA–1	1954	
Bettis	PWR core 2 physics	PWR–FA–2		
Bettis	High temperature physics and mockup	HTTF	1957	
Bettis	S3W/S4W mockup	SFR–FA	1954	
Bettis	S3W/S4W clean critical physics	SFR–FC	1954	
B&W—Cell 1	Consolidated Edison reactor		1957	
BMI—Cell 1	Reflector control critical [21]	BMI–CX	1957	
BNL—Bldg. T–526	Exponential and critical assembly		1956	
CE—Bldg. 1, Cell 1, Pot 1	S1C physics and mockup	S1C–FC	1956	
CE—Bldg. 2, Cell 1, Pot 1	Vacant			
CE—Bldg. 2, Cell 2, Pot 1	S1C advanced mockup	S1C–AC	1956	
Canel—Physics Bldg. Cell 1	Propulsion experiments		1957	
Canel—Physics Bldg. Cell 2	No current experiment			
ETRC—ETR–MTR Area	ETR physics and core loading		1957	
GDC—Cell 1	Zirconium-uranium hydride fuel for TRIGA		1957	
GE—Cell 1	Commonwealth Edison reactor		1957	
GE—Cell 2	Checkout test for Spanish swimming pool reactor [22]		1957	
GEANP	Aircraft propulsion		1954	
GEANP	Aircraft propulsion		1956	
PCTR—Bldg. 305–A	Physical constants not directly connected with power generation		1955	
KAPL	Physical data [20] [23]	PPA	1948	

KAPL	SAR physics and mockup [20]	FPR	1955	
KAPL	Plastic physics and mockup [24]	PMA	1954	
KAPL	Submarine advanced reactor mockup	ATR	1954	
KAPL	DIG cold water mockup	CWA	1957	
Martin—Cell 1	Martin power reactor		1957	
Martin—Cell 2	APPR core life		1957	
RMF—MTR Canal	Reactivity changes as function of test reactor irradiation history		1954	
West—Cell 1	Yankee power reactor		1957	
NDA—Cell 1 [23]	Development of research reactor	NDA-CX	1957	
ORNL-CF—Bldg. 9213, Cell E	Uranium-paraffin experiments related to physics and safety of homogeneous reactors.	CA-28	1950	
ORNL-CF—Bldg. 9213, Cell W	Reactor physics and nuclear safety studies with homogeneous uranium solutions		1950	
ORNL-CF—Bldg. 9213, Cell S	Comparison of nuclear properties of U-235 and U-233		1950	
Being built:				
B&W—Cell 2	NS Savannah fuel assembly and core		1958	
B&W—Cell 3 [26]	LMFRE physics data		1958	
BNL—Bldg. T-525	LMFRE physics data		1958	
KAPL	SAR high temperature physics and mockup	PTR	1958	
Lockheed	Reactor core tests at near zero power levels		1957	
LPTF—Cell 1	Air-cooled reactor		1958	
LPTF—Cell 2	Air-cooled reactor		1958	
ORNL-PTCA—Bldg. 3010	ORR control system		1958	
Planned:				
ANL—Bldg. 316 addition	Fast nuclear and core mockup	ZPR-6		
ANL—Bldg. 316 addition	Fast neutron instrumentation and physics studies	FNS-1		
ANL—Bldg. 316 addition	Thermal reactor core tests	CTF		
NACA—Materials and Stresses Bldg	NACA test reactor critical experiments		1958	

REACTOR LIST FOOTNOTES

[1] Of total capacity shown, 163,000 kw. will be nuclear and 112,000 kw. oil-fired superheat.

[2] Contract awarded by Commission under Power Demonstration Reactor Program.

[3] In addition to the projects listed, there have been announcements of preliminary plans for full-scale reactors by the following: Pacific Gas & Electric Co., Southwest Atomic Energy Associates, and General Public Utilities Corp.

[4] Approved as a basis for Commission contract negotiations under Power Demonstration Reactor Program.

[5] About 20 percent of total capacity shown will be nonnuclear.

[6] Contract signed with Nuclear Development Corp. of America for research and development under Power Demonstration Reactor Program. Contract under negotiation with Chugach and NDA for later phases of the project.

[7] Proposal submitted under Power Demonstration Reactor Program.

[8] Design study only as authorized by Public Law 85-162.

[9] Bilateral agreements for cooperation prerequisite to supplying these reactors have not been executed.

[10] Achieved criticality with third core November 1957.

[11] To be located in Alaska.

[12] Reactor was built and first operated at Downey, Calif. It was moved to Van Nuys in 1957.

[13] Original 10-kw. reactor was started up in 1953 and dismantled in 1955. Reactor was reactivated with 500-w. core in March 1957.

[14] Either this reactor or an AGN is to be operated on loan at Brussels International Exhibition, Apr. 15–Oct. 1, 1958.

[15] Geneva Conference reactor rebuilt and now operating at Wuerenlingen.

[16] Construction not authorized.

[17] Status uncertain pending investigation of alternative gamma sources.

[18] Critical experiments at Los Alamos and other weapons sites not included.

[19] For comparability purposes, this list of dismantled critical experiments is based on lists carried in previous issues of this table. It is now known to be incomplete and is being reviewed.

[20] Cell has 1 control panel. Experiment may be operated in either part but not both simultaneously. Only a single count is made in statistical summary.

[21] Experiments being transferred from Battelle Memorial Institute to Connecticut Nuclear Engineering Laboratory.

[22] Experiment dismantled, but cell is intact.

[23] Formerly located at Sacandaga, N. Y.

[24] Modified from SIR Proof Test Reactor (PTR).

[25] Facility designed to accommodate 2 experiments, but has a present capability of 1.

[26] B&W cells 2 and 3 share a control panel with only cell 2 or cell 3 capable of being operated at any one time.

APPENDIX 9

Current Commission Unclassified Research Contracts in Physical and Biological Sciences, Raw Materials, and Reactor Development [1]

PHYSICAL RESEARCH CONTRACTS

Chemistry

Alabama, University of. J. L. Kassner, E. L. Grove, and D. F. Smith, A Study of the Principles, Theory, and Practice of High Frequency Titrimetry.

Alabama, University of. D. F. Smith, Cryoscopic Determinations in Fused Salt Systems.

Arizona, University of. D. S. Chapin, The Mechanism of the Heterogeneous Low Temperature Ortho-Hydrogen Conversion.

Arizona, University of. Edward N. Wise, Coulometric Analysis of Rare-Earth Elements at Controlled Potential.

Arkansas, University of. E. S. Amis, Electron-Transfer Reactions.

Arkansas, University of. R. R. Edwards, R. W. Fink, and A. Fry, Nuclear Chemistry Research.

Arkansas, University of. T. C. Hoering and R. R. Edwards, Nuclear Geochemistry.

Boston University. L. C. W. Baker, Preparations, Structures, and Properties of Heteropoly Ions.

Boston University. A. H. A. Heyn, Analytical Separations in the Presence of a Large Proportion of Bismuth.

Brandeis University. Henry Linschitz, Photochemical Reactions of Complex Molecules in Condensed Phase.

Brooklyn, Polytechnic Institute of. H. Morawetz, Study of Radiation Induced Solid State Polymerization.

Brown University. John O. Edwards, Mechanisms of Peroxide Reactions.

Buffalo, University of. G. M. Harris, Applications of Isotopes in Chemical Kinetics.

California Institute of Technology. Harrison Brown, Study of the Fundamental Geochemistry of Critical Materials and the Development of Economic Processes for Their Isolation.

California Institute of Technology. Norman Davidson, Complex Ions and Reaction Mechanisms in Solutions.

California, University of. C. S. Garner, Isotopic Exchange Reactions.

California, University of. J. H. Hildebrand, Intermolecular Forces and Solubility.

California, University of. R. L. Scott, Fluorocarbons Solutions.

Carnegie Institute of Technology. A. A. Caretto, Nuclear Chemistry Research.

Carnegie Institute of Technology. G. J. Mains, High Intensity X-Radiolysis.

Case Institute of Technology. Louis Gordon, Coprecipitation from Homogeneous Solution.

[1] Contracts listed as of November 30, 1957

Catholic University of America. F. O. Rice, The Production and Identification of Free Radicals.

Chicago, University of. Edward Anders, Radiochemical and Geochemical Studies.

Chicago, University of. Robert Gomer, Corrosion Research with Field and Ion Microscopy.

Chicago, University of. C. A. Hutchison, Jr., Paramagnetic Resonance Absorption.

Chicago, University of. J. E. Mayer, Statistical and Quantum Mechanics of Interacting Atoms.

Chicago, University of. Henry Taube, Reactions of Solvated Ions.

Chicago, University of. A. Turkevich and N. Sugarman, Nuclear Chemistry Research.

Chicago, University of. A. Turkevich and N. Sugarman, Synchrocyclotron Operation.

Chicago, University of. H. C. Urey, Research on the Natural Abundance of Deuterium and Other Isotopes in Nature.

Clark University. A. E. Martell, Reactions of Partially-Chelated Metal Ions.

Clark University. T. T. Sugihara, Nuclear Chemistry and Radiochemistry.

Clarkson College of Technology. Milton Kerker, A Study of the Size and Shape of Colloidal Particles by Light Scattering and Electron Microscopy.

Clarkson College of Technology. H. L. Shulman, The Determination of Interfacial Area in Packed Absorption and Distillation Columns.

Colorado, University of. R. N. Keller, The Scintillation Properties of Coordination Compounds.

Colorado, University of. H. F. Walton, Specific Attractions in Ion Exchange.

Columbia University. V. K. LaMer, The Preparation and Evaluation of Superior Flocculating Agents for Phosphate Slimes.

Columbia University. P. F. Kerr, Alteration and Mineralization of Primary Uranium Deposits.

Columbia University. J. L. Kulp, Isotope Geology of Uranium and Lead.

Columbia University. J. L. Kulp, Helium and Argon in Rocks and Minerals.

Columbia University. J. M. Miller, Research in the Field of Radiochemistry.

Columbia University. R. M. Noyes, Photochemical Reactions of Iodine.

Columbia University. T. I. Taylor, Separation of Isotopes by Chemical Exchange.

Connecticut, University of. J. T. Stock and W. C. Purdy, Analytical Chemistry of Low Concentrations.

Connecticut, University of. Rowland Ward and W. C. Orr, Tracer Element Distribution Between a Solid and a Melt.

Cornell University. Richard Bersohn, Gradient of the Electric Field in Ionic Crystals.

Cornell University. R. M. Diamond, Exchange Resin and Solvent Extraction Mechanisms.

Cornell University. F. A. Long, Mechanism of Acid Catalysis and Studies in Deuterium Oxide as Solvent.

Delaware, University of. R. L. Pigford, Thermal Diffusion in Liquids.

Drexel Institute of Technology. H. H. Anderson, Fundamental Exploratory Investigations of Chemical Reactions at High Temperatures (500°–1,000° C.)

Duke University. H. A. Strobel, Ion Exchange in Polar Non-Aqueous Solvents.

Duquesne University. N. C. Li, Solution Chemistry of Metal Complexes.

Emory University. A. L. Underwood, Jr., Anion Analysis by Infrared Spectrophotometry

Florida State University. Gregory R. Choppin, Study of the Chemistry of the Actinide and Lanthanide Elements.

Florida State University. R. H. Johnsen, Radiation Induced Effects in Heterogeneous Organic Systems.

Florida State University. R. E. Johnson, Exchange Between Labeled Halogens and Certain Inorganic Halides.

Florida State University. R. K. Sheline, Search for Long Lived Radioactivities; Theoretical Nuclear Studies.

Fordham University. Michael Cefola, Studies on Formation of Complexes by Thenoyltrifluoroacetate and other Chelating Agents.

General Dynamics Corp. Merten Ulrich, The High-Temperature Chemistry of Fission-Product Elements.

Georgia Institute of Technology. Jack Hine, The Effect of Structure on the Reactivity of Polyfluoro Inorganic Compounds.

Georgian Court College. Sister Mary Peter Coakley, Absorption Spectra of Some Coordination Compounds of Beryllium, Magnesium, Zinc, Nickel, Copper, and Mercury.

Harvard University. Clifford Frondel, Synthesis of Uranium and Thorium Minerals.

Illinois Institute of Technology. M. L. Bender, Correlation of Isotopic Rate Effects with Reaction Mechanism.

Illinois Institute of Technology. T. J. Neubert, Color Centers and Related Phenomena in Sodium Cyanide Single Crystals.

Illinois, University of. H. G. Drickamer, The Mechanism of Molecular Motion as Determined from Diffusion and Thermal Measurements.

Illinois, University of. R. H. Herber, Isotope Exchange Reactions in Non-Aqueous Solvents.

Illinois, University of. P. E Yankwich, Studies in Radiochemistry.

Indiana University. R. B. Fischer, Precipitation Processes in Analytical Chemistry.

Indiana University. F. T. Gucker, Thermodynamic Properties of Solutions.

Indiana University. L. L. Merritt, Jr., Studies with Radioactive Tracers.

Indiana University. W. J. Moore, Rate Processes in Inorganic Solids at High Temperatures.

Indiana University. W. B. Schaap and F. C. Schmidt, Electrochemical Research in Amine Solvents.

Indiana University. R. L. Seifert, Chemical Equilibria at High Temperatures and the Mechanism of Vaporization of Compounds.

Indiana University. R. L. Seifert, Study of Inorganic Salts at High Temperatures.

Iowa, State University of. Leroy Eyring, Preparation of Rare Earth Oxides.

Iowa, State University of. Karl Kammermeyer, Separation of Gases by Diffusion Thru Permeable Membranes.

Johns Hopkins University. P. H. Emmett, Study of Catalytic Surfaces and the Mechanism of Catalytic Reactions.

Johns Hopkins University. W. S. Koski, Studies in Nuclear Chemistry.

Kansas State College. H. C. Moser, Chemical Effects of Neutron Irradiation of Phosphorus Compounds.

Kansas, University of. P. W. Gilles, High Temperature Research.

Kansas, University of. P. W. Gilles, Hot Laboratory Assistance.

Kansas, University of. Ernest Griswold and Jacob Kleinberg, Some Problems in the Chemistry of Low Oxidation States of Metals.

Kansas, University of. F. S. Rowland, The Chemical Reactions of Energetic Recoil Atoms.

Kansas, University of. E. J. Zeller, Thermoluminescence and the Geochemistry of Calcium Carbonate in relation to Radioactive Impurity Content.

Kentucky Research Foundation. A. W. Fort, Rearrangement in the 3-Phenyl-1-butyl-3-^{14}C System.

Kentucky Research Foundation. W. F. Wagner and J. F. Steinbach, Solvent Extraction and Spectrographic Analysis of Rare Earths.

Little, Arthur D., Inc. A. Pastuhov and B. M. Bailey, A Low Temperature Separation Study.

Louisville, University of. R. H. Wiley, Synthesis and Properties of Ion-Exchange Resins.

Louisville, University of. R. H. Wiley, Organic Radiation Chemistry.

Maryland, University of. E. R. Lippincott, Raman Spectra of Colored and Absorbing Substances.

Maryland, University of. E. A. Mason, Thermal Diffusion in Gases.

Massachusetts Institute of Technology. C. D. Croyell, D. N. Hume and J. C. Sheehan, Nuclear Chemistry Research.

Massachusetts Institute of Technology. F. A. Cotton, Thermodynamic, Spectral, and Structural Studies of Complex Ions.

Massachusetts Institute of Technology. A. M. Gaudin, Techniques in Mineral Engineering.

Massachusetts Institute of Technology. P. M. Hurley, Investigations of Isotopic Abundances of Strontium, Calcium, and Argon in Certain Minerals.

Mellon Institute of Industrial Research. F. A. Miller, Vibrational Spectra of Inorganic Compounds.

Michigan State University. C. H. Brubaker, Jr., Studies of Certain Complex Compounds of Platinium.

Michigan State University. J. L. Dye, Thermodynamic Investigation of Dilute Solutions of the Alkali Metals in Liquid Ammonia.

Michigan State University. M. T. Rogers, A Physico-Chemical Investigation of the Interhalogen Compounds.

Michigan, University of. R. B. Bernstein, Fundamental Research on Isotope Reactions.

Michigan, University of. P. J. Elving, Polarographic Behavior of Organic Compounds.

Michigan, University of. W. W. Meinke, Nuclear Chemical Research.

Michigan, University of. E. F. Westrum, Jr., Low Temperature Chemical Thermodynamics.

Minnesota, University of. W. M. Lauer, Deuteration of Aromatic Hydrocarbons.

Montana State University. R. J. Hayden and Jack Wehrenberg, Geological Correlation Program Utilizing Argon-Potassium Dating.

New Hampshire, University of. A. R. Amell, The Beta Decay of C^{14} in Doubly Labeled Ethane in the Presence of Methyl Amine.

New Hampshire, University of. H. M. Haendler, Reactions in Non-Aqueous Solvents.

New Mexico Highlands University. G. E. Meyer, The Kinetics of the Radiochemical Exchange of Some Organo-Metallic Compounds.

New York State College for Teachers. O. E. Lanford, Concentration of Nitrogen 15 by Chemical Exchange.

North Carolina State College of Agriculture and Engineering. F. P. Pike, Performance of Contactors for Liquid-liquid Extraction.

Northwestern University. Fred Basolo and R. G. Pearson, Mechanism of Substitution Reactions of Inorganic Complexes.

Northwestern University. Malcolm Dole, Mechanism of High Energy Radiation Effects on Polyethylene.

Notre Dame, University of. Milton Burton, Radiation Chemistry Studies.

Ohio State University. M. H. Kurbatov and J. D. Kurbatov, Study of Complex Beta Decay Spectra.

Ohio State University. David White, Specific Heat Determinations of Pure, Solid Para Deuterium.

Ohio University. R. J. Kline, The Reaction of Uranium with Solutions of Ammonium Salts in Liquid Ammonia.

Ohio University. W. B. Smith, The Pinacol Rearrangement of 1,1,2-Trimethylethylene Glycol.

Oklahoma Agricultural & Mechanical College. E. M. Hodnett, The Isotope Effect in the Study of Chemical Reactions.

Oklahoma Agricultural & Mechanical College. T. E. Moore, Separation of Inorganic Salts by Liquid-Liquid Extractions.

Oklahoma, University of. J. R. Nielsen, Spectroscopic Properties of Fluorocarbons and Fluorinated Hydrocarbons.

Oregon State College. T. H. Norris, A Study of Generalized Acid-base Phenomena in Non-Aqueous Ionizing Solvents with Radioactive Tracers.

Oregon, University of. D. F. Swinehart, Study of Gaseous Chemical Reaction Kinetics, Using a Mass Spectrometer.

Pennsylvania State University. T. F. Bates, An Investigation of the Mineralogy and Petrography of Uranium-Bearing Shales.

Pennsylvania State University. T. F. Bates and Wm. Spackman, Jr., An Investigation of the Mineralogy, Petrography, and Paleobotany of Uranium-Bearing Lignites.

Pennsylvania State University. W. C. Fernelius, Stabilities of Coordination Compounds and Related Problems.

Pennsylvania State University. C. R. Kinney, Investigation of the Chemical Nature of the Organic Matter of Uraniferous Shales.

Pennsylvania State University. W. W. Miller, Chemical Reactions Induced in Condensed Systems by B-Decay.

Pennsylvania State University. R. P. Seward, Chemical Properties of Fused Sodium Hydroxide.

Pennsylvania, University of. John O'M. Bockris, A Study of the Structure of Molten Salts and Silicates.

Pittsburgh, University of. Henry Freiser, The Development and Testing of Organic Reagents for Use in Inorganic Analysis.

Pittsburgh, University of. Robert Levine, Synthesis of Beta-Diketones and Beta-Ketoesters with Heterocyclic Nuclei.

Princeton University. John Turkevich, Temporary and Permanent Effects Produced by Radiation on Solids.

Princeton University. John Turkevich, Study of Nucleation Processes.

Providence College. M. A. Fineman, The Study of Gaseous Negative Ions Formed by Electron Impact.

Purdue Research Foundation. J. W. Cobble, Chemistry and Nuclear Chemistry of the Heavy Elements.

Purdue Research Foundation. Thomas DeVries, Polarography in Non-Aqueous Solvents.

Purdue Research Foundation. W. F. Edgell, Studies in Molecular Spectroscopy.

Purdue Research Foundation. W. H. Johnston, Radiochemical Studies in Kinetics and Nuclear Chemistry.

Purdue University. H. C. Brown, Chemistry of Polyvalent Metal Halides.

Reed College. A. F. Scott, The Diffusion of Cathodic Hydrogen Through Metals.

Rensselaer Polytechnic Institute. H. M. Clark, Extraction of Inorganic Substances by Organic Solvents.

Rensselaer Polytechnic Institute. G. J. Janz, Thermodynamics and Conductance of Simple Electrolytes in Polar Organic Solvents.

Rensselaer Polytechnic Institute. R. A. Osteryoung, A Study of Complex Ions in Fused Melts.

Rochester, University of. E. O. Wiig, Studies of Spallation Reactions.

Rutgers University. E. R. Allen, Polar Inorganic Molecules.

Rutgers University. William Rieman, III, Analytical Chemistry of the Polyphosphates.

South Carolina, University of. O. D. Bonner, Fundamental Studies of Ion Exchange Equilibria.

Southern California, University of. A. W. Adamson, The Photochemistry of Complex Ions.

Southern California, University of. H. L. Friedman, Solutions of Inorganic Electrolytes in Solvents of Low Dielectric Constant.

Southern California, University of. W. K. Wilmarth, Homogenous Solution Reactions of Molecular Hydrogen.

Southern Research Institute. R. B. Ellis, Surface Tension of Fused Salts.

Stanford Research Institute. Daniel Cubicciotti, A Fundamental Study of Fused Salts and Salt-Metal Systems.

Stetson University. John V. Vaughen, High Temperature Electromotive Force Measurements.

Stevens Institute of Technology. Everett R. Johnson, Effect of Radiation on Solids.

Syracuse University. B. P. Burtt, The Mechanisms of Some Radiation Induced Gas Reactions and the Chemical Reactions of Electrons.

Temple University. A. V. Grosse, Research in Basic Inorganic Chemistry.

Tennessee, University of. J. F. Eastham and C. W. Keenan, Determination and Application of Separation Factors for some Chemical Fractionations of Hydrogen Isotopes.

Tennessee, University of. H. A. Smith, Studies dealing with the Rates of Catalytic Reactions Involving Deuterium and Vapor Pressures Studies of H_2O–D_2O Mixtures in the Presence of Salts.

Tennessee, University of. P. B. Stockdale, Investigation of the Chattanooga Black Shale of Tennessee as a Source of Uranium.

Texas University of. G. W. Watt, Unusual Oxidation of Transitional Elements.

Tufts College. T. R. P. Gibb, Research on the Preparation of Uranium Hydride; Research on Hydrides.

Utah, University of. Henry Eyring and C. J. Christensen, Studies on Surface Chemistry.

Utah, University of. A. L. Wahrhaftig, Ionization and Dissociation of Molecules by Electron Bombardment.

Vanderbilt University. D. C. Bardwell, Radiation Stability and Inorganic Radiochemistry.

Vanderbilt University. E. A. Jones, Raman Spectra of Some Inorganic Fluorine Compounds.

Washington, State College of. R. J. Carr, Mechanism of Nuclear Reactions.

Washington, State College of. John P. Hunt, Use of N–15 to Study Certain Problems in Nitrogen Chemistry.

Washington, University of. A. L. Babb, Separation Efficiency of Pulsed Extraction Columns.

Washington University. H. A. Potratz, Geologic Dating of Corals and other Calcareous Materials.

Washington University. A. C. Wahl, Radiochemical Studies of the Fission Processes.

Washington University. S. I. Weissman, Generation of High Voltages by Means of Nuclear Radiation.

Western Reserve University. E. L. Pace, Thermodynamic Properties of Gases.

Wisconsin, University of. W. J. Blaedel, Ion Exchange Separation Scheme for the Identification of Radioelements.

Wisconsin, University of. J. O. Hirschfelder, Quantum Mechanical and Semi-empirical Determination of Intermolecular Forces.

Wisconsin, University of. E. L. King, Studies of Rates and Equilibria in Inorganic Reactions in Solution.

Wisconsin, University of. Irving Shain, Kinetic and Mass Transfer Problems in Electrochemistry: Application to Analytical Methods.

Wisconsin, University of. John E. Willard, Application of Radioisotopes to Chemical Problems.

Yale University. P. A. Lyons, Diffusion Coefficients of Electrolytes and Molecules.

Yale University. Richard Wolfgang, Research in Nuclear Chemistry.

Physics

Arkansas, University of. M. K. Testerman, Mass Spectrometry Instrumentation.

Brown University. Russell A. Peck, Jr., Reaction Studies with Fast Neutrons.

California Institute of Technology. R. F. Bacher, Research in High Energy Physics.

California Institute of Technology. Jesse W. DuMond, Nuclear Spectroscopy and X-ray Studies.

California, University of. C. D. Jeffries, A Study of Nuclear Moments.

California, University of. J. A. Jungerman, Precision Beta-ray Spectroscopy.

California, University of. J. H. Reynolds, Mass Spectroscopy Research.

California, University of. J. R. Richardson, Research in High Energy Physics.

California, University of. S. A. Schaaf, Diffusion in Low Density Jets.

Carnegie Institute of Technology. George Hinman, Beta-Ray Spectrometry.

Carnegie Institute of Technology. R. B. Sutton, 400 Mev Synchrocyclotron and Associated Research.

Case Institute of Technology. E. C. Gregg, Electron and Gamma Interactions with 26 Mev Betatron.

Case Institute of Technology. Robert Shankland, Purchase of a High Voltage Engineering Corp. 3 Mev Type KN (V) Van de Graaff Accelerator.

Chicago, University of. S. K. Allison, Reactions of Light Nuclei and the Penetration of Charged Particles through Matter.

Chicago, University of. G. Wentzel, Theoretical Research in Elementary Particle Physics.

Colorado, University of. J. J. Kraushaar and D. A. Lind, A Joint Program of Research in Nuclear Spectroscopy and Inelastic Nuclear Scattering.

Colorado, University of. David A. Lind, Design of a 10–30 Mev Cyclotron and Associated Structures.

Columbia University. W. W. Havens, Jr., Nuclear Physics Research.

Columbia University. L. M. Lederman, Research in Particle Physics.

Columbia University. Robert Serber, Theoretical Research.

Duke University. Martin M. Block, Development and Application of Helium Bubble Chamber.

Duke University. Henry W. Newson, Fast Neutron Cross-Sections and Shell Structure.

Florida State University. Alex E. S. Green, Analysis of Nuclear Forces.

Franklin Institute (Bartol Research Foundation). C. E. Mandeville, Neutron Scattering Measurements.

Harvard University. Garrett Birkhoff, Hydrodynamical Computations.

Illinois, University of. R. E. Meagher, Study of a High-Speed Computing Machine.

Iowa, State University of. J. A. Jacobs, Research in Nuclear Structure.

Johns Hopkins University. G. H. Dieke, Absorption and Fluorescence Spectra of Uranium Salts and Other Solids—Spectra of Molecules Containing Tritium.

Johns Hopkins University. G. E. Owen, Acquisition of 3 Mev Electrostatic Generator.

Johns Hopkins University. G. E. Owen and Leon Madansky, Studies of Neutron and Charged Particle Reactions.

Kansas, University of. R. W. Krone, Excited States of Medium Light Elements.

Kentucky Research Foundation. B. D. Kern, Study of Nuclear Energy Levels.

Louisiana State University and Agricultural and Mechanical College. Ralph C. Mobley, Neutron Scattering.

Maryland, University of. W. F. Hornyak, The Structure of Light Nuclei.

Massachusetts Institute of Technology. George R. Harrison, The Development and Use of New Spectroscopic Methods for Isotope Analysis and Zeeman Effect Studies.

Michigan, University of. Peter Franken, Electric and Magnetic Resonance Absorption.

Michigan, University of. Donald A. Glaser, Study of High Energy Nuclear Interactions.

Michigan, University of. W. C. Parkinson, 42″ Cyclotron Program.

Michigan, University of. R. W. Pidd, Nuclear Research with 300 Mev Synchrotron.

Michigan, University of. R. W. Pidd, Experiments on the G-Factor of the Free Electron and the Polarization of Electrons in Scattering.

Minnesota, University of. John H. Williams, 68 Mev Proton Linac.

National Academy of Sciences. Kay Way, Nuclear Data Project.

Nebraska, University of. Theodore Jorgensen, Jr., Energy Transfer of Slow Ions.

New York University. Hartmut Kallman, High Speed Storage in Phosphors.

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Purdue University. T. R. Palfrey, Basic Research with High Energy Electrons and X-rays produced by a 300 Mev Synchrotron.

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The Anderson Physical Laboratory. Scott Anderson, Research for Purification of Metal Halides.

Arkansas, University of. P. C. Sharrah and R. F. Kruh, Study of the Structure of Liquids by X-ray Diffraction.

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Purdue University. Richard E. Grace, Diffusion in Liquid Alloys.

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Biology

Agnes Scott College. Josephine Bridgman, A Comparison of Irradiation Effects on Wet and Dry Ciliate Cysts in Nitrogen, Oxygen, and Air.
Agriculture, U. S. Department of. P. B. Pearson, The Intermediary Metabolism of Proteins and Amino Acids in Avian and Mammalian Species.
Agriculture, U. S. Department of. R. F. Reitemeier, Accumulation and Movement of Fission Products in Soils and Plants.
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Amherst College. G. W. Kidder, Studies on Nucleic Acid and Free Nucleotide Synthesis in Normal Tissue and in Tumor Tissue, Using C–14.
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Arizona, University of. W. H. Fuller, W. T. McGeorge, Utilization of Phosphorus from Biological Material and Uptake of Strontium by Various Type Crops.
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Arkansas, University of. Frances E. Clayton, Developmental Genetic Study of the Effects of X-ray Irradiation in *Drosophila virilis* and *Bufo valliceps.*
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California, University of (Berkeley). H. A. Barker, W. Z. Hassid, and C. C. Delwiche, Tracer and Enzymatic Studies on the Metabolism of Plants and Bacteria.

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California, University of (Berkeley). W. G. Dauben, Mechanism of Biosynthesis of Polycyclic Compounds.

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California, University of (Berkeley). Louis Jacobson and Roy Overstreet, Study of the Internal or Metabolic Factors and the External or Environmental Factors Affecting Ion Absorption by Plants.

California, University of (Davis). Max Kleiber, Intermediary Metabolism of Organic Compounds and Biological Synthesis in Farm Animals.

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Mississippi, University of. D. R. Parker, Chromosome Breakage in Oocytes of Drosophila.

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Nebraska, University of. F. A. Haskins, Effects of X-rays and Thermal Neutrons on Plant Metabolism.

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Michigan, University of. I. A. Bernstein, Effects of Radiation on the Intermediary Metabolism of Mammalian Skin.

Michigan, University of. A. C. Curtis, Effect of Irradiation on the Localizing Response (to Antigen) of Different Tissues in Immunity.

Michigan, University of. F. J. Hodges, and Isadore Lampe, Clinical Evaluation of Teletherapy.

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Minnesota, University of. L. A. French and S. N. Chou, Study of Mechanisms of Radioactive Isotopic Localization in Tissues of the Central Nervous System.

Minnesota, University of. Bruce Jarvis and J. G. Brunson, The Effects of Gram Negative Bacterial Endotoxin on Irradiated Rabbits.

Minnesota, University of. Samuel Schwartz, Studies on the Relationships of Porphyrins, Tumors, and X-rays.

Montefiore Hospital (Pittsburgh, Pa.). Richard Abrams, Synthesis of Nucleic Acid Purines in Bone Marrow.

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Montefiore Hospital for Chronic Diseases (New York). Daniel Laszlo, Dynamics of Strontium Distribution in the Body.

Nebraska, University of. W. J. Arnold, Effects of Cranial X-Irradiation on Psychological Processes in Rats.

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New England Center Hospital. William Dameshek, Physiopathology of Platelets and Development of Platelet Substitutes.

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New England Deaconess Hospital. Shields Warren, Acute and Chronic Radiation Injury.

New York Medical College. H. B. Eiber, Preparation of Radioactive Heparin.

New York University, Bellevue Medical Center. Bernard Altshuler, The Distribution and Persistence of Radioactive Aerosols in the Lungs of Animals.

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New York University. B. E. Zweifach, Histochemical Studies of Metabolic Alterations in Rats Receiving Lethal and Sublethal Doses of Radiation, with Emphasis on Terminal Vascular Bed.

New York, State University of. Alfred Farah, Changes in Protein-Bound Sulfhydryl in Renal Cells Under Varying Experimental Conditions.

New York, State University of. Albert Hirschman, Effects of Irradiation on the Calcifying Mechanisms of Epiphyseal Cartilage.

New York, State University of. I. M. Murray and A. R. Seaman, The Effect of X-Irradiation on a "Megakarocytosis" Produced in Gelatin-Treated Animals.

Northwestern University. D. P. Earle, The Effects of Irradiation on Renal Transport Systems.

Northwestern University. Harold Koenig, A Study of Nucleoprotein Metabolism in Normal, Degenerating, Regenerating and Stimulated Nerve Cells with Radioisotopic Tracers.

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Pennsylvania, University of. L. V. Heilbrunn, Changes in the Capillary Fragility and the Colloidal Properties of Blood Following Irradiation.

Peter Bent Brigham Hospital. F. D. Moore, Injury, Wounding and Convalescence; A Study by Isotopic and Metabolic Methods.

Philadelphia General Hospital. H. P. Schwarz, The Effect of X-ray Radiation of the Lipids of the Skin.

Pittsburgh, University of. L. V. Beck, Attempted Modification of Mammalian Tumor Radiosensitivity with Agents and Procedures Altering Host Sensitivity.

Pittsburgh, University of. Herman Cember, Lung Hazards from Inhaled Radioactive Particulate Matter.

Pittsburgh, University of. F. J. Dixon, The Study of the Effects of Radiation on the Immune Response.

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Puerto Rico, University of. A. A. Cintron-Rivera, Studies of Protein and Fat Metabolism in the Normal and in Those Patients with Malnutrition and Malabsorptive Syndromes.

Retina Foundation. M. A. Jakus, A Comparison of the Fine Structure of the Normal and the Irradiated Lens.

Rice Institute R. V. Talmage, Endocrine and Metabolic Studies Utilizing Radioisotopes and Labelled Hormones.

Rochester, University of. G. B. Forbes, Metabolism of Bone Sodium.

Rochester, University of. L. H. Hemplemann, Individual Response to Ionizing Radiation in Animals and Patients.

Rochester General Hospital. H. L. Rosenthal, A Study of the Uptake, Turnover and Metabolism of the Chemical Constituents of Bone.

Rochester, University of. A. R. Terepka, Dynamic Aspects of Skeletal Metabolism.

R. B. Jackson Memorial Laboratory (Bar Harbor, Maine). Meredith Runner, Physiological Studies on Induced Congenital Deformities in Mice.

Sloan-Kettering Institute for Cancer Research. C. P. Rhoads et al., Biological Effects of Radiation, and Related Biochemical and Physical Studies.

Southwest Foundation for Research and Education (San Antonio, Tex.). N. T. Werthessen, An Investigation of the Production and the Possible Isolation of Substances Capable of Stimulating Recovery from Radiation by Utilizing Techniques of *in vitro* Maintenance of Spleen and Other Organs.

Stanford University. H. S. Kaplan and E. L. Ginzton, Biological and Medical Investigations with the 70 Mev Linear Electron Accelerator.

St. Louis University. E. A. Smolik, The Blood Volume and Blood Turnover in Cases of Head Injury as Determined by Isotope-Labeled Red Blood Cells.

Syracuse University. W. R. Boss, Effects of X-Radiation upon the Renal-Endocrine System.

Tennessee, University of. N. R. DiLuzio, The Response of the Reticulo-Endothelial System to X-Irradiation.

Tennessee, University of. W. M. Hale, A Study of the Effects of Cobalt 60 Gamma Irradiation on Infection and Immunity.

Tennessee, University of. A. W. Jones, A Survey of the Effects of Radiation on Host-Parasite Relations.

Tennessee, University of. F. W. Lengemann, The Metabolism of Alkaline Earth Metals by Bone.

Tennessee, University of. R. R. Overman, Radiation Physiology and Pharmacology in the Primate.

Tennessee, University of. L. Van Middlesworth, Studies in Iodide Metabolism.

Tennessee, University of. J. L. Wood, The Origin and Fate of Thiocyanate Ion in Metabolism.

Texas Technological College. S. J. Kaplan, The Effects on Rat Behavior of Developmental Aberrations Induced by Ionizing Radiation *in utero.*

Texas, University of, M. D., Anderson Hospital and Tumor Institute. W. K. Sinclari, Physical and Radiobiological Investigations with 22 Mev X-rays and Electrons, as Compared with Cobalt 60 and 250 Kv X-rays.

Tufts College. W. C. Moloney and F. H. L. Taylor, Investigation of Enzymic, Biochemical and Other Cytological Activities of Human Leukocytes.

Tufts College. Richard Wagner, Enzyme Studies on White Blood Cells and Blood Platelets.

Utah, University of. T. F. Dougherty, Toxicity Studies of Plutonium and Other Radioactive Substances in Animals.

Utah, University of. M. M. Wintrobe and G. E. Cartwright, Metabolism of Trace Elements in Animals and Man with Special Reference to Their Role in Erythropoiesis.

Vanderbilt University. G. W. Meier, Fetal Irradiation and the Patterns of Behavior Development.

Virginia, University of. J. N. Dent, A Study of the Pituitary Glands of Thyroidectomized Newts.

Washington, University of (Seattle). C. A. Finch, Erythropoiesis and Iron Metabolism.

Washington, University of (Seattle). B. W. Gabrio and F. M. Huennekens, Erythrocyte Preservation and Metabolism.

Washington, University of (Seattle). R. L. Huff, Hemodynamics; Blood Dynamics as Measured by Simultaneous Multiple Port Scintillation Detection of I–131 Human Serum Albumin.

Wayne State University. J. E. Lofstrom, Evaluation of Radioactive Isotope Gamma Ray Source for Medical Teletherapy.

Wayne State University. J. E. Lofstrom, Studies on the Effects of Maternally Administered Phosphorus 32 on Foetal and Post-Natal Development of the Rat.

Western Biological Laboratories (Culver City, Calif.). B. H. Ershoff, Further Studies of an Unidentified Factor in Liver which Prolongs Survival of Animals Administered Multiple Sublethal Doses of X-Irradiation.

Western Reserve University. B. M. Dobyns, A Study of the Physiological Function and Histological Changes of Thyroids Irradiated with Radioactive Iodine.

Western Reserve University. Hymer L. Friedell, Investigations of the Biological Effects of Internally Deposited Radioisotopes and Related Radiobiology Studies.

Wisconsin. University of. H. F. Harlow, The Effect of Various Forms of Irradiation of the Brain on Learned and Unlearned Behavior of Monkeys and Chimpanzees.

Worcester Foundation for Experimental Biology. M. C. Chang, Effects of Cobalt 60 Irradiation on Rabbit Eggs *in vitro.*

Yale University. J. W. Hollingsworth, Biologic Implications of Isologous and Heterologous Bone Marrow Repopulation in Irradiated Animals.

Yerkes Laboratory of Primate Biology, Inc. (Orange Park, Fla.). H. W. Nissen, Behavioral Effects of Ionizing Radiation on Chimpanzees of Various Ages.

Radiation Instrumentation

Airborne Instruments Laboratory (Mineola, Long Island, N. Y.). K. C. Speh, Automatic Scanning of Nuclear Emulsions.

Allen B. Dumont Laboratories, Inc. (Clifton, N. J.). S. J. Koch, Photomultiplier Tube Development.

Army, U. S. Department of, Corps of Engineers. N. F. Blackburn, Program of Research and Development on Scintillation Crystals.

The Borden Co., Philadelphia Research Laboratory. B. D. Halpern, Plastic Scintillators.

Commerce, U. S. Department of, National Bureau of Standards. L. Costrell, Radiation Monitoring Systems.

Commerce, U. S. Department of, National Bureau of Standards. L. Costrell, Nucleonic Instrumentation Utilizing Memory Devices.

Commerce, U. S. Department of, National Bureau of Standards. Michael Danos, Precision Measurements of Variable Non-Homogeneous Strong Magnetic Fields.

Commerce, U. S. Department of, National Bureau of Standards. F. H. Day, Evaluation and Testing of Radiation Instruments.

Commerce, U. S. Department of, National Bureau of Standards. L. B. Leder, Electron Scattering.

Commerce, U. S. Department of, National Bureau of Standards. E. C. Lloyd, High Temperature Strain Gages.

Commerce, U. S. Department of, National Bureau of Standards. J. W. Motz, Spectrometry of Low Energy X-rays.

Commerce, U. S. Department of, National Bureau of Standards. J. S. Pruitt, Intensity Measurements on High Energy X-rays.

Commerce, U. S. Department of, National Bureau of Standards. E. K. Plyler, Instrumentation on Far Infrared.

Commerce, U. S. Department of, National Bureau of Standards. Ugo Fano, Radiation Data.

Commerce, U. S. Department of, National Bureau of Standards. W. A. Wildhack, Miscellaneous Investigations on Basic Instrumentation.

Commerce, U. S. Department of, National Bureau of Standards. H. O. Wyckoff, Radiation Shielding Problems.

Commerce, U. S. Department of, National Bureau of Standards. H. O. Wyckoff, Electron Interactions.

Commerce, U. S. Department of, National Bureau of Standards. H. O. Wyckoff, Assistance to the National Committee on Radiation Protection.

Levinthal Electronic Products, Inc. (Redwood City, Calif.). W. J. Van Sciver, Study of Scintillation and Other Related Properties of NaI Crystals.

Louisville, University of. C. H. Jarboe, Jr., Synthesis and Properties of Organic Scintillators.

Michigan, University of. H. J. Gomberg, High Resolution Detection of Nuclear Radiations.

New England Center Hospital. C. V. Robinson, Development of Small *in Vivo* Detectors.

New York University—Washington Square College. M. H. Shamos, Investigation of Physical Dosimetric Techniques.

Notre Dame, University of. E. A. Coomes, Fundamental Research on Photoemission.

Pilot Chemicals, Inc. (Watertown, Mass.). Mark Hyman, Jr., Research and Development Work on Plastic Scintillators Containing High Z Materials.

Radio Corporation of America, RCA Laboratories. G. A. Morton, Photomultiplier Tube Research and Development.

Radiochemistry, Inc. (Tulsa, Okla.). William Johnston, J. E. Lewis, Medium Low Level Soft Beta Counting Equipment.

Sloan-Kettering Institute for Cancer Research. J. S. Laughlin, Equivalence of Absorbed Radiation Energy and Cavity Ionization.

St. Procopius College (Lisle, Ill.). F. R. Shonka, W. P. Jesse—(1) Special Problems in Nuclear Instrumentation; (2) Ionization of Gases.

Vanderbilt University. J. I. Hopkins, Nuclear Physics Studies on Instrumentation Problems.

Vanderbilt University. G. R. Meneely, R. T. Lagemann, Preliminary Survey for Low Level Counting Facility.

Special Training

Duke University. H. S. Roberts, Jr., Radiation Biology Course for High School Teachers.

Harvard University. A. K. Solomon and Fletcher Watson, Intensive Summer Program Devoted to Furthering the Scientific Education of High School Teachers with Particular Emphasis on the Use of Radioactive Materials.

New Mexico, University of. S. D. Aberle and John Harty, Radiation Biology Course for High School Teachers.

Wayne State University. A. J. Vorwald, Summer Institute on Radiobiology for High School Science Teachers.

RAW MATERIALS RESEARCH CONTRACTS

Columbia University. H. D. Hassialis, Recovery of Uranium from the Chattanooga Shale.

Massachusetts Institute of Technology. Theodore R. Madden, Problems of Induced Polarization Properties of Rocks and Their Causes.

Minnesota, University of. J. W. Gruner, Mineralogic and Petrographic Nature and Genesis of Uranium Ores in the Western United States.

Minnesota, University of. Harold W. Mooney, Investigations of Spontaneous Electrical Potentials as Related to Geophysical Exploration for Uranium.

National Lead Co., Inc. Charles K. McArthur, Process Development Studies on the Recovery of Uranium from its Ores.

Nevada, University of. V. E. Scheid, Development Studies on the Beneficiation of Uranium Ores, and Extractive Metallurgy for Recovery of Uranium from Ores.

New Mexico, University of. Dr. Vincent C. Kelley,[2] Studies of Regional Fracture Patterns in Relationship to Uranium Deposits of the Colorado Plateau and Adjacent Areas.

Pennsylvania State University. Harold Wright, Research on Trace Quantities of Uranium in Sulfides of Veins.

U. S. Bureau of Mines. J. Bruce Clemmer, Amenability Testing and Assaying of Uranium Ores and Unit Process Studies.

REACTOR DEVELOPMENT RESEARCH CONTRACTS

Arcos Corp. R. D. Thomas, Jr., Welding of Specialized Reactor Materials.

Armor Research Foundation. H. B. Karplus, Measurement of Sound Velocity in Liquid Containing Gas Bubbles.

Armour Research Foundation. F. B. Forzel, Study of Reactor Containment.

Armour Research Institute. John Rounki, Scavenging of Particulate Matters in Connection with Nuclear Powered Ships.

Army Ordnance Corps. Joe Sperraza, Safety Design Requirements of Reactor Retaining Structures.

California, University of. Dr. W. J. Kaufman and Dr. Gerhard Klein, Disposal of Radioactive Wastes into the Ground.

California, University of. R. K. Forster, Study of the Dynamics of Vapor Bubbles and on Boiling Heat Transfer.

Carnegie Institute of Technology. Robert B. Beckmann, Thermal and Hydraulic Studies at High Reynolds Numbers.

Columbia University. Charles F. Bonilla, Boiling and Condensing of Liquid Metals.

Fluor Corp., Ltd. Systems Evaluation of the Flowable Solids Reactor.

Ford Instrument Co. Theodor Jarvis, Application of Digital Techniques to Reactor Control Systems.

General Nuclear Engineering Corp. Dr. W. H. Zinn, Reactivity Effects on Fuel Lifetime.

Georgia Institute of Technology. Dr. Werner Grune, Treatment & Disposal of Radioactive Sludges.

Harvard University. Dr. Leslie Silverman, Air Cleaning Research and Development.

[2] Contract with Dr. Kelley personally.

Harvard University. Prof. H. A. Thomas, Jr., Mechanisms of Dilution of Radiocontaminants in Surface Waterways.

Illinois, University of. Dr. H. F. Johnstone, Investigation of Fundamental Properties of Aerosols as Related to Air Cleaning.

Johns Hopkins University. Dr. Walter A. Patrick, Separation and Fixation of Specific Isotopes from Radioactive Wastes.

Johns Hopkins University. Dr. Charles E. Renn, Ultimate Disposal of Radioactive Wastes to the Natural Environment.

Kentucky, University of. Joseph P. Hammond, Study of Zirconium-Base Alloys for Air Exposure at High Temperature.

Little, A. D. Malcolm K. White, Literature Survey on Radiation in the area of Hazards, Health, and Safety—Applicable to the Nuclear Powered Merchant Ship Program.

Massachusetts Institute of Technology. Dr. Rolf Eliassen, Decontamination of Radioactive Liquid Wastes.

Massachusetts Institute of Technology. Dr. M. Benedict, Cost of Nuclear Fuel Cycles.

Minnesota, University of. Herbert S. Isbin, Two-Phase Heat Transfer Studies to Steam-Water Flows.

National Academy of Sciences. Drs. R. J. Russell and W. Thurston, Disposal of Radioactive Wastes into Surface and Subsurface Geologic Structures.

Naval Bureau of Ordnance. E. C. Noonan, Damage from the Excursion of Nuclear Reactors.

North Carolina, University of. Dr. H. C. Thomas, Disposal of Radioactive By-Products of Nuclear Fission.

Northwestern University. Dr. Carlos G. Bell, Study of Waste Disposal Dilution Factors in the Des Plaines River and Chicago Drainage Canal.

Parsons, Ralph M. W. A. Siegrist, Literature Survey of Data Applicable to Nuclear Powered Merchant Ship Operation.

Pennsylvania State University. Prof. Joseph Marin, Stresses at Nozzle Connections of Pressure Vessels.

Purdue Research Foundation. Dr. A. Sesonske, Free Convection and Natural Circulation Heat Transfer Variables in Ordinary Fluids Containing Volume Heat Sources.

Rensselaer Polytechnic Institute. Prof. Paul Harteck, Operation of a Modified Distillation-Diffusion Apparatus in the Separation of Isotopes of Metals and a Study of the Reaction Rates of Gases Under Pile Irradiation.

Stanford Research Institute. C. A. Trexel, Jr., Survey of Space and Process Heat Generation for Use in Determining Potential Nuclear Energy Application.

Texas, University of. Dr. E. Gloyna, Storage of Radioactive Wastes in Salt Formations.

U. S. Bureau of Mines. R. C. Corey, Incineration of Radioactive Wastes. To Develop a Practical Incinerator for Disposal of Solid Combustible Radioactive Wastes.

U. S. Weather Bureau. H. A. Thomas, Jr., Research on the Dispersal of Atmospheria Wastes Which May Be of Practical Use in the Location, Design, and Operation of Nuclear Energy Facilities.

Westinghouse Electric Corp. T. Fahrner, Study of a Supercritical Water Reactor System in a Merchant Ship Applic.

APPENDIX 10

Maximum Permissible Radiation Exposures to Man

A PRELIMINARY STATEMENT OF THE NATIONAL COMMITTEE ON RADIATION PROTECTION AND MEASUREMENT

January 8, 1957

Introduction

Since the publication of NBS Handbook 59 on Permissible Dose from External Sources of Ionizing Radiation, the National Committee on Radiation Protection and Measurement (NCRP) has continued the study and review of its recommendations, particularly with respect to genetic effects and the possible shortening of average life expectancy due to radiation exposure of a larger fraction of the population. The NCRP proposals resulting from these studies had an important influence on the decisions reached by the International Commission on Radiological Protection (ICRP) in Geneva in April 1956, which resulted in a general lowering of the maximum permissible accumulated dose (MPD) for occupational radiation exposures, as well as for exposures of the population as a whole. These changes are in accord with the informal agreements reached by the ICRP in Stockholm in 1952.

The NCRP has now agreed upon the formulation of revised recommendations on maximum permissible doses which integrate the national and international views for practical application. The committee is pleased to note that the findings of the ICRP are reinforced by the important information and data provided in the subsequent reports of the National Academy of Sciences and the British Medical Research Council.

The changes in the accumulated MPD are not the results of positive evidence of damage due to use of the earlier permissible dose levels, but rather are based on the desire to bring the MPD into accord with the trends of scientific opinion; it is recognized that there are still many uncertainties in the available data and information. Consideration has also been given to the probability of a large future increase in radiation uses. In spite of the trends, it is believed that the risk involved in delaying the activation of these recommendations is very small if not negligible. Conditions in existing installations should be modified to meet the new recommendations as soon as practicable, and the new MPD limits should be used in the design and planning of future apparatus and installations. Because of the impact of these changes and the time required to modify existing equipment and installations, it is recommended on the basis of present knowledge that a conversion period of not more than 5 years be adopted within which time all necessary modifications should be completed.

Definitions

For the purposes of this preliminary statement, the following tentative definitions are given:

Controlled Area. A defined area in which the occupational exposure of personnel to radiation or to radioactive material is under the supervision of a radiation safety officer. (This implies that a controlled area is one that requires control of access, occupancy, and working conditions for radiation protection purposes.)

Workload. The output of a radiation machine or a radioactive source integrated over a suitable time and expressed in appropriate units.

Occupancy Factor. The factor by which the workload should be multiplied to correct for the degree or type of occupancy of the area in question.

RBE Dose. RBE stands for relative biological effectiveness. An RBE dose is the dose measured in rems. (This is discussed in the forthcoming report of the International Commission on Radiological Units and Measurement.)

MPD Recommendations for Occupational Conditions (Controlled Areas)

1. *Accumulated Dose.* The maximum permissible accumulated dose, in rems, at any age, is equal to 5 times the number of years beyond age 18, provided no annual increment exceeds 15 rems. Thus the accumulated MPD=5 (N–18) rems where N is the age and greater than 18. This applies to all critical organs except the skin, for which the value is double.

2. *Weekly Dose.* The previous permissible weekly whole-body dose of 0.3 rem, and the 13–week dose of 3 rems when the weekly limit is exceeded are still considered to be the weekly MPD with the above restriction for accumulated dose.

3. *Emergency Dose.* An accidental or emergency dose of 25 rems to the whole body, occurring only once in the lifetime of the person, shall be assumed to have no effect on the radiation tolerance status of that person. (See National Bureau of Standards Handbook 59.)

4. *Medical Dose.* Radiation exposures resulting from necessary medical and dental procedures shall be assumed to have no effect on the radiation tolerance status of the person concerned.

MPD Recommendations for the Whole Population

5. The maximum permissible dose to the gonads for the population of the United States as a whole from all sources of radiation, including medical and other manmade sources, and background, shall not exceed 14 million rems per million of population over the period from conception up to age 30, and one-third that amount in each decade thereafter. Averaging should be done for the population group in which crossbreeding may be expected.

Recommendations for Internal Emitters

6. In controlled areas, the permissible radiation levels for internal emitters will conform to the general principles outlined above. Where the critical organ is the gonad or the whole body, the maximum permissible concentrations of radionuclides in air and water will be one-third the values heretofore specified for radiation workers. Where single organs other than the gonads are regarded as the critical organ, the present maximum permissible concentrations will continue. For individuals outside of controlled areas, the maximum permissible concentrations should be one-tenth of those for occupational exposures. (Other changes in the maximum permissible concentrations for radionuclides may be introduced because of additional information developed since the publication of National Bureau of Standards Handbook 52.)

Discussion of Revised Recommendations

7. The MPD for occupational exposure is based on the absence of detectable injury to the individual. It remains at its present level of 0.3 rem/week for the whole body. Where the dose in any week exceeds this value, a dose of 3 rems in 13 weeks may be accepted. The 13-week period may start at the beginning of the

calendar quarter or the beginning of the week during which the permissible weekly dose was exceeded.

8. The rules given in Handbook 59 will be continued for operational and administrative purposes, but some of the rules will be modified by provisions related to an average yearly limitation of occupational exposure to external sources of ionizing radiation of 5 rems to the blood-forming organs, gonads, and lens of the eyes, and of 10 rems to the skin. The use of "5 rems" in the statement of the revised rules is for the purpose of design and administration. The critical limitation will be that defined for the total accumulated dose in paragraph 1 above.

9. If a person's occupational exposure is documented or otherwise known with reasonable certainty, he may be permitted to use his reserve exposure in accordance with paragraphs 1 and 2 above. In all other cases, he shall be assumed to have received his maximum accumulated dose as indicated in paragraph 1 above.

10. It is considered that with the current and proposed low levels of occupational exposure, it is presently not necessary to make special allowance for medical exposure in conjunction with occupational exposure. This consideration may later become important. The effects of medical exposures have long been considered by this committee to be the responsibility of the attending physician; it is his responsibility to evaluate medical radiation exposure in relation to the health of the individual. (See National Bureau of Standards Handbook 59.)

11. In the determination of the population dose in the vicinity of radiation sources, proper consideration should be given to occupancy factor and to workload. The exposure of individuals outside of controlled areas may be integrated over periods up to one year.

12. While at the moment it is not feasible to determine the average exposure for the population with any reasonable accuracy, the adoption of some figure is necessary for planning purposes. For the immediate future, it may be assumed that the total integrated RBE dose received by all radiation workers will be small in comparison with the integrated RBE dose of the whole population. Furthermore, persons outside of controlled areas, but exposed to radiation from a controlled area, constitute only a small portion of the whole population. Therefore, if this small portion is assumed to receive yearly an average per capita dose of 0.5 rem, the total dose to the whole population from manmade radiations is not likely to exceed 10 million rems per million of population up to age 30. (This assumes a dose of 4 million rems per million of population over this age period from background radiation.)

APPENDIX 11

Monitoring Stations

U. S. PUBLIC HEALTH SERVICE MONITORING STATIONS

Albany, N. Y.
Anchorage, Alaska
Atlanta, Ga.
Austin, Tex.
Baltimore, Md.
Berkeley, Calif.
Boise, Idaho
Cheyenne, Wyo.
Cincinnati, Ohio
Denver, Colo.
El Paso, Tex.
Gastonia, N. C.
Harrisburg, Pa.
Hartford, Conn.
Honolulu, T. H.
Indianapolis, Ind.
Iowa City, Iowa
Jacksonville, Fla.
Jefferson City, Mo.
Juneau, Alaska
Klamath Falls, Oreg.
Lansing, Mich.
Lawrence, Mass.
Little Rock, Ark.
Los Angeles, Calif.
Minneapolis, Minn.
New Orleans, La.
Oklahoma City, Okla.
Phoenix, Ariz.
Pierre, S. Dak.
Portland, Oreg.
Richmond, Va.
Salt Lake City, Utah
Santa Fe, N. Mex.
Seattle, Wash.
Springfield, Ill.
Trenton, N. J.
Washington, D. C.

AEC MONITORING STATIONS

Berkeley, Calif	Radiation Laboratory, University of California.
Cincinnati, Ohio	General Electric Co.—Aircraft Nuclear Propulsion Department.
Idaho Falls, Idaho	Idaho Operations Office.
Lemont, Ill	Argonne National Laboratory.
Los Alamos, N. Mex	Los Alamos Scientific Laboratory.
New York, N. Y	New York Operations Office.
Richland, Wash	Hanford Operations Office.
Oak Ridge, Tenn	Oak Ridge National Laboratory.
Rochester, N. Y	The Atomic Energy Project, University of Rochester.
Salt Lake City, Utah	Radiobiology Laboratory, University of Utah.
West Los Angeles, Calif	Atomic Energy Project, UC–Los Angeles.
Sandia Corp	Albuquerque, N. Mex.

U. S. WEATHER BUREAU FALL-OUT SAMPLING STATIONS

Abilene, Tex.
Albany, N. Y.
Albuquerque, N. Mex.
Alpona, Mich.
Amarillo, Tex.
Atlanta, Ga.
Bakersfield, Calif.
Baltimore, Md.
Billings, Mont.
Binghamton, N. Y.
Bishop, Calif.
Boise, Idaho
Boston, Mass.
Buffalo, N. Y.
Caribou, Maine
Casper, Wyo.
Charleston, S. C.
Cheyenne, Wyo.
Chicago, Ill.
Cleveland, Ohio
Colorado Springs, Colo.
Concord, N. H.
Corpus Christi, Tex.
Concordia, Kans.
Dallas, Tex.
Del Rio, Tex.
Denver, Colo.
Des Moines, Iowa
Detroit, Mich.
Elko, Nev.
Ely, Nev.
Eureka, Calif.
Fargo, N. Dak.
Flagstaff, Ariz.
Fort Smith, Ark.
Fresno, Calif.
Goodland, Kans.
Grand Junction, Colo.
Grand Rapids, Mich.
Green Bay, Wis.
Hatteras, N. C.
Helena, Mont.
Huron, S. Dak.
Jackson, Miss.
Jacksonville, Fla.
Kalispell, Mont.
Knoxville, Tenn.
Las Vegas, Nev.
Los Angeles, Calif.
Louisville, Ky.
Lynchburg, Va.
Marquette, Mich.
Medford, Oreg.
Memphis, Tenn.
Miami, Fla.
Milford, Utah
Milwaukee, Wis.
Minneapolis, Minn.
Mobile, Ala.
Montgomery, Ala.
New Haven, Conn.
New Orleans, La.
New York (La Guardia), N. Y.
Philadelphia, Pa.
Phoenix, Ariz.
Pittsburgh, Pa.
Pocatello, Idaho
Port Arthur, Tex.
Portland, Oreg.
Prescott, Ariz.
Providence, R. I.
Pueblo, Colo.
Rapid City, S. Dak.
Reno, Nev.
Rochester, N. Y.
Roswell, N. Mex.
Sacramento, Calif.
Salt Lake City, Utah
San Diego, Calif.
San Francisco, Calif.
Scottsbluff, Nebr.
Seattle, Wash.
Spokane, Wash.
St. Louis, Mo.
Syracuse, N. Y.
Tonopah, Nev.
Tucson, Ariz.
Washington, D. C. (Silver Hill, Md.)
Wichita, Kans.
Williston, N. Dak.
Winnemucca, Nev.
Yuma, Ariz.

FOREIGN MONITORING STATIONS

Addis Ababa, Ethiopia
Anchorage, Alaska
Bangkok, Thailand
Beirut, Lebanon
Belem, Brazil
Bermuda
Buenos Aires, Argentina
Canal Zone
Canton Island
Churchill, Manitoba, Canada
Clarke AFB, Philippines
Colombo, Ceylon
Dakar, French West Africa
Deep River, Ottawa, Ontario, Canada
Dhahran, Saudi Arabia
Durban Natal, South Africa
Edmonton, Alberta, Canada
Fairbanks, Alaska
French Frigate Shoals
Goose Bay, Labrador
Guam
Hilo, Hawaii
Hiroshima, Japan
Honolulu, Hawaii
Iwo Jima
Johnson Island
Juneau, Alaska
Keflavik, Iceland
Koror
Kwajalein
La Paz, Bolivia
Lagens, Azores
Lagos, Nigeria
Leopoldville, Belgian Congo
Lihue
Lima, Peru
Melbourne, Australia
Mexico City, Mexico
Midway Island
Milan, Italy
Misawa, Japan
Moneton, New Brunswick, Canada
Monrovia, Liberia
Montreal, Quebec, Canada
Moosoonee, Ontario, Canada
Nagasaki, Japan
Nairobi Kenya, East Africa
Nome, Alaska
North Bay, Ontario, Canada
Noumea, New Caledonia
Oslo, Norway
Ponape
Prestwick, Scotland
Pretoria, South Africa
Quito, Ecuador
Regina, Saskatchewan, Canada
Rhein Main, Germany
San Jose, Costa Rica
San Juan, Puerto Rico
Sao Paulo, Brazil
Seven Islands, Quebec, Canada
Sidi Slimane, French Morocco
Singapore
Stephenville, Newfoundland
Sydney, Australia
Tai Pei, Formosa
Thule, Greenland
Tokyo Air Base, Japan
Truk
Wake Island
Wellington, New Zealand
Wheelus AFB, Tripoli
Winnipeg, Manitoba, Canada
Yap

APPENDIX 12

Text of Addresses and Other Details of Headquarters Building Dedication

Program

Dedication Ceremony

U. S. Atomic Energy Commission

Headquarters Building

Prelude	The United States Marine Band Major Albert Schoepper, USMC, *Director* Lt. Dale L. Harpham, USMC, *Conducting*
Presiding	The Hon. Lewis L. Strauss *Chairman, U. S. Atomic Energy Commission*
Arrival of the President of the United States	
Invocation	The Rev. Frederick Brown Harris, D. D. *Chaplain of the Senate*
Laying of the Cornerstone	The President of the United States *Assisted by* The Hon. Lewis L. Strauss and The Hon. Carl T. Durham *Chairman, Joint Committee on Atomic Energy*
Dedication of the Building	The President of the United States
Benediction	The Rev. Frederick Brown Harris, D. D.
National Anthem	The United States Marine Band
Postlude	The United States Marine Band

Public Inspection of the Building

REMARKS OF THE CHAIRMAN AT DEDICATION CEREMONIES

November 8, 1957

It is my great pleasure, on behalf of my colleagues, Commissioners Libby, Vance, Graham, and Floberg, and all our fellow workers to welcome you on this occasion.

The laying of a cornerstone stimulates the imagination to speculate on how Americans of some distant date will regard the exhibits which today we will seal away for the future.

Into this cornerstone go the more important documents tracing the first 15 years of man's control of atomic energy, samples of various nuclear materials and isotopes, and linen wrappings from the Dead Sea Scrolls whose age has been determined by one of the unexpected applications of atomic energy. I refer, of course, to the technique of radiocarbon dating originated by our colleague, Commissioner Libby.

And finally, this cornerstone will preserve for future time a record in picture and sound of the most inspiring of the many historic developments that have occurred during the 15 years since controlled atomic fission was achieved—President Eisenhower's memorable "Atoms for Peace" address of December 8, 1953—a pronouncement which for men and women the world over transformed the atom from an unrelieved symbol of fear and terror to a promise of great blessing.

Mr. President, it is my great honor now to ask you to help Mr. Durham and me to lay this cornerstone . . .

THE CHAIRMAN'S INTRODUCTION OF THE PRESIDENT

We come now to the climax of this happy occasion.

Behind this curtain there is a dedicatory tablet—which as a permanent marker will be located within the vestibule behind us.

The switch which we will ask the President to use to draw the curtain will operate batteries which have been charged with electricity flowing from the nine United States power reactors that are producing atomic power on land and at sea.

This nuclear power comes from the plants of three atomic submarines—the *Nautilus*, the *Seawolf*, and the *Skate*—from the Army Package Power Reactor at Fort Belvoir, from the land-based submarine prototype in Idaho, from three of the Commission's experimental nuclear power plants at Argonne and Arco and Santa Susana, and from the nuclear power plant at Vallecitos, Calif., the first such plant in the United States—or anywhere in the world—built entirely with private capital.

Ladies and gentlemen, the President of the United States . . .

REMARKS OF THE PRESIDENT AT DEDICATION CEREMONIES

As we contemplate the great scientific achievement of turning the atom and its mysteries to the use of man, we are tempted to turn our memories back toward the dawn of history and think of some of the other occasions when men have succeeded in penetrating Nature's secrets, using her laws for his own purposes.

The strange thing about this is that every one of these inventions or these discoveries has been capable of a wicked or of a good use. When man discovered fire, he found possibly the greatest secret that has ever yet been brought to man's knowledge for his betterment. It is difficult to imagine a world without fire.

Yet fire is also used in bombs in war. We have the crime of arson on our books. The discovery itself was good but men can make good or evil use of it.

The whole field of chemistry has brought to us curing drugs, sulfa drugs, the wonder drugs—Salk vaccine. It has also brought to us the most deadly poisons. And even poisons themselves, they may be used to exterminate vermin that are the curse of men, or they can be used for wicked purposes of destroying men.

And so in this modern time man has discovered another of the great secrets of nature. What differentiates it from all others is the terrible possibilities it opens for wicked men, people who want to use this new discovery for the destruction of mankind now have placed in their hands a power that certainly should give all of us pause. It should awaken man's conscience and appeal to his commonsense. Because not only does it bring a sudden possibility of self-destruction but on the other side of that same coin again we have new possibilities for good—the production of power where no power was possible or was known—its usefulness in agriculture, in medicine, biology—everything we can think of. Mr. Strauss just called our attention to the fact that through it we can determine the age of objects that we find upon our earth.

That is the kind of choice that men must soon face up to, and we must do our part to see that the choice is correctly made. Man's judgement and intelligence must measure up quickly to his inventive genius or mankind's future is bleak indeed.

And so we must be strong in faith, in the faith of our fathers. We must be strong in our own determination to do right, to understand the feelings and fears and aspirations of others, as we expect them to understand our peaceful purposes.

The United States craves no other's territory. It wants no additional power in the world, or domination over any other people. It needs no greater extent of territory or of riches. It wants nothing but a peaceful world in which all peoples can share in the great happiness and betterment that a just peace can bring.

So, as I stand here, I would like to salute the people who have worked so hard in the development of this new science. On the one hand, you have devoted your talents and energies, no matter in what capacity, to help make our country secure against those who would use this new power wickedly. And at the same time, through the efforts of yourselves and the people that work with you throughout the United States, found new ways to make this great discovery useful to man.

I think that if in our time, or before our time is done, we can point to one single real step that can give the whole world the conviction that the peaceful use of atomic energy is now on the way, that all people—those who are our friends now and those who hope—who can one day be our friends—all people can then live in greater contentment and greater peace.

I think that if this convocation here today—I am positive—that if they could have one wish, it would be that the curse of the atomic explosion may pass from man's knowledge and only the good that results from this great discovery would be with us always.

And now it is my very great pleasure, and my proud privilege, to push this button that Chairman Strauss has told how it works—and I certainly hope it does.

CONTENTS OF CORNERSTONE BOX

ARCHEOLOGICAL SPECIMEN

Linen wrappings from Dead Sea Scrolls. (Radiocarbon dated A. D. 35, plus or minus 200 years)

DEDICATION CEREMONY—U. S. Atomic Energy Commission Headquarters Building, Germantown, Md.
- Invitation (including parking permit and commemorative Atoms for Peace postage stamp)
- Program

FILM BADGE

IONIZATION PENCIL

MEDALS, PATCHES, AND SERVICE PINS
- Distinguished Service Medal
- Fermi Medal
- Outstanding Service Medal
- Manhattan District Patches—Officer and Enlisted Man
- Atomic Energy Commission Service Pin
- Manhattan District Service Pins—Silver and Bronze

MOTION PICTURE
- President's 1953 Atoms for Peace Address before the United Nations and President's 1956 International Atomic Energy Agency statement delivered by Mr. Strauss

MICROFILM
- Documents representative of development of atomic energy. (Approximately 9,000 pages including a complete set of semiannual reports Nos. 1 through 22, January 1947 through July 1957.)
- Nucleonics—10th anniversary issue

PHOTOGRAPHS
- The President and U. S. Atomic Energy Commissioners
- Atomic Energy Commission Facilities
- Atomic Energy Commission Seal
- Atomic Submarine Launchings—*Nautilus* and *Seawolf*
- Crop experiments
- "Mike" Shot, Operation Ivy
- Stagg Field Reactor
- Swimming Pool Reactor. (Displayed at the first International Conference on Peaceful Uses of Atomic Energy.)

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APPENDIX 13

Statement on Radioactive Fallout by the Advisory Committee on Biology and Medicine

1. *The Problem.* The testing of nuclear weapons has injected into the atmosphere large amounts of radioactive materials in the form of dust of different particle sizes. These particles descend to the surface of the earth at different rates and constitute what is known as [radioactive] "fallout." Measurements of samples collected in different localities indicate that this radioactive material is widely distributed over the surface of the earth, but with notable differences in surface concentrations. The worldwide fallout is due almost entirely to the explosion of megaton weapons which deliver fine radioactive dust into the stratosphere from which it descends slowly over a period of many years. Thus, in this case, fallout continues for a long time after the weapon has been exploded. Because of this long retention time, only radioactive substances of long half-life, such as strontium 90 and cesium 137, need be considered in connection with the problem of worldwide fallout in peacetime.

Ionizing radiation, in sufficient amounts, is known to produce deleterious effects in living organisms including man. Radioactive fallout on the surface of the earth can deliver radiation to animals and man in two ways: (1) by the external route, in which case the penetrating gamma radiation is of chief importance; and (2) by the internal route when the material is taken into the body with food, water, and air, in which case the radiation of low penetrating power can also reach the internal organs and, in fact, is of chief concern. Therefore, the problem is to estimate what harm may possibly result to man from the general increase in background radiation and from radioactive substances introduced into the body. This requires quantitative data on the accumulation of radioactive material on the ground and in the body.

Through many projects sponsored by the Atomic Energy Commission and from other sources, a great deal of information is available as to existing levels and the rates at which they are increasing. Assumptions have been made by different authorities to permit extrapolation to future levels on the basis that weapons testing will continue at the average rate of the past 5 years. Numerical values are constantly being revised as more information accumulates. The figures given below have been chosen by this Committee as typical ones but may not be the latest ones. It will be seen later that the general conclusions would not be altered by doubling or halving the numerical values used.

2. *Increase in Gamma Ray Background Attributable to Fallout.* Radioactive fallout began in 1945 when the first atomic bombs were exploded in New Mexico and Japan. Subsequent tests of "conventional" atomic bombs in the Pacific and Nevada also produced fallout. However, in all these cases it was small in amount and more or less localized in extent. Fallout became a problem of worldwide interest after the firing of the first hydrogen bomb. The report of the Committee on the Biological Effects of Atomic Radiation, of the National Academy of Sciences (hereafter called the NAS report) states that "U. S. residents have, on the average, been receiving from fallout over the past 5 years a dose which, if weapons testing were continued at the same rate, is estimated to produce a total 30-year dose of about one-tenth of a roentgen: and since the accuracy

involved is probably not better than a factor of five, one could better say that the 30-year dose from weapons testing, if maintained at the past level, would probably be larger than 0.02 *r* and smaller than 0.5 *r*." The average worldwide 30-year dose is estimated to be considerably lower.

3. *Accumulation of Strontium 90.* Strontium 90 fallout has been determined in a great variety of samples collected from different parts of the world. The item of chief interest in the present discussion is the concentration in human bones, especially those of children. However, the more extensive data on soil and milk show the trends with respect to time and are useful in the estimation of future concentrations in human bones.

a) *Soil.* The strontium 90 content of soil has been increasing considerably since 1954. Neglecting minor fluctuations, largely attributable to the periodicity of weapons tests, the increase in this period has been roughly proportional to time. At the end of 1956 the average surface concentration in the United States amounted to approximately 25 mc. of strontium 90 per square mile. Merril Eisenbud estimates that the average for the North Temperate Zone is 9.4 mc/mi^2, and that for the South Temperate Zone 2.6 mc/mi^2.

b) *Milk.* The concentration of strontium 90 in milk has increased steadily with time and reached 5.6 micromicrocuries per gram of calcium in New York State milk in November 1956. It dropped to 3 micromicrocuries per gram calcium in April 1957, but the decrease may be due in part to seasonal variations (e. g., indoor feeding of cows during the winter).

c) *Human Bones.* The strontium 90 concentration in human bones is higher in children than in adults, as would be expected. Until whole skeletons, or sufficient representative samples thereof have been analyzed, quantitative figures must be regarded as rough approximations. In the meantime it seems reasonable to assume that, at least in the United States, the steady state concentration in bone per gram of calcium will be about one-half of that in milk. (The values for milk are quite reliable because large samples can be used in making the measurements.) Accordingly, in very young children it should be approximately one-half of that in milk averaged over their lifetime (including fetal life). The concentration in children's bones analyzed by Kulp et al. is given as 0.75 micromicrocurie of strontium 90 per gram of calcium. It is estimated that during their life the concentration in milk ranged from 1 to 2 micromicrocuries of strontium 90 per gram of calcium.

Since fallout will continue for a considerable time, even if weapons tests are stopped today, and we are interested in long-term effect, it is necessary to estimate the accumulation of strontium 90 in bone over a long period of time. Because strontium 90 decays spontaneously at the rate of one-half in 28 years, it follows that if it is injected into the atmosphere at a constant rate (that is, a constant weapons testing rate in terms of radioactivity released), the total amount present anywhere will gradually reach a maximum value and will then remain constant. At the time when this radioactive equilibrium is reached (roughly 150 years hence), the amount decaying per year would be equal to the amount produced per year. This is not an assumption but a well-established fact in radioactivity. Assumptions must be made, however, as to the amount that has already settled on the surface of the earth, the settling rate and the amount still in the stratosphere, particularly in view of the fact that the largest amount was injected in 1 year. This influences materially the estimation of the time when equilibrium will be reached. Additional assumptions are involved in estimating the concentration in bone over such a long period of time. It is evident, therefore, that estimates of the eventual concentration of strontium 90 in human bones and

the time when it will be reached are subject to considerable variation, depending on the assumptions made.

It seems unrealistic to assume that tests of weapons of the present type will continue for generations. For the present purpose we shall use estimates of the predicted concentration of strontium 90 in the average human skeleton in the United States in equilibrium with fallout, under the following conditions: *a*) if tests were stopped now, *b*) if tests were to continue for 30 years at an annual rate equal to the average of the past 5 years, *c*) if tests were to continue at this rate for many generations.

a) *If weapons tests by all nations were stopped now,* the concentration of strontium 90 in the skeletons of children in equilibrium with the concentration in milk would gradually rise to an average value of 4 micromicrocuries per gram of calcium in the 1970's and would decrease slowly thereafter. This is based largely on estimates made by Merril Eisenbud and Wright Langham.

b) *If weapons tests of all nations were to continue for 30 years at an annual rate equal to the average of the past 5 years* (about 10-megaton equivalent of fission yield per year), the equilibrium concentration of strontium 90 in bone would reach an average value of about 15 micromicrocuries per gram of calcium (as estimated by Langham) early in the 21st century.

c) *If tests were to continue under the conditions stated in b*), *but for many generations,* the equilibrium concentration of strontium 90 in bone would reach an average value of about 30 micromicrocuries per gram of calcium in 100 years (as estimated by Langham) and would remain substantially at this level so long as testing continued at the same rate.

It should be noted that long-range estimates of this kind are only intelligent guesses at best. For one thing, there is practically no information as to how strontium 90 will be distributed in the soil after a long period of time, which, obviously, will influence its incorporation in plants. However, it seems fair to say that most of the envisaged factors that cannot be evaluated today, will probably make the actual concentration of strontium 90 in human bones lower than the estimated values, rather than higher. For the purpose of evaluating possible injury to the population of the United States, we shall *assume* that the average concentration of strontium 90 in bone in equilibrium with fallout will eventually reach 20 micromicrocuries per gram of calcium, if tests continue at the present rate for many years. Since the average surface concentration of worldwide fallout is considerably lower outside the United States, the value applicable to the world's population is considerably lower than this.

The present maximum permissible concentration of strontium 90 in bone for a large population is 100 micromicrocuries per gram of calcium according to the National Committee on Radiation Protection and Measurement and the International Commission on Radiological Protection. The NAS Committee recommends the same concentration, but 50 micromicrocuries of strontium 90 per gram of calcium is also mentioned. Therefore, the estimated (biological and radioactive) equilibrium concentration of strontium 90 from fallout in human bones in the United States, is 20 percent or 40 percent of the MPC for large populations, recommended by authoritative bodies.

It should be noted that all figures given above are averages. Through a combination of unusual circumstances it is possible that fairly large numbers of people in some localities may accumulate strontium 90 in their bones to a value 5 or 10 times greater than the average for the United States or the world, as the case may be. This would bring the bone concentration of strontium 90 above the permissible limit for large populations, but still below the limit for occupational exposure.

4. *Estimate of Possible Damage.*

a) *General Considerations.* The biological effects with which we are concerned in the peacetime fallout problem are those that might possibly result from long-continued, low-level exposure to radiation (externally or internally). Our knowledge of such effects has been derived largely from animal experiments. Since the effects occur also spontaneously, it is always a matter of determining whether there is a real increase in the number of animals showing the effect in question caused by exposure to radiation. In order to obtain a statistically significant difference at very low levels of exposure, thousands of animals would have to be used. In practice, it has been found expedient to use instead a high level of exposure to obtain statistically valid results using small numbers of animals. The question then arises as to how to estimate the effects of exposure at a much lower radiation level than was used in the experiments.

In the case of gene mutations, it has been established or at least it is believed by practically all geneticists—that the number of induced mutations is proportional to the dose received by the gonads up to the time of reproduction, no matter how low the dose is and no matter how it has been distributed with respect to time. On this basis it is then a simple matter to calculate the number of mutations that would be produced by a dose of radiation however small, once the number for a large dose is known. To apply the results of animal experiments to man, various assumptions must be made, but there is good agreement among geneticists at least as to the order of magnitude of the effect.

In the case of somatic effects; that is, effects manifested in the exposed individual himself rather than in his descendants, the extrapolations to very low radiation levels and from animals to man are carried out in a similar manner. Here, however, the situation is more complex and the estimates are less reliable. The most important reason for the unreliability is that the mechanisms by which these effects are produced are not known. The extrapolation may be made by assuming direct proportionality between dose and number of individuals affected (as in the genetic case). This assumption implicitly denies the possibility that if the radiation level is low enough, a given somatic effect may not be produced at all—a conclusion that at the present time can neither be denied nor affirmed. It may be concluded, therefore, that proportional extrapolation to very low radiation levels establishes the maximum value that may reasonably be expected but it does not preclude the possibility that there may be no effect at all—insofar as somatic effects are concerned.

b) *Genetic Damage.* Genetic damage from strontium 90 is generally accepted as negligible because this element does not concentrate in the reproductive organs. There may be, however, some minor effect from its presence in the circulating blood or even from incorporation into the chromosomes themselves. Until more is known about such possibilities, calculations about genetic damage must continue to be based on the increase of background radiation due to long-lived gamma-ray-emitting isotopes in the fallout. It is estimated in the NAS report that in the United States the accumulated 30-year dose will be about 0.1 *r*, if weapons testing continues at the average rate of the previous 5 years. If the dose corresponding to the spontaneous mutation rate (doubling dose) in man is 50 *r* in 30 years (30 to 80 *r* is mentioned as the probable range in the NAS report), this means that the mutation rate will be increased by 0.2 percent. Even if the doubling dose were as little as 10 *r*, which is probably the reasonable minimum, the increase would only amount to 1.0 percent.

In the NAS report it is stated that 2 percent of the total live births in the United States have tangible defects of genetic origin that appear prior to sexual

maturity. According to genetic principles, it may be expected that the number of such defective individuals will ultimately be increased by 0.2–1.0 percent of the present frequency by the predicated increase in background radiation resulting from gamma ray fallout. There are approximately 4 million children born alive per year in the United States. The ultimate increase in genetically defective children will therefore be 0.2 to 1.0 percent of 2 percent of 4 million—160 to 800 per year as compared to 80,000 per year resulting from the spontaneous mutation rate. One may get larger *absolute* numbers by extending the calculation to the world's population of 2.7 billion. Assuming the same birth rate *and the same estimated gonad dose of 0.1 r in 30 years* as for the United States, the ultimate worldwide increase of defective children is 2,500 to 13,000 per year. It should be noted that this is the ultimate increase; that is, the increase that would occur if the additional 0.1 *r* in 30 years persisted for a great many generations. In the first generation, the increase might amount to 10 percent of the ultimate value. If the radiation from fallout were not to continue after the first generation, the *manifestation* of mutations would continue to increase for some generations and then would gradually return to the initial level. It should be noted also that the worldwide average increase in background radiation ascribable to fallout is considerably lower than in the United States. Therefore, the above worldwide estimates are definitely too high by a considerable factor.

The NAS report also stresses the conclusion that in any evaluation of genetic damage, the total damage must include the effects of many mutations that do not produce tangible defects, at least when inherited from only one parent. The total damage, in fact, is more nearly equal to the frequency of mutations induced. The NAS report gives the estimates of six geneticists on the Committee that the induced mutation rate is probably about 0.5 percent per roentgen per individual. If this figure is used as the basis of calculation, the total number of detrimental mutations induced by *a gamma ray fallout dose of 0.1 r* would be 2,000 in the United States and 32,000 for the entire world, in contrast to a spontaneous frequency 100 to 800 times higher.

c) *Leukemia.* It is well known from animal experiments and from observations on humans that exposure to radiation in sufficient amounts induces leukemia in susceptible individuals. That some sort of susceptibility of unknown nature (perhaps genetic) is involved in the process, is evident from the study by W. M. Court Brown and R. Doll (Medical Research Council report) of the incidence of leukemia in ankylosing spondylitis patients treated with X-rays. Of the patients treated with maximum bone marrow doses of 2,750 *r* or more, 0.176 percent developed leukemia.

Neither the above-mentioned study nor any other made so far provides the necessary information to decide whether there is a threshold dose that must be exceeded before leukemia is induced in man, but some animal experiments indicate the existence of a threshold. Also, the absence of a threshold is considered doubtful by most authorities in the field of hematology. In estimating the effect of fallout radiation on the incidence of leukemia, it is generally assumed that there is no threshold and that the increase is proportional to the dose, even at very low levels of exposure. Based on this assumption and on the scanty available data, it may be calculated that exposure at the rate of 0.1 *r* in 30 years (the estimated gamma ray fallout dose rate) would increase the annual leukemia incidence in the population of the United States by 36 cases.

It has been suggested that strontium 90 in the bone irradiates bone marrow in close proximity to bone and that this might induce leukemia. There is at present no evidence that leukemia can be produced in this way, but the possibility cannot

be excluded. It may be estimated that when the equilibrium concentration of strontium 90 in bone (20 micromicrocuries per gram of calcium, stated in sec. 3) is reached, the dose rate to adjacent bone marrow will be about 0.03 rad per year. On the assumptions made above (and the inference that only leukemia of bone marrow origin could possibly be produced in this way), it may be estimated that at worst leukemia deaths in the population of the United States would be increased by about 160 per year, some years after the above-mentioned equilibrium concentration of strontium 90 had been reached. According to these calculations, the total possible increase in the leukemia deaths in the United States attributable to external and internal radiation from the estimated equilibrium amount of fallout would be 196 per year. This amounts to 1.7 percent of the present annual leukemia deaths (11,400).

It should be noted that any analysis or interpretation of the effect of fallout on the incidence of leukemia must take into account the fact that the *reported* death rates from leukemia in this country rose sharply between 1930 and 1954, as contrasted to a much more gradual increase between 1910 and 1930. Whether this increase represents an absolute increased incidence is less clear, for during these years there have been great changes in the span of coverage of reporting, in listings of cause of death, and in diagnostic criteria. Furthermore, analyses of 1954 figures demonstrate a striking age distribution with a peak during the first 5 years of life, a leveling off until the fifth decade, followed by a precipitous increase into the eighth decade. It should also be borne in mind that many drugs and industrial chemicals, by injuring hematopoietic organs, could be capable of inducing leukemia.

d) *Bone Tumors.* The induction of bone tumors in humans by ingested radium has been established clearly. Radiographic studies of the bones of living persons, apparently in good health, with long-term radium body burdens of the order of 1 microcurie, show small regions of damaged bone in different parts of the skeleton. Presumably these nonmalignant bone lesions are the result of local concentrations of radium. It is surmised that when bone sarcoma develops, it originates in one of these regions. This is in accord with the well-known fact that cancer of the skin in grossly overexposed radiologists develops in localized areas showing persistent damage. It seems that the existence of a damaged region of tissue is a usual prerequisite for the development of cancer. In the case of radiation-induced cancer of the skin in radiologists, it is known that to produce the preliminary permanently damaged skin areas, large doses of radiation are required (certainly more than 1,000 *r*). Because of the high energy and the short range of the alpha rays of radium and its disintegration products, small local concentrations of radium are sufficient to deliver very large doses to the surrounding tissue in the course of the long latent period before bone sarcoma develops (15 or more years). It is well known that in general the smaller the radium body burden the longer it takes for cancer to develop. Among the radium dial painters, those who swallowed large amounts of material died within a few years of anemia, hemorrhages, and infections, rather than cancer.

A radium body burden of 1 microcurie produces a bone dose rate of about 40 rads per year (depending somewhat on the proportion of radon decaying in situ)—*if it is uniformly distributed throughout the skeleton.* If, as is likely, there are local concentrations of radium, the dose rate in these regions can be much higher. The smallest body burdens of *pure* radium that is known to have caused bone sarcoma in 24 years is 3.6 microcuries at the time the tumor developed. Since a considerable fraction of the initial body burden was eliminated in this time, the bone dose in this case, *for a uniform distribution,* was nearly 6,000 rads.

In X-ray therapy it is often necessary to irradiate bone in order to deliver the desired dose to a deep-seated lesion. Occasionally tumors have appeared in such irradiated bones after a long latent period. The bone doses have always been large—the minimum being 1,500 *r* in one of the reported cases.

The fallout equilibrium concentration of strontium 90 in human bones of 20 micromicrocuries per gram of calcium—when it is attained—will deliver 0.056 rad per year, on the basis of a uniform skeletal distribution. The equilibrium concentration will obtain in individuals who have been exposed to fallout throughout life. Therefore, the strontium 90 has been assimilated gradually and, since chemically strontium is very similar to calcium, a uniform distribution throughout the skeleton may well be expected. Certainly it should be more uniform than in the case of the radium dial painters who started ingesting the material in adult life. Furthermore, a spotty distribution of the strontium 90 itself would produce a more uniform dose distribution in bone than in the case of radium, because of the much greater ranges of the beta rays of strontium 90 plus yttrium 90 as compared to the ranges of the alpha rays of radium. Accordingly, much higher dose rates than 0.056 rad per year, due to local strontium 90 concentrations, are very unlikely. It is difficult to see, therefore, how local doses of the magnitude required to produce bone damage, and subsequently bone sarcoma, can possibly be reached in a lifetime. In 70 years the accumulated uniform distribution dose would be 3.9 rads, without allowing for radioactive decay of the more or less "fixed" strontium 90 initially incorporated in the skeleton, which would make it even lower. Any reasonable allowance for nonuniform distribution cannot make the dose large.

If the mechanism for the induction of bone sarcoma is as outlined above, it is evident that proportional extrapolation to very low dose rates is hardly justified. Therefore, a dose rate in bone of 0.056 rad per year, which is about one-half of the natural background level, may well be expected to produce no bone sarcomas at all. On any plausible basis, even the absolute number for the population of the United States cannot be large, since the annual deaths from bone sarcoma are approximately 2,000.

e) *Life Shortening.* A statistical shortening of life has been obtained experimentally by exposing animals continuously or intermittently throughout life at daily rates in excess of 0.5 *r*. In some experiments exposure at the rate of 0.1 *r* per day seemed to prolong the average life. Since the number of animals used in these experiments has been too small to produce statistically significant results at this radiation level, no definite conclusions can be drawn from low-level exposure experiments. Estimates of the life shortening in man quoted in the literature, ranging from 5 to 20 days per roentgen, have been derived from theoretical relationships between dose and life shortening based on animal experiments in which relatively large doses or dose rates were used. These estimates give a greater appearance of accuracy than is warranted by the basic data.

A recent survey conducted by Shields Warren shows that the average age at death for radiologists who died between 1930 and 1954 was 60.5 years as compared to 65.7 years for other physicians having no known contact with radiation. The doses received by these radiologists in the exercise of their profession are estimated to vary from rather low values to about 1,000 *r*. Dublin and Spiegelman, on the basis of a shorter period of study (1933 to 1942), found no life shortening for radiologists. Hardin B. Jones, in a study of a group of radiologists and on the basis of a reanalysis of certain of Warren's data, finds that they have the same death rate risk as the general population at ages under 60, but over 60 the death rate is about twice as high as expected.

It should be noted that the higher incidence of leukemia among radiologists cannot lower appreciably the average age at death, because the disease is very rare, even among radiologists. The question is whether the not inconsiderable doses of radiation formerly accumulated by radiologists over a long period of time may have caused an acceleration of the aging process. A categorical answer to this question cannot be given at this time, but it may be assumed that the higher levels of radiation to which some of these radiologists were exposed may have caused an appreciable life shortening in a statistical sense. The estimated accumulated dose from fallout gamma rays (0.1 *r* in 30 years) is so small in comparison to the occupational exposure of radiologists in the past 50 years, that this effect, if it exists at all at very low dose rates, can only be extremely small—a few days at worst.

5. *Appraisal of the Acceptability of Possible Damage.* If extrapolation to very low exposure levels is justified, it may be expected that some damage, however slight, will be produced by radioactive fallout in the present and future generations. Estimates of the number of individuals in the world's population who may show some damage in the course of time (many generations in the case of genetic damage) are large in absolute terms. Whether they are considered to be small in comparison to the unavoidable damage caused by spontaneous mutations and the presently accepted hazards of life, depends on the ethical and emotional makeup of the individual and, therefore, there can be honest differences of opinion. It is a fact, however, that we accept death and maiming through preventable accidents. (Most automobile accidents could be prevented by reducing the speed limit to 10 miles per hour.) We discount the harm by considering the advantages. Also, in the case of most accidents the individual at least believes he can exercise some control. The fallout hazard is essentially beyond the control of the individual and involves, also, his descendants. This has a strong emotional impact.

Ionizing radiation has played an important part in many of the scientific and technological advances of this century. It is also an unavoidable byproduct of the "atomic age." A certain amount of exposure, even under the most rigid controls, is inevitable. Thus, diagnosis of disease by means of X-rays necessarily involves irradiation of the body region under examination, even when the most stringent protective measures are employed. The NAS Committee on Genetic Effects of Atomic Radiation, recognizing the benefits as well as the harm that might result from the ever-increasing production and use of ionizing radiation in our civilization, has recommended "that the general public of the United States be protected, by whatsoever controls may prove necessary, from receiving a total reproductive lifetime dose (conception to age 30) of more than 10 roentgens of manmade radiation to the reproductive cells." The same committee emphasizes that this is a *reasonable* but not a *harmless* average dose for the whole population, insofar as genetic effects are concerned. This means, in effect, that if this average 30-year dose is not exceeded, the presently predictable genetic damage to the population is expected to be tolerable.

The same committee estimated that a dose of 10 *r* to the population of the United States would give rise to some 50,000 new instances of tangible inherited defects in the first generation and about 500,000 per generation ultimately, assuming an indefinite continuation of the 10 *r* increased rate and also assuming a stationary population. The total number of mutants that would be induced by this radiation dose to the population of the United States and passed on to the next total generation was estimated to be roughly 5 million by six geneticists on the NAS Committee. These increases in the number of children with tangible

inherited defects and the total number of mutants in the United States, therefore, are considered tolerable by present genetic standards. By the same token, the genetic damage that may be expected from the estimated gamma ray fallout dose of 0.1 *r* in 30 years—which is 100 times less—must be considered negligible.

The significance of possible somatic injury from fallout may be appraised similarly by reference to the "genetic dose" of 10 *r* in 30 years. Since fallout gamma rays reach the body essentially from all directions, the dose to the gonads is considerably less than that to the surface of the body. It may be assumed, therefore, that in a fallout field that would give a gonad dose of 10 *r* of penetrating gamma radiation in 30 years, this is also the approximate dose in rads received by internal organs such as the bloodforming organs and the skeleton. Consequently, the genetically acceptable dose corresponds to a dose rate in these organs of 0.33 rad per year. The estimated bone marrow dose rate from a strontium 90 concentration in bone of 20 micromicrocuries per gram of calcium is 0.03 rad per year and that in bone is 0.056 rad per year. Hence the possible increase in the leukemia death rate attributable to strontium 90 in the skeleton would be 9 percent of that resulting from the genetically acceptable dose rate. The corresponding figure for the possible increase in the death rate from bone sarcoma is 17 percent. Hence, by the standards used by the Genetics Committee in arriving at the average population gonad dose of 10 *r* in 30 years, the possible increase in death rate from leukemia or bone sarcoma attributable to the estimated fallout is well below the acceptable degree of damage. The same reasoning and conclusion apply to any other possible effect of fallout radiation of comparable dose rate in any organ, since the 10 *r* in 30 years was set for external radiation that penetrates the whole body. (The conclusion remains unchanged even when the medical X-ray dose to the population is subtracted from the 10 *r* dose in 30 years.)

It will be seen that this appraisal of the tolerability of possible genetic and somatic damage does not involve the estimation of the number of possibly injured individuals or the degree of damage. The appraisal is made on the basis of dose rates which are more readily determinable. The usual assumption that the effect is proportional to the dose rate was made in calculating the 9 percent and 17 percent figures given above. However, this is not essential because, if the dose rate in the tissue of interest is considerably lower than 0.33 rad per year, the effect is bound to be considerably less than that attributable in 10 *r* in 30 years. Nevertheless, it was thought desirable to include in this review the numerical estimates given in the preceding sections.

6. *General Considerations and Recommendations.* As previously stated, the setting of an upper limit of 10 *r* in 30 years for the genetic dose to the population of the United States involved an estimated balance between possible harm and possible benefit. Since it must be assumed that some harm will result from fallout radiation, the question naturally arises as to whether this is justified by the benefit, even if it be well within recommended limits. In this country a large fraction of the annual budget is for military expenditures—which in a democracy gives a measure of the citizens' concern about the safety of their country. It seems obvious, therefore, that if we wish to maintain a first-class military organization for the safety of the country, we must at least keep abreast of new weapons developments. No such developments can be carried out successfully without tests. (Obviously, it would be impossible for the Air Force to develop better military planes without ever testing them in flight.) Therefore, in terms of national security, necessary tests of nuclear weapons are justified.

There are, however, other considerations that must be weighed carefully by those responsible for our national policy.

Radioactive fallout from our tests spreads all over the world. Similarly, tests made by others affect us. Other countries may want to develop nuclear weapons later. In time, the situation may well become serious. Estimates of ultimate damage to the world's present and future population, expressed in absolute terms, are large and impress many people. Judging from discussions in the public press, it is not generally realized that the estimated damage is well within tolerable limits, applicable to radiation exposure of the whole population in its normal peacetime activities. The question arises in the minds of many thoughtful persons whether the number and power of bombs exploded in the tests are being kept at the minimum consistent with scientific and military requirements. In view of the adverse repercussions caused by the testing of nuclear weapons, the committee recommends that tests be held to a minimum consistent with scientific and military requirements and that appropriate steps be taken to correct the present status of confusion on the part of the public.

Respectfully submitted by the Advisory Committee on Biology and Medicine.

JOHN C. BUGHER
CHARLES H. BURNETT
SIMEON T. CANTRIL
H. BENTLEY GLASS
SHIELDS WARREN
G. FAILLA, *Chairman*

Appendix 14

Commission's Financial Report for Fiscal Year 1957

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON 25, D. C.

October 7, 1957

MEMORANDUM TO THE COMMISSIONERS

Transmitted herewith is the unclassified financial report of the Atomic Energy Commission for fiscal year 1957. It contains financial statements which set forth the financial position of AEC at June 30, 1957, the results of operations for fiscal year 1957, and other information of general use to the Commission.

The financial statements are similar to those of industrial firms in form and content and are derived from the accounts maintained directly by AEC and cost-type contractors who have established cost and accounting systems for their AEC operations. The accounts are audited by the AEC audit staff.

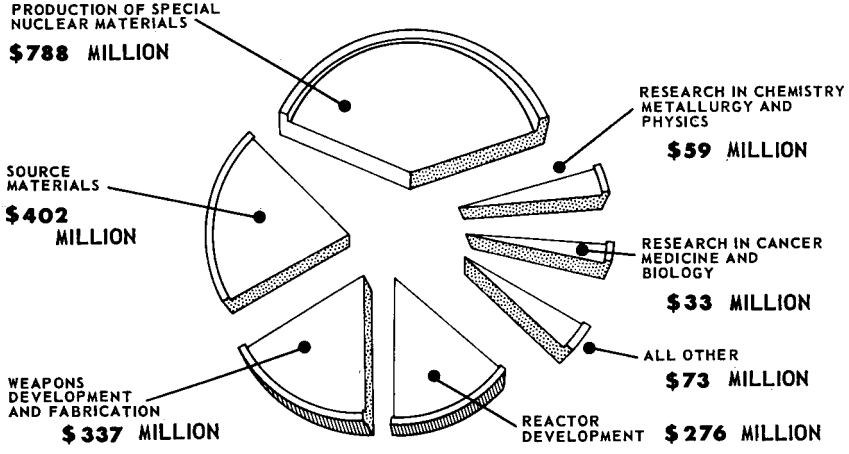
Consistent with accepted commercial accounting principles, costs and income are recorded on an accrual basis and financial control is maintained over all inventories and other assets of the Commission.

Don S. Burrows,
Controller.

Honorable Lewis L. Strauss, *Chairman.*
Commissioner John F. Floberg.
Commissioner John S. Graham.
Commissioner Willard F. Libby.
Commissioner Harold S. Vance.

COST OF OPERATIONS FISCAL YEAR 1957

$2 BILLION



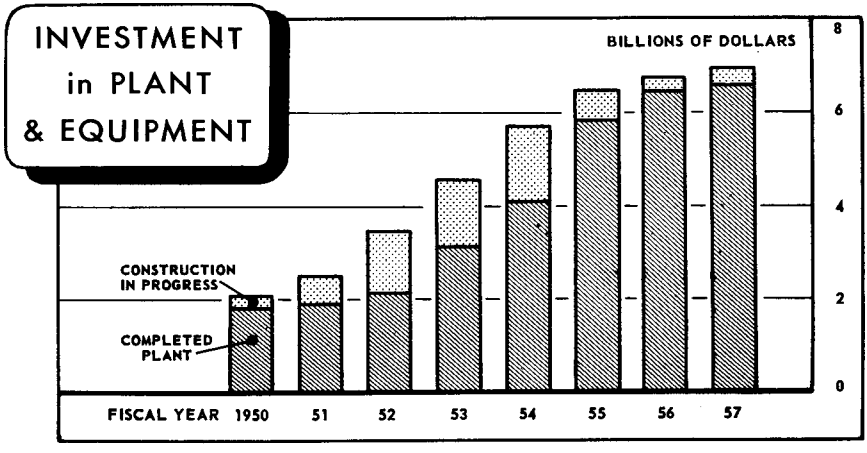
HIGHLIGHTS

	Fiscal year	
	1957	*1956*
Cost per pound of uranium concentrates delivered from all sources decreased 3 percent	$11.00 lb.	$11.35 lb.
Cost per pound of uranium concentrates delivered from domestic sources decreased 10 percent	$10.80 lb.	$11.96 lb.
Cost per pound of uranium concentrates delivered from other countries increased 2 percent	$11.18 lb.	$10.94 lb.
Source materials delivered to AEC increased 43 percent	$402 million.	$281 million.
Manufacturing and processing of special nuclear materials increased 8 percent	$788 million.	$729 million.
Weapons design, development, and fabrication increased 20 percent	$337 million.	$281 million.
Reactor research and development increased 62 percent	$276 million.	$170 million.
Research in chemistry, metallurgy, and physics increased 16 percent	$59 million.	$51 million.
Research in cancer, medicine, and biology increased 10 percent	$33 million.	$30 million.

Plant

The investment in production plants, research laboratories, and other facilities owned by AEC increased to $6.9 billion at June 30,

1957, from $6.7 billion at the beginning of the year. The growth in AEC-owned facilities is shown in the following chart:



Plant completed during the year includes production reactor facilities at Richland, Wash., and Aiken, S. C., of $69 million; gaseous diffusion facilities at Oak Ridge, Tenn., Paducah, Ky., and Portsmouth, Ohio, of $47 million; feed material facilities at Weldon Spring, Mo., and Fernald, Ohio, of $45 million; various research facilities of $46 million and weapons production facilities of $43 million.

These additions were partially offset by plant retirements of $87 million, including $21 million for the prototype of the sodium reactor at West Milton, N. Y., and $33 million of production facilities at Oak Ridge, Tenn., which were retired because of obsolescence.

Changes in investment in plant and equipment during the fiscal year were as follows:

CHANGES IN INVESTMENT IN PLANT AND EQUIPMENT

[In thousands]

	Completed plant	*Construction in progress*	*Total*
Investment—June 30, 1956	$6, 466, 037	$247, 024	$6, 713, 061
Construction and equipment costs	—	317, 022	317, 022
Facilities completed during the year	252, 829	(252, 829)	—
Plant retirements	(86, 700)	—	(86, 700)
Sale of community facilities	(32, 269)	—	(32, 269)
Transfers to other Federal agencies	(3, 218)	—	(3, 218)
Investment—June 30, 1957	6, 596, 679	311, 217	6, 907, 896

The following table shows the investment in plant and equipment by types of facilities:

450234—58——28

INVESTMENT IN PLANT AND EQUIPMENT
June 30, 1957
(*in thousands*)

	Completed plant	*Construction in progress*	*Total*	*Percent of total*
Production facilities:				
Raw materials	$7,066	$362	$7,428	0.1
Feed materials	233,911	21,885	255,796	3.7
Gaseous diffusion plants	2,318,223	8,428	2,326,651	33.7
Production reactors and separation areas	1,560,729	68,029	1,628,758	23.6
Weapons production and storage	709,831	39,058	748,889	10.8
Heavy water	262,668	1,349	264,017	3.8
Other production facilities	340,913	13,856	354,769	5.2
Total production	5,433,341	152,967	5,586,308	80.9
Research facilities:				
Laboratories	541,378	24,254	565,632	8.2
Reactors	84,092	94,765	178,857	2.6
Accelerators	60,168	13,428	73,596	1.1
Other	66,118	11,855	77,973	1.1
Total research	751,756	144,302	896,058	13.0
Communities	267,293	4,070	271,363	3.9
Other	144,289	9,878	154,167	2.2
Total	6,596,679	311,217	6,907,896	100.0

Inventories

The inventories shown below increased to $1.7 billion at June 30, 1957, from $1.6 billion at June 30, 1956. The increase of $95 million in production in process is largely the result of plant expansion. Production inventories in process include uranium, thorium, plutonium, and other products in the process of refinement and manufacture of special nuclear materials and weapons. The amount of source and special nuclear materials diverted from the production chain for use in research and development operations increased $37 million during the year. The major portion of this increase was fuel for experimental reactors at research installations. The lease of uranium to one commercial fabricator for the manufacture of fuel elements accounted for the major portion of the $9 million increase in source and special nuclear materials leased. Special reactor material increased $33 million largely as a result of increased inventories of heavy water produced in anticipation of future requirements.

UNITED STATES ATOMIC ENERGY COMMISSION SUMMARY OF FINANCIAL DATA

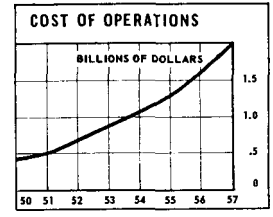
(in thousands of dollars)

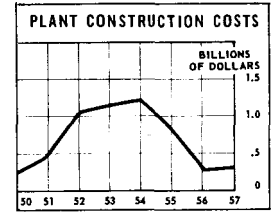
	1957	1956	1955	1954	1953	1952	1951	1950
Cost of operations [1]	$1,968,157	$1,607,973	$1,289,535	$1,039,178	$ 904,596	$ 684,181	$ 494,638	$ 414,766
Procurement and production of nuclear materials	1,190,030	1,009,918	782,031	552,528	400,408	278,256	188,312	168,544
Weapons development and fabrication	337,183	280,765	259,706	251,066	257,888	229,228	163,644	111,970
Development of nuclear reactors	276,164	169,895	119,404	99,715	104,492	64,884	44,472	31,530
Research in chemistry, metallurgy and physics	58,860	51,282	43,898	43,149	42,452	36,147	31,595	31,197
Research in cancer, medicine and biology	33,148	30,126	29,144	27,237	26,728	25,234	21,866	18,673
Community operations—net	8,897	8,954	10,321	11,822	15,157	16,363	17,322	19,895
Administrative expenses	38,499	38,195	34,027	34,671	35,514	31,432	24,541	22,868
Other expenses and income—net	25,376	18,838	11,004	18,990	21,957	2,637	2,886	10,089
Plant construction and equipment costs incurred during the year	$ 317,022	$ 301,682	$ 842,504	$1,215,141	$1,125,579	$1,082,174	$ 459,192	$ 256,126
Total AEC assets, excluding inventories of certain products, at June 30	$8,717,625	$8,602,519	$9,139,219	$8,951,800	$8,577,007	$4,692,584	$3,680,333	$2,216,487
Completed plant at June 30	$6,596,679	$6,466,037	$5,858,349	$4,090,271	$3,149,513	$2,133,875	$1,924,812	$1,809,645
Production plants	5,433,341	5,250,134	4,654,408	2,957,784	2,118,137	1,327,335	1,287,447	1,251,022
Research facilities	751,756	716,110	698,449	616,548	548,009	338,836	233,702	184,393
Communities	267,293	299,292	299,290	300,248	298,454	287,999	281,727	261,831
Other	144,289	200,501	206,202	215,691	184,913	179,705	121,936	112,399
Plant construction in progress at June 30	$ 311,217	$ 247,024	$ 628,952	$1,615,134	$1,429,576	$1,363,082	$ 591,202	$ 294,788
Appropriations received	$1,898,700	$ 834,227	$1,209,860	$1,042,492	$4,136,476	$1,605,756	$2,032,143	$ 702,931
Operations [2]	1,740,400	[3] 1,146,400	1,098,978	886,483	808,935	—	—	—
Plant acquisition and construction [2]	158,300	[3] (312,173)	110,882	156,009	3,327,541	—	—	—
Number of employees at June 30	119,368	110,143	112,555	141,949	148,799	149,371	99,126	63,739
AEC employees	6,823	6,583	6,013	6,123	6,894	6,662	5,646	4,941
Operating contractor employees	98,176	90,238	82,936	73,312	71,775	58,101	47,745	39,095
Construction contractor employees	14,369	13,322	23,606	62,514	70,130	84,608	45,735	19,703

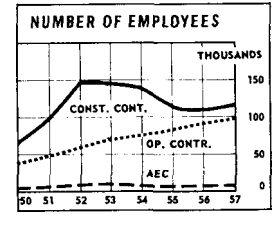
[1] Includes depreciation.

[2] In fiscal year 1957 funds for equipment not included in construction are included in appropriations for operations. In 1956 and prior years such funds are included in appropriations for plant acquisition and construction.

[3] Includes transfer to operations of $571 million appropriated in prior years as plant and equipment funds.







	June 30, 1957	*June 30, 1956* (*in thousands*)	*Increase*
Production inventories in process	$1, 329, 172	$1, 234, 247	$94, 925
Source and special nuclear research material	227, 205	189, 863	37, 342
Source and special nuclear materials leased	9, 429	666	8, 763
Special reactor material	79, 770	47, 066	32, 704
Other special materials	18, 573	18, 391	182
Stores	84, 901	83, 384	1, 517
Total	1, 749, 050	1, 573, 617	175, 433

SALES OF MATERIALS AND SERVICES

Sale and Lease of Source and Special Nuclear Materials

President Eisenhower announced on July 3, 1957, that an additional 59,800 kilograms of uranium 235 would be furnished for peaceful applications of atomic energy. This, together with amounts previously announced, brought to 50,000 kilograms the amount designated for domestic users, and to 50,000 kilograms the amount designated for foreign users. At current prices established by the Commission, the value of this 100,000 kilograms of uranium 235 is $1.7 billion. Through June 30, 1957, applications have been approved and commitments made to furnish domestic users $300 million worth of source and special nuclear materials over the next 40 years. The Commission also may be called upon to sell or lease up to $135 million worth of reactor fuel under its offer to the International Atomic Energy Agency and under the bilateral agreements signed with foreign nations.

The Atomic Energy Act of 1954 requires AEC to retain title to all special nuclear material in the United States. The AEC may sell special nuclear materials to other countries at established prices.

Licensed users of special nuclear materials are required to pay a use charge of 4 percent per annum, the established price for material consumed and the cost of reprocessing used materials. As an incentive toward the development of a nuclear power industry, contracts under the power reactor demonstration program have waived the use charge for a period of 5 years. Similarly, the use charge for source and special nuclear materials furnished approved educational institutions for research and educational purposes has been waived for the period through June 30, 1961.

The cost of material leased to licensed domestic users and foreign nations at June 30, 1957, was $9.4 million. A major portion of this material was with industrial organizations engaged in fuel element fabrication. Income from use charges for leased materials totaled $238,000 through June 30, 1957. The aggregate amount of use charges waived through June 30, 1957 totaled $24,000.

Sales of source materials in fiscal years 1957 and 1956 were as follows:

	Fiscal year 1957	*Fiscal year 1956*
	(in thousands)	
Commercial enterprises	$341	$652
Other countries	1,853	2,642
Other Federal agencies	4	1
Total	2,198	3,295

Nuclear materials are also committed to the military services for propulsion of submarines and other vessels, for generation of electric power, and for other purposes. AEC provides the military services with the initial fuel requirements for these purposes without charge and is reimbursed for fuel consumed and for the cost of reprocessing spent fuel cores.

Sale of Heavy Water and Other Special Materials

Sales of heavy water to other countries and to domestic organizations for use as a moderator and coolant in reactors and for other research and development purposes were $4.4 million in fiscal year 1957. The AEC established sales price for heavy water is $28 a pound. Sales during fiscal years 1957 and 1956 were as follows:

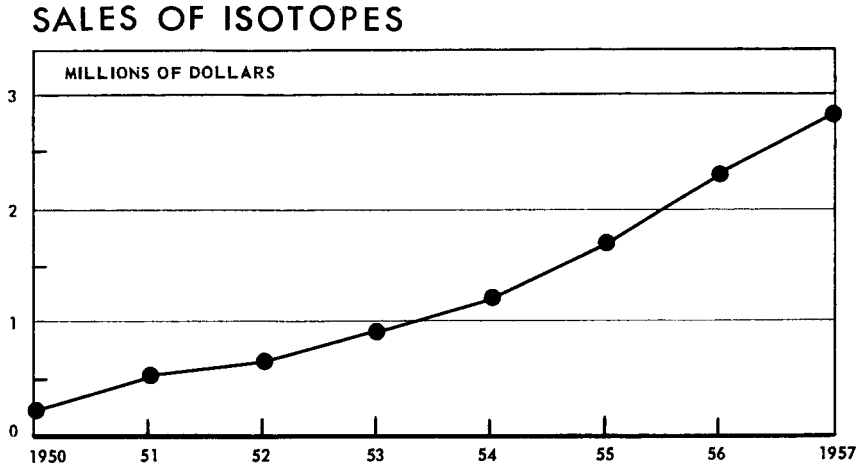
	Fiscal year 1957	*Fiscal year 1956*
	(in thousands)	
Canada	$2,819	$1,694
France	928	309
United Kingdom	620	1,850
Belgium	14	—
India	—	1,177
Domestic organizations	7	29
Total	4,388	5,059

Sales of other special products for use in reactors, for research and development, and for educational purposes in fiscal year 1957 totaled $1.0 million.

Sales of Isotopes and Irradiation Services

Sales of radioactive and stable isotopes continued to increase in fiscal year 1957 as they were put to greater use in industry, medicine, and research. Sales in fiscal year 1957 totaled $2.9 million as compared with $2.3 million in fiscal year 1956. While more than 86 kinds of radioisotopes are being distributed by AEC, one item (cobalt 60) represented 39 percent of the dollar sales in fiscal year 1957.

The Commission distributes radioisotopes at the National Reactor Testing Station, Idaho Falls, Idaho; the Oak Ridge National Labora-



tory, Oak Ridge, Tenn.; Argonne National Laboratory, Lemont, Ill.; Brookhaven National Laboratory, Long Island, N. Y.; and at Mound Laboratory, Miamisburg, Ohio. In addition to the radioisotopes produced in reactors, the Commission recovers some radioisotopes from spent fuel elements discharged from production reactors. The chart above shows radioisotope and stable isotope sales for fiscal years 1950 through 1957.

Industrial, educational, and research organizations have various materials and articles such as chemicals, seeds, foods, gears, piston rings, etc., irradiated in AEC reactors. These irradiation services are performed at the Oak Ridge National Laboratory, National Reactor Testing Station, Brookhaven National Laboratory, and Argonne National Laboratory. In fiscal year 1957, 2,531 irradiation services of this type were performed, and AEC charged $284,000 for processing, handling, and irradiation of the materials and articles. The Engineering Test Reactor at Idaho Falls, Idaho, a new facility capable of handling larger articles than can be irradiated in other reactors, achieved criticality in September 1957.

Other Services

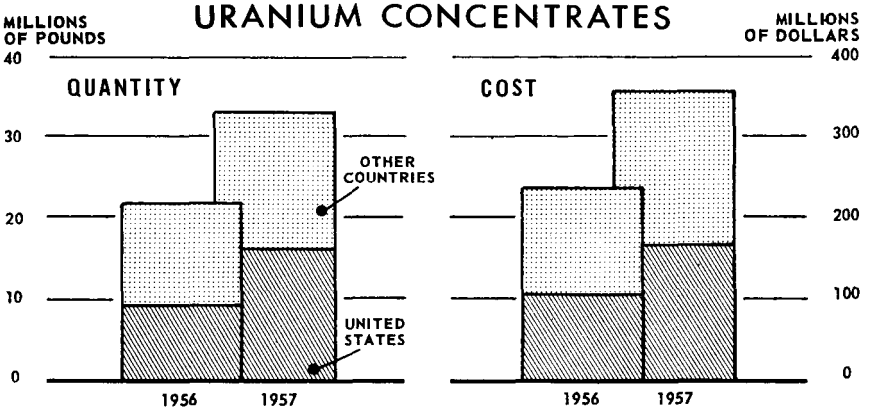
Access to certain classified information is granted to private organizations and individuals who have a need for such information. To obtain classified information personnel of access permit holders are required to obtain appropriate security clearances. No charge is made by the Commission for the first 25 clearances requested by the holder of an access permit. In fiscal year 1957, AEC collected $1.3 million for security clearances requested by access permit holders.

Charges for use of AEC-owned facilities, special fabrications, and miscellaneous other services for others totaled $780,000 in fiscal year 1957.

PROCUREMENT OF SOURCE MATERIALS

Uranium and other source materials procured in fiscal year 1957 cost $402 million as compared with $281 million in 1956.

The quantity of uranium concentrates procured in fiscal year 1957 increased 54 percent over 1956. This represented an increase of 80 percent in concentrates procured from domestic sources and an increase of 37 percent in concentrates purchased from sources outside the United States. The increased deliveries from domestic sources resulted from completion by private enterprise of additional ore-processing facilities. The chart below shows a comparison of the quantity and cost of concentrates obtained from domestic sources and other countries during fiscal years 1956 and 1957.



	1956	1957		1956	1957
	12,512,000	17,151,000	OTHER COUNTRIES	$136,933,000	$191,683,000
	8,470,000	15,204,000	UNITED STATES	$101,282,000	$164,182,000
	20,982,000	32,355,000	TOTAL	$238,215,000	$355,865,000

The average unit cost of uranium concentrates delivered during fiscal years 1956 and 1957 is shown below. These costs include bonus payments for initial production of uranium ore. They do not include AEC exploration costs.

AVERAGE COST PER POUND OF URANIUM CONCENTRATES

	Fiscal year 1956	*Fiscal year 1957*	*Change (percent)*
From domestic sources	$11. 96	$10. 80	10 decrease.
From other countries	10. 94	11. 18	2 increase.
From all sources	11. 35	11. 00	3 decrease.

AEC exploration costs continued to decrease as participation by private enterprise expanded the uranium industry. Exploration

costs were $7.4 million in fiscal year 1957 and $9.4 million in 1956. Bonus payments for initial production of uranium ore were $3.0 million in fiscal year 1957 and $2.2 million in 1956. Bonus payments have totaled $10.5 million since the beginning of the program in 1952.

Private industrial organizations own all the uranium ore milling plants in the United States with the exception of the AEC-owned mill at Monticello, Utah. The magnitude of the privately-owned uranium ore milling industry is shown below.

URANIUM ORE PROCESSING MILLS

Company	*Location*	*Tons of ore per day*	*Investment (in thousands)*
MILLS IN OPERATION AT JUNE 30, 1957:			
The Anaconda Co	Grants, N. Mex	3,000	$19,358
Uranium Reduction Co	Moab, Utah	1,500	8,250
Union Carbide Nuclear Co	Uravan, Colo	1,100	5,000
Rare Metals Corporation of America.	Tuba City, Ariz	250	3,600
Kerr-McGee Oil Industries, Inc.	Shiprock, N. Mex	500	3,161
Climax Uranium Co	Grand Junction, Colo	350	3,088
Vitro Corporation of America	Salt Lake City, Utah	550	5,500
Vanadium Corporation of America.	Durango, Colo	430	813
Mines Development Co	Edgemont, S. Dak	300	1,900
Union Carbide Nuclear Co	Rifle, Colo	280	1,600
Vanadium Corporation of America.	Naturita, Colo	350	1,000
In operation		8,610	53,270
MILLS UNDER CONSTRUCTION AT JUNE 30, 1957:			
Kermac Nuclear Fuels Corp	Grants, N. Mex	3,300	16,000
Homestake-Sapin Partners	Grants, N. Mex	1,500	9,000
Texas-Zinc Minerals Corp	Mexican Hat, Utah	775	7,000
Lucky Mc Uranium Corp	Fremont Co., Wyo	750	6,900
Union Carbide Nuclear Co	Rifle, Colo	1,000	[1] 8,500
Homestake-New Mexico Partners.	Grants, N. Mex	750	5,325
Western Nuclear Corp	Split Rock, Wyo	400	3,600
Dawn Mining Co	Ford, Wash	400	3,100
Trace Elements Corp	Maybell, Colo	300	2,208
Gunnison Mining Co	Gunnison, Colo	200	2,025
Under construction		9,375	[2] 63,658
Total		17,985	116,928

[1] To replace plant now in operation.
[2] Estimated cost of mills.

The AEC owns the ore-processing mill at Monticello, Utah; handling, storage, sampling, and assaying facilities at Grand Junction, Colo.; and ore-buying stations at Monticello, Utah, Riverton, Wyo., Grants, N. Mex., White Canyon, Utah, Crooks Gap, Wyo., Marysvale, Utah, Edgemont, S. Dak., Moab, Utah, Globe, Ariz., and Tuba City, Ariz. The investment in these facilities was $6.8 million at June 30, 1957. AEC has discontinued buying ore at the last seven stations listed. The inventory of uranium ore stored at the ore-buying stations totaled $42 million at June 30, 1957. Contracts have been executed with operators of ore-processing mills committing $37.7 million of the inventory of uranium ore.

Under provisions of section 66 of the Atomic Energy Act of 1954, AEC has long-term contracts for the delivery of domestic uranium concentrates through March 31, 1962, and has guaranteed minimum prices for uranium ores through March 31, 1962, and for concentrates for the period April 1, 1962, to December 31, 1966. The guaranteed price for U_3O_8 concentrates delivered after March 31, 1962, is $8 a pound, subject to certain specified limitations. The Commission also has long-term commitments for the purchase of concentrates from Canadian and overseas sources. The aggregate dollar amount of AEC's commitments for purchase of source materials subsequent to June 30, 1957, is estimated at $5 billion. Appropriations are requested each year in the amount of estimated deliveries to be made during the year.

PRODUCTION OF NUCLEAR MATERIALS

Feed Materials

AEC plants for the production of feed materials for reactor and gaseous diffusion plant operations are located at St. Louis, Mo., Weldon Spring, Mo., and Fernald, Ohio. The St. Louis facility and the Weldon Spring facility, operated by Mallinckrodt Chemical Works, produce high purity uranium metal from uranium concentrates. The Fernald facility, operated by National Lead Company of Ohio, performs the same operations as the St. Louis plant plus the rolling and machining of fuels for production reactor operations. The Hanford facilities at Richland, Wash., and Savannah River facilities at Aiken, S. C., are used for the recovery and processing of feed materials. Plants for the production of uranium hexafluoride from high purity uranium oxide are located at Oak Ridge, Tenn., and Paducah, Ky., and are operated by Union Carbide Nuclear Co. An additional plant for the production of uranium hexafluoride is under construction at Portsmouth, Ohio, and will be operated by Goodyear

Atomic Corp. The investment in plant and equipment used to produce feed materials is shown in the following table:

	Completed plant at June 30		Construction work in progress at June 30	
	1957	1956	1957	1956
	(in millions)			
Fernald, Ohio	$106.0	$91.8	$1.1	$11.8
Richland, Wash	35.4	35.7	—	1.6
Weldon Spring, Mo	29.8	—	14.1	23.6
Paducah, Ky	25.2	20.8	.5	3.5
St. Louis, Mo	21.3	20.3	.4	—
Oak Ridge, Tenn	10.5	11.4	.5	1.6
Aiken, S. C	5.7	5.7	—	—
Portsmouth, Ohio	—	—	5.3	1.6
Total	233.9	185.7	21.9	43.7

Enriched Uranium

Enriched uranium is produced in the gaseous diffusion plants at Oak Ridge, Tenn., and Paducah, Ky., operated by Union Carbide Nuclear Co., and at Portsmouth, Ohio, operated by Goodyear Atomic Corp. The AEC investment in gaseous diffusion facilities at these sites is shown below:

	Completed plant at June 30		Construction work in progress at June 30	
	1957	1956	1957	1956
	(in millions)			
Oak Ridge, Tenn	$835.7	$828.4	$2.9	$3.3
Paducah, Ky	741.7	733.2	.8	6.5
Portsmouth, Ohio	740.8	722.6	4.7	19.8
Total	2,318.2	2,284.2	8.4	29.6

Plutonium and Other Reactor Products

Plutonium and other reactor products are produced at the Hanford Works operated by General Electric Co., and at the Savannah River plant, operated by E. I. du Pont de Nemours & Co., Inc. The products of these facilities are principally for weapons use. The facilities at these locations include reactors and plants for chemical separation and processing of products. Shown below is the investment in plant and equipment for these facilities:

	Completed plant at June 30		Construction work in progress at June 30	
	1957	1956	1957	1956
	(in millions)			
Savannah River Plant	$838.2	$829.5	$50.6	$30.5
Hanford Works	722.5	708.6	17.4	32.7
Total	1,560.7	1,538.1	68.0	63.2

HEAVY WATER PRODUCTION

The AEC has two plants for the production of heavy water by the dual-temperature chemical exchange process. The plants were constructed during the period 1950 through 1955 to supply the initial heavy-water requirements for the Savannah River production reactors and to provide an economical source of heavy water for research and reactor use in the United States The construction cost of the plant at Dana, Ind., was $100 million, and the cost of the plant at Savannah River was $164 million. Both plants were constructed and operated for AEC by the E. I. du Pont de Nemours & Co., Inc. By the latter part of fiscal year 1957 the inventory of heavy water, together with the production from the Savannah River plant, was sufficient for both domestic and foreign requirements in the foreseeable future, and the Dana, Ind., plant was placed in standby. After the plant was placed in standby the staff was reduced to 12 maintenance employees. Approximately 900 employees were required when the Dana plant was in operation.

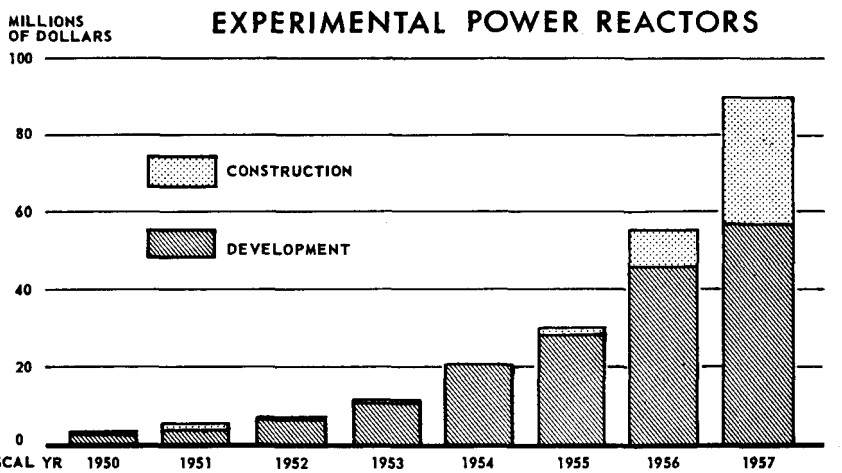
WEAPONS DEVELOPMENT AND FABRICATION

During fiscal year 1957, the costs of manufacturing weapons, the development, design, and testing of new types of weapons, and the maintenance of stockpiled weapons in a state of constant readiness increased to $337 million from $281 million in 1956.

These amounts exclude the cost of source and special nuclear materials contained in weapons components or consumed in weapons research and tests.

EXPERIMENTAL POWER REACTORS

The AEC is conducting experiments with various reactor systems to provide technical information concerning problems involved in producing economic electric power from nuclear energy. Research and development costs related to these experiments were $56.7 million in fiscal year 1957, an increase of 24 percent over 1956. Construction costs in fiscal year 1957 were $33.3 million as compared with $9.4 million in 1956. The chart on the following page shows costs of the increased effort for research and development and construction of reactors from 1950 through 1957.



EXPERIMENTAL POWER REACTOR DEVELOPMENT AND CONSTRUCTION COSTS

[In millions]

	Research and Development		*Construction*	
	1957	*1956*	*1957*	*1956*
Pressurized water	$14.7	$15.2	$32.3	$7.1
Homogeneous	10.9	10.7	.1	.1
Fast power breeder	6.8	4.7	.3	1.5
Sodium graphite	6.0	5.0	—	—
Boiling water	5.0	4.7	.3	.6
Organic moderated	3.7	.3	.3	.1
Liquid metal fuel	3.9	1.6	—	—
Plutonium recycle	1.4	—	—	—
Pressurized heavy water	.4	—	—	—
Depreciation of facilities	3.6	3.1	—	—
Special nuclear materials consumed	.3	.5	—	—
Total	56.7	45.8	33.3	9.4

The *pressurized water reactor* now under construction at Shippingport, Pa., will be the first reactor in this country to produce large quantities of electric power. The electrical output is estimated at 60,000 kilowatts. The Duquesne Light Co. is building the electric generation portion of the plant and is contributing $5 million to AEC toward the construction of the reactor portion of the plant. The Westinghouse Electric Corp. is building the reactor under a cost-type contract with AEC, and contributed $500,000 to the United States Government for the project. It is estimated that construction of the reactor portion of the plant will cost approximately $55 million, with AEC contributing $50 million. The construction cost of the entire

plant, including fuel element fabrication, is estimated at $72.5 million. The plant is expected to begin producing electric power in fiscal year *1958*. The Duquesne Light Co. will pay AEC for steam supplied to the turbine generator from the nuclear portion of the plant at the rate of 8 mills per kilowatt-hour for the net electrical output of the generator.

The *homogeneous reactor concept* is being developed at Oak Ridge, Tenn., and Los Alamos, N. Mex. The uranyl sulfate approach has been followed at the Oak Ridge National Laboratory with the fabrication of two homogeneous reactor experiments. HRE–1 was completed in 1953 and was dismantled in 1954 after experimental operations. It had a heat output of 1,000 kilowatts and an electrical output of 140 kilowatts. HRE–2 was completed in 1956 and has a heat output of 5,000 kilowatts and an electrical output of 300 kilowatts, limited by the capacity of the generators. The uranyl phosphate approach has been explored by the Los Alamos Scientific Laboratory with the fabrication of two power reactor experiments. LAPRE–1 was completed in 1956 with a design heat output of 2,000 kilowatts, and was abandoned in June 1957 after failure due to excessive corrosion. LAPRE–2 will have a heat output of 1,000 kilowatts and is expected to be completed in fiscal year 1958. The LAPRE experiments do not include turbogenerators for the production of electricity. Since development work started on the homogeneous reactor concept in 1950, the cost of research and development and the cost of constructing and operating experimental homogeneous reactors have totaled $43.6 million.

The *fast power breeder reactor concept* is being developed at the Commission's Argonne National Laboratory, Lemont, Ill., and Los Alamos Scientific Laboratory, Los Alamos, N. Mex. The Argonne National Laboratory has built an Experimental Breeder Reactor at the National Reactor Testing Station near Idaho Falls, Idaho. The EBR–1 was completed in 1951, and has a heat output of 1,400 kilowatts and a electrical output of 200 kilowatts. The EBR–2 is scheduled for completion in 1959, and will have a heat output of 62,500 kilowatts and an electrical output of 20,000 kilowatts. The Los Alamos Molten Plutonium Reactor Experiment (LAMPRE) is scheduled for completion in 1958, and will have a heat output of about 1,000 kilowatts. Since development work started on the fast power breeder reactor in 1948, the cost of research and development and the cost of constructing and operating experimental fast breeder reactors have totaled $28.1 million.

The *sodium graphite reactor concept* is being developed for the Commission by North American Aviation, Inc., at Santa Susana, Calif. The Sodium Reactor Experiment (SRE) was completed in 1957, and has a heat output of 20,000 kilowatts and an electrical output of 6,000

kilowatts. North American is contributing $2.9 million toward the cost of building the reactor and the Southern California Edison Co. is providing the power-generating equipment at a cost of $1.1 million. The Southern California Edison Co. will pay AEC 45 cents per million BTU for the heat used to generate electricity. AEC costs related to this concept since 1951 have totaled $15.6 million.

The *boiling water reactor concept* is being developed at the Commission's Argonne National Laboratory in Lemont, Ill. The developmental work includes the BORAX experiments at the National Reactor Testing Station near Idaho Falls, Idaho, and the Experimental Boiling Water Reactor at Argonne. BORAX–4 at NRTS has a heat output of 8,000 kilowatts and an electrical output of 2,400 kilowatts. Facilities built for previous BORAX experiments were used for BORAX–4. The Experimental Boiling Water Reactor (EBWR) completed at Argonne in 1957 has a heat output of 20,000 kilowatts and an electrical output of 5,000 kilowatts. Since development work started on the boiling water reactor concept in 1951, the cost of research and development and the cost of constructing and operating experimental boiling water reactors have totaled $19.9 million.

The *organic moderated reactor concept* is being developed for the Commission by North American Aviation, Inc., Santa Susana, Calif. The Organic Moderated Reactor Experiment (OMRE) completed in 1957 at the National Reactor Testing Station has a heat output of 5,000 to 16,000 kilowatts. North American is contributing $750,000 toward the cost of the reactor. Since development work started on the organic moderated concept in 1956, the cost of research and development and the cost of construction have totaled $4.4 million.

The *liquid metal fuel reactor concept* is being developed at the Commission's Brookhaven National Laboratory, Upton, N. Y., and the Commission has a contract with the Babcock & Wilcox Co. to develop, design, and build a Liquid Metal Fuel Reactor Experiment (LMFRE). Since development work started on this reactor concept in 1956, research and development costs have totaled $5.5 million.

The *plutonium recycle reactor concept* and the *pressurized heavy water reactor concept* are being developed for the Commission by the General Electric Co. at Richland, Wash., and at E. I. du Pont de Nemours & Co., Inc., at Aiken, S. C., respectively. Research and development costs on these concepts through June 30, 1957 totaled $1.8 million.

POWER DEMONSTRATION REACTOR PROGRAM

The cost to the AEC of research and development assistance to groups participating in developing industrial power reactors under the

Power Demonstration Reactor Program was $1.5 million during fiscal year 1957, as compared with $85,000 during fiscal year 1956.

Contracts have been executed for reactor projects with the Yankee Atomic Electric Co., Boston, Mass., and the Power Reactor Development Co. Detroit, Mich., for pressurized water and fast breeder reactors, respectively. Under these contracts AEC has agreed to incur costs up to $9.5 million for research and development work applicable to these projects and has agreed to waive fuel use charges of $6.7 million. The power companies have agreed to do research and development work and to construct facilities estimated to cost $87 million.

The Commission also has a contract with the Nuclear Development Corporation of America, White Plains, N. Y., for research and development work applicable to the proposal from the Chugach Electric Association, Anchorage, Alaska, and has seven additional proposals for power reactors under consideration.

ARMY REACTORS

The cost of research and development on reactor systems capable of fulfilling military requirements for package powerplants to be used in remote areas and for overland carriers and food preservation amounted to $3 million during fiscal year 1957, an increase of $2 million over fiscal year 1956.

The first pressurized water reactor for Army use went into operation at Fort Belvoir, Va. in April 1957. Development and construction cost of the Army Package Power Reactor was $4.8 million, of which AEC provided $3.3 million and the Department of the Army provided $1.5 million. The Argonne Low Power Reactor (ALPR) is under construction at the National Reactor Testing Station, near Idaho Falls, Idaho. Construction costs of this project are estimated at $2 million. This reactor is intended for use in remote military installations smaller than those for which the APPR was developed.

A gas-cooled reactor experiment to develop engineering data and provide experience for the design and construction of gas-cooled reactors to meet military needs and civilian requirements for small central power stations was started in fiscal year 1956. Costs for fiscal year 1957 were $1.5 million, compared with $94,000 in fiscal year 1956. As a result of these experiments the fabrication of such a reactor experiment is being undertaken at the National Reactor Testing Station.

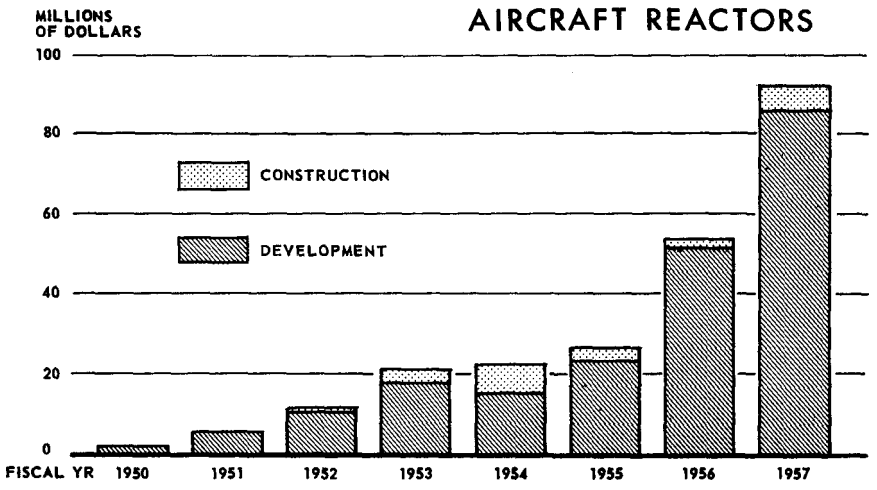
MERCHANT SHIP REACTOR

The cost of design and feasibility studies to demonstrate the general practicability of nuclear-powered merchant ships and to develop

nuclear propulsion systems which can compete economically in world trade amounted to $878,000 in fiscal year 1957. Construction costs during this year totaled $293,000. On April 8, 1957, a fixed-price contract of $9.9 million was executed with the Babcock & Wilcox Co. to furnish the basic propulsion system, including the reactor and components of the steamplant and auxiliary systems, for the first nuclear-powered merchant ship. This powerplant will deliver 20,000 shaft-horsepower and is expected to be completed in early 1960.

AIRCRAFT PROPULSION REACTORS

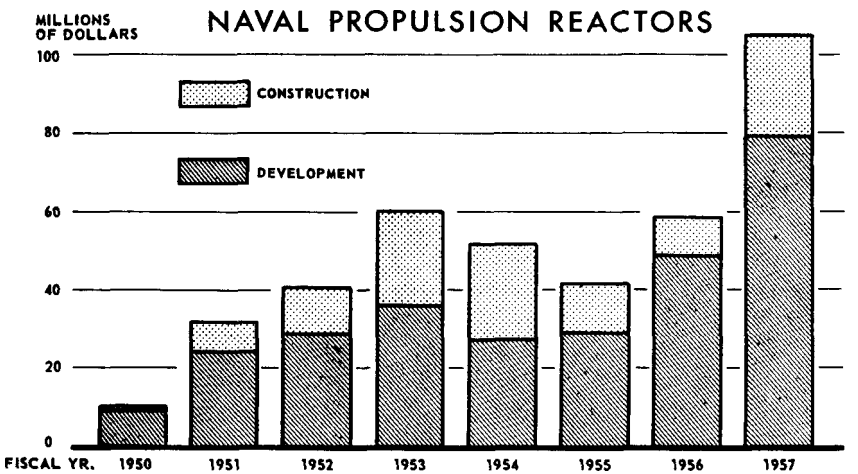
The Aircraft Reactor Program is concerned with the development of reactors for the propulsion of aircraft and missiles. In order to accomplish these objectives, work is being performed on improved shielding techniques, extensions of technology applicable to high temperature materials and moderators, improved coolants, methods of power conversion, and improvement in power density. This program is an important factor in advancing reactor technology for use in peaceful applications of atomic energy. In fiscal year 1957, research and development costs increased to $86.7 million from $52 million in fiscal year 1956, or 67 percent. Construction costs during fiscal year 1957 totaled $6.2 million as compared with $2.4 million in fiscal year 1956, an increase of 158 percent. The following chart shows the trend of research and development and construction costs of the aircraft reactor program from 1950 through fiscal year 1957.



NAVAL PROPULSION REACTORS

The naval propulsion program includes the design, development, construction, and test of nuclear propulsion plants for submarine and surface ship application, the development of naval reactor cores of increased life and lower cost, research effort to evaluate new concepts that may produce higher performance, and special-purpose powerplants for naval ships. This program is an important factor in advancing reactor technology for use in peaceful applications of atomic energy. Naval reactor research and development costs totaled $79.1 million in fiscal year 1957, an increase of 63 percent over fiscal year 1956. Construction costs totaled $26 million in fiscal year 1957, an increase of 165 percent over fiscal year 1956. In addition to research and development costs of $79.1 million, the cost of naval reactor development shown in the statement of operations includes a charge of $20.5 million resulting from the retirement of the obsolete prototype of the sodium reactor developed for the submarine U. S. S. *Seawolf*.

The following chart shows the trend of research and development and construction costs of the naval propulsion reactor program from 1950 through fiscal year 1957.



RESEARCH LABORATORIES

AEC research and development activities are conducted in government-owned laboratories operated by industrial concerns and educational institutions and under contracts for work in facilities owned by such organizations. The investment in AEC-owned research facilities at June 30, 1957 was $896 million, including $144 million in construction work in progress. This was an increase of

$125 million over the investment in such facilities at the end of the preceding year. The facilities include research and development reactors, electronic computing machines, accelerators, and laboratory buildings and equipment.

Research and development relating to production of nuclear materials; reactor design and development; weapons design, development and test; and fundamental research in the fields of chemistry, metallurgy, physics, medicine, cancer and biology are conducted in these facilities. The research and development laboratories shown below, are the principal centers of the Commission's research effort. The investment in completed facilities at these laboratories and the operating costs for fiscal years 1957 and 1956 are as follows:

	Number of contractor employees	*Investment in completed plant*		*Operating costs*	
		June 30, 1957	*June 30, 1956*	*Fiscal year 1957*	*Fiscal year 1956*
		(dollar amounts are in thousands)			
Los Alamos Scientific Laboratory, Los Alamos, N. Mex	3,300	$123,002	$121,973	$55,222	$47,046
Argonne National Laboratory, Lemont, Ill	2,903	87,784	81,876	29,132	25,526
Oak Ridge National Laboratory, Oak Ridge, Tenn	3,924	70,067	63,978	51,538	47,019
Brookhaven National Laboratory, Upton, Long Island, N. Y	1,751	59,021	57,746	16,810	14,221
Radiation Laboratory, Livermore and Berkeley, Calif	4,303	58,697	52,166	47,284	37,163
Bettis Plant (including Naval Reactor Facility at NRTS), Pittsburgh, Pa	3,957	47,305	38,234	60,354	37,089
Knolls Atomic Power Laboratory, Schenectady, N. Y	2,014	46,988	66,487	28,959	25,024
	22,152	492,864	482,460	289,299	233,088

Los Alamos Scientific Laboratory, Los Alamos, N. Mex. The investment of $123 million in completed plant and equipment at Los Alamos at June 30, 1957, includes $79 million in land improvements and buildings, and $44 million in equipment and utilities. In addition to research plant and equipment, AEC has an investment of $70 million in community facilities at Los Alamos, and $57 million in general facilities such as utility systems, transportation shops, and general service buildings. The community facilities accommodate scientific and other personnel and their families. The work performed at the Los Alamos Scientific Laboratory includes improving present weapons, reactor design, and development and basic weapons

research. The University of California operates the laboratory under contract with AEC.

Argonne National Laboratory, Lemont, Ill. The investment in completed plant and equipment totals $86 million at Lemont, Ill., and $1.6 million at the National Reactor Testing Station, Idaho Falls, Idaho. Included are $57 million in land, land improvements, and buildings, and $31 million in equipment and utilities. Facilities at Argonne include the CP–5 reactor, accelerators, and other devices and laboratory equipment. In the three major fields of endeavor in fiscal year 1957, 57 percent of the operating costs were directed to reactor research; 32 percent to chemistry, metallurgy, and physics; and 11 percent to cancer, medicine, and biology. The University of Chicago operates the laboratory under contract with AEC.

Oak Ridge National Laboratory, Oak Ridge, Tenn. The investment of $70 million in completed plant and equipment at the Oak Ridge National Laboratory includes $40 million in land improvements and buildings, and $30 million in equipment and utilities. The facilities include a graphite reactor used primarily for the production of radioisotopes distributed for commercial, medical, and research purposes, research reactors, accelerators, and other devices and laboratory equipment. The Union Carbide Nuclear Co. operates the laboratory under contract with AEC. In fiscal year 1957, 70 percent of its operating costs were incurred in connection with the development of reactors, and 30 percent were in connection with other research activities.

Brookhaven National Laboratory, Upton, Long Island, N. Y. The investment of $59 million in completed plant and equipment at Brookhaven National Laboratory includes $30 million in land, land improvements, and buildings, and $29 million in equipment and utilities. Completed facilities include a graphite air-cooled research reactor, a cyclotron, and a cosmotron. An alternating gradient proton synchrotron accelerator estimated to cost $26 million upon completion in 1960 is presently about 25 percent complete, and a medical research center, including a 48-bed hospital, a research reactor, and related facilities estimated to cost $6.5 million are now under construction. Associated Universities, Inc., operates the laboratory under contract with AEC. The major fields of endeavor at this laboratory include radiation chemistry, physical chemistry, and biological and medical effects and applications of atomic energy.

Radiation Laboratory, Livermore and Berkeley, Calif. The investment in completed plant and equipment totals $33 million at Livermore, Calif., and $26 million at Berkeley, Calif. Included are $20 million in land, land improvements, and buildings, and $39 million in equipment and utilities. The plant and equipment include

a bevatron, cyclotron, research reactors, facilities for thermonuclear research, and other research facilities. The University of California operates the laboratory under contract with AEC. Research conducted at this laboratory is applicable to nearly all AEC programs.

Bettis Plant (including The Naval Reactor Facility at NRTS), Pittsburgh, Pa. The investment in completed plant and equipment totals $32 million for the Pittsburgh, Pa., location, and $15 million for the Naval Reactor Testing Facility at the National Reactor Testing Station, Idaho Falls, Idaho. Included are $12 million in land improvements and $35 million in equipment and utilities. In fiscal year 1957, 74 percent of the operating costs were related to the naval reactor program, and 26 percent of the costs were related to the civilian power reactor program. The Westinghouse Electric Corp. operates the facilities under contract with AEC.

Knolls Atomic Power Laboratory, Schenectady, N. Y. The investment of $47 million in completed plant and equipment at Knolls Atomic Power Laboratory includes $22 million in land, land improvements, and buildings, and $25 million in equipment and utilities. In fiscal year 1957, 97 percent of the operating costs were related to reactor research and development and 3 percent were in connection with other research activities. Operating costs totaled $29 million in fiscal year 1957. The reduction of $20 million in plant and equipment at Knolls Atomic Power Laboratory was the result of the retirement of the obsolete land-based prototype of the sodium reactor built to develop and test a reactor for the U. S. S. *Seawolf* which began sea trials on January 21, 1957. The facilities at West Milton, N. Y., will now be used in developing reactors for other naval prototypes. The General Electric Co. operates the laboratory under contract with AEC.

RESEARCH IN CHEMISTRY, METALLURGY AND PHYSICS

The research costs shown in the following table increased to $58.9 million for fiscal year 1957 from $51.3 million for fiscal year 1956, or 15 percent:

	Fiscal years		Increase (decrease)
	1957	1956	
	(in thousands)		
Chemistry	$19,352	$16,925	$2,427
Metallurgy	6,060	4,826	1,234
Physics	28,711	24,095	4,616
Special nuclear materials produced	(367)	(193)	(174)
Depreciation of facilities	5,104	5,629	(525)
Total	58,860	51,282	7,578

The principal increases were the result of greater effort in basic research in high temperature and radiation chemistry and metallurgy, the study of the effects of irradiations on materials, and physics research using the higher energy accelerators that are now in operation and in the development of accelerators of higher energies and greater intensities.

RESEARCH IN CANCER, MEDICINE, AND BIOLOGY

The research costs shown in the following table increased to $33.1 million for fiscal year 1957 from $30.1 million for fiscal year 1956, or 10 percent:

	Fiscal years		*Increase (decrease)*
	1957	*1956*	
		(in thousands)	
Cancer	$3,423	$3,109	$314
Medicine	9,215	8,776	439
Biology	11,558	10,302	1,256
Biophysics	4,388	3,159	1,229
Dosimetry and instrumentation	1,918	2,229	(311)
Special nuclear materials produced	—	(83)	83
Depreciation of facilities	2,646	2,634	12
Total	33,148	30,126	3,022

The principal increases were the result of greater emphasis in all areas relating to the effects of radiation, the treatment of these effects and protection against them, and the use of radioisotopes in studies of diseases and their alleviation.

CONTROLLED THERMONUCLEAR POWER DEVELOPMENT

During fiscal year 1957 research directed toward the development of a method of controlled release of energy from nuclear fusion cost $11.1 million. This represented an increase of 57 percent over fiscal year 1956. Construction costs during 1957 totaled $495,000 compared with $141,000 in 1956.

The purpose of this research is to develop a method of utilizing thermonuclear energy to produce electric power. Research in this field is being carried out at Princeton University, Oak Ridge National Laboratory, Los Alamos National Laboratory, and at the Radiation Laboratory.

VOCATIONAL AND EDUCATIONAL TRAINING

In fiscal year 1957 vocational and educational training costs were $5.9 million, as compared with $1.7 million in 1956.

AEC sponsors training for scientists, engineers, and others who will

be engaged in the development of peaceful uses of atomic energy. The training is conducted through the Oak Ridge School of Reactor Technology and the Oak Ridge Institute of Nuclear Studies at Oak Ridge, Tenn., the International School of Nuclear Science and Engineering at Argonne National Laboratory, Lemont, Ill., and the Life Science Fellowship Program. A portion of the training is conducted at State universities and colleges. The courses provide training in reactor technology, in the use and handling of radioisotopes, and in life sciences related to hazards resulting from exposure to radioactive materials. In fiscal year 1957 the cost of this training was $1.8 million.

The National Science Foundation and AEC jointly sponsor summer training for high school teachers at universities. The Commission provides equipment and teaching assistance, and the foundation provides student stipends and family support. The Commission furnishes each participant who successfully completes the course with a scientific demonstration kit for use in teaching high school students.

During the year the Commission furnished high school and elementary students and teachers with 16,636 kits of published material, and also provided direct aid to colleges and universities for the purchase of teaching aids and laboratory equipment for conducting courses in nuclear energy technology. Grants to 34 universities and colleges totaled $3.4 million. The Commission also aided universities and colleges by lending uranium and neutron sources and by waiving use charges and charges for material and services. The charges waived in fiscal year 1957 amounted to $84,000.

INTERNATIONAL COOPERATION

The statute for establishment of an International Atomic Energy Agency has been ratified by the United States and more than 30 other countries. Also the first Inter-American Symposium on Nuclear Energy was held at Brookhaven National Laboratory. In addition, a special mission was sent to Argentina to evaluate a proposal to establish a multimillion-dollar Inter-American Nuclear Training Center.

The United States has concluded 51 Agreements for Cooperation with foreign nations in the fields of research and power. Thirty-six of these agreements (29 in research and 7 in power) have become effective, with the remaining 15 agreements expected to come into force following completion of statutory and constitutional requirements.

Three countries received commitments for grants of $350,000 each, payable upon completion of their research reactor projects. These were made to Portugal, Japan, and Venezuela, and bring to seven the total number of countries approved for financial aid from the United States. Four grants were approved in fiscal year 1956. A total of $2,450,000 for these seven projects will be made available through AEC by the International Cooperation Administration from Mutual Security Program funds. No disbursements are expected to be made until fiscal year 1958.

Sales of materials and commitments to foreign nations under the President's Atoms for Peace Program are in the Sales of Materials and Services portion of this report, beginning on page 428.

COMMUNITIES

Results of Community Operations

The net cost of operating AEC-owned communities built to accommodate contractor and Government personnel employed in laboratories and plants engaged in the development and production of nuclear products was $8.9 million in fiscal year 1957 as compared with $9.0 million in 1956. The following table shows a comparison of the result of operations of each of the major communities:

Community	*Estimated Population*	*Net cost Fiscal year 1957*	*Net cost Fiscal year 1956*	*Increase (decrease)*
		(in millions)		
Oak Ridge, Tenn	29,000	$3.1	$3.8	$(.7)
Richland, Wash	28,000	2.5	2.6	(.1)
Los Alamos, N. Mex	13,400	3.2	2.3	.9
Other	------	.1	.3	(.2)
Total	------	8.9	9.0	(.1)

Community	*Fiscal year 1957 Revenues*	*Fiscal year 1957 costs*		
		Expenses	*Depreciation*	*Net cost*
		(in millions)		
Oak Ridge, Tenn	$7.9	$7.5	$3.5	$3.1
Richland, Wash	6.0	4.8	3.7	2.5
Los Alamos, N. Mex	4.6	4.2	3.6	3.2
Other	.5	.4	.2	.1
Total	19.0	16.9	11.0	8.9

Investment in Community Facilities

AEC's investment in completed community facilities at June 30, 1957, was as follows:

Community	Cost	Accumulated depreciation (in millions)	Net
Richland	$99.1	$33.7	$65.4
Oak Ridge	89.7	29.9	59.8
Los Alamos	70.3	15.9	54.4
Other	8.2	1.8	6.4
Total	267.3	81.3	186.0

The changes in completed community facilities during the year are summarized below:

	Total	Oak Ridge	Richland	Los Alamos	Other
		(in millions)			
Investment—June 30, 1956	$299.3	$121.0	$102.9	$66.7	$8.7
Additions—fiscal year 1957	6.1	.6	1.7	3.6	.2
Less—sales	(32.3)	(29.1)	(3.2)	—	—
Other retirements	(5.8)	(2.8)	(2.3)	—	(.7)
Investment—June 30, 1957	267.3	89.7	99.1	70.3	8.2

New homes built to replace substandard accommodations at Los Alamos, N. Mex., were the principal additions completed during the year. The sales during the year represent the cost of community facilities sold by HHFA, or by AEC for the account of HHFA, under the community disposal program.

Community Disposal

Public Law 221, 84th Congress, approved August 4, 1955, authorized the sale to occupants or other interested parties of the houses, apartments, and business buildings in the Oak Ridge, Tenn., and Richland, Wash., communities. The Act also provides for transferring municipal facilities and utilities to the city governments or other legal entities. Under Executive Order number 10657 issued by the President, the Administrator of the Housing and Home Finance Agency is responsible for the sale and financing of the property.

The status of community property disposals at June 30, 1957, was as follows:

	Number of units of property		
	Available for sale	*Offered for sale*	*Sold*
Residential:			
Single-family dwellings	7,313	3,729	3,190
Duplex dwellings	1,852	834	654
Apartments	275	—	—
Dormitories	32	—	—
Vacant lots	1,309	908	156
Leased subdivided lots	523	—	—
Leased housing sites	25	—	—
Nonresidential:			
Commercial buildings	92	37	—
Leased commercial land	102	—	—
Vacant commercial land	79	—	—
Nonprofit property	50	1	1
Industrial and other	243	—	—

Sales of single and duplex houses are made at appraised value, less a discount of 15 percent to priority purchasers and 10 percent to those who do not avail themselves of the indemnity provision contained in sections 63 through 66 of the Act. The Federal Housing Administration has posted the appraised value of each property offered for sale in each community. Sales of community property by HHFA through June 30, 1957, were as follows:

	Total	*Vacant lots*	*Residential homes*	*Telephone system* [1]
	(dollar amounts are in thousands)			
Oak Ridge, Tenn.:				
Number of units	3,960	130	3,830	—
Book value	$29,111	$52	$29,059	—
Accumulated depreciation	11,569	—	11,569	—
Net book value	17,542	52	17,490	—
Appraised value	19,111	105	19,006	—
Sales price	14,359	105	14,254	—
Richland, Wash.:				
Number of units	42	27	14	1
Book value	$3,158	$29	$399	$2,730
Accumulated depreciation	862	8	122	732
Net book value	2,296	21	277	1,998
Appraised value	2,253	50	176	2,027
Sales price	2,170	50	132	1,988

[1] Sold by AEC for the account of HHFA.

The Kadlec Hospital at Richland, Wash., was transferred to the Board of Hospitals and Homes of the Methodist Church on September 9, 1956. This was the first disposal of a facility to a local entity under the Atomic Energy Community Act of 1955. Transfers to the board included land, buildings, equipment, supplies, and working funds with an acquisition value of $2.1 million.

GUARANTEED LOANS

The outstanding balance of loans made by the Export-Import Bank to South African uranium producers was $104 million at June 30, 1957. The maximum additional credit available to borrowers under approved guarantees at June 30, 1957, was $1.3 million. Since the inception of these guarantees in 1952, the Export-Import Bank has loaned $121 million to 28 borrowers. The loans bear interest at 4 percent per annum and the Export-Import Bank has agreed to pay AEC a guarantee fee of one-fourth of the amount of interest collected from the borrowers, less the amount of losses on the loans, if any. AEC has guaranteed the entire balance of the loans.

The outstanding balance of loans to AEC contractors made by commercial banking institutions and guaranteed by AEC under the V-loan program was $8 million at June 30, 1957. Of this amount, $7.4 million, an average of 92 percent, was guaranteed by AEC. The maximum additional credit available to borrowers under approved guarantees at June 30, 1957, totaled $58,000. Since the beginning of these guarantees in 1951, the lending institutions have loaned $34 million to 16 borrowers and have received repayments of $26 million. Payments in full have been made by 13 borrowers. AEC has earned guarantee fees totaling $350,000 and has paid the lending institutions loan service charges totaling $9,000. Guarantee fees earned during fiscal year 1957 totaled $145,000.

At the end of the year no losses had been sustained, and all unpaid loans were current.

ADMINISTRATIVE EXPENSES

The direct cost of general management, executive direction, administration of contracts, and supporting administrative services was $38.5 million in fiscal year 1957, an increase of 1 percent over 1956. This increased effort was directed toward accelerated development of civilian and military reactors, increased production operations, growth in international cooperation activities, weapons program expansion, and to other civilian applications of atomic energy. In fiscal year 1957 administrative costs amounted to 2.0 percent of the total cost of operations, compared with 2.4 percent in 1956.

Administrative expenses for fiscal years 1957 and 1956 were as follows:

	Fiscal years	
	1957	*1956*
	(in millions)	
Salaries	$30.0	$28.3
Travel	2.0	1.7
Other	5.6	7.1
Depreciation	.9	1.1
Total	38.5	38.2

Construction costs incurred for the AEC headquarters office building at Germantown, Md., were $7.4 million through June 30, 1957. It is estimated the building will be ready for occupancy by the first part of 1958 and will cost approximately $13.3 million.

UNITED STATES ATOMIC ENERGY COMMISSION
COMPARATIVE BALANCE SHEET

ASSETS

	June 30, 1957	June 30, 1956
	(in thousands)	
CASH:		
In U. S. Treasury	$1, 377, 353	$1, 409, 115
With integrated contractors	23, 124	23, 204
	1, 400, 477	1, 432, 319
WORKING CAPITAL ADVANCES:		
With other Federal agencies	41, 162	75, 277
With nonintegrated contractors	714	5, 514
	41, 876	80, 791
ACCOUNTS RECEIVABLE:		
From other Federal agencies	1, 228	2, 007
Other, less allowance for uncollectible accounts of $131,000 in 1957 and $129,000 in 1956	18, 434	12, 994
	19, 662	15, 001
INVENTORIES:		
Production inventories in process	1, 329, 172	1, 234, 247
Source and special nuclear material at research installations	227, 205	189, 863
Source and special nuclear materials leased	9, 429	666
Stores, less allowance for loss of $11,120,000 in 1957 and $10,635,000 in 1956	84, 901	83, 384
Special reactor material	79, 770	47, 066
Other special materials	18, 573	18, 391
	1, 749, 050	1, 573, 617
PLANT:		
Completed plant and equipment	6, 596, 679	6, 466, 037
Less—Accumulated depreciation	1, 466, 546	1, 269, 719
	5, 130, 133	5, 196, 318
Construction work in progress	311, 217	247, 024
	5, 441, 350	5, 443, 342
COLLATERAL FUNDS AND OTHER DEPOSITS	24, 099	25, 016
PREPAYMENTS AND DEFERRED CHARGES	41, 111	32, 433
TOTAL ASSETS	8, 717, 625	8, 602, 519

LIABILITIES AND AEC EQUITY

	June 30, 1957	*June 30, 1956*
	(in thousands)	
LIABILITIES:		
Accounts payable and accrued expenses:		
To other Federal agencies	$12,863	$21,313
Other	203,164	198,826
	216,027	220,139
Working fund advances from other Federal agencies	90,701	51,792
Funds held for others	7,835	7,041
Deferred credits	549	726
TOTAL LIABILITIES	315,112	279,698
AEC EQUITY, JULY 1	8,322,821	8,840,007
Additions:		
Appropriated funds—net	1,898,700	834,227
Nonreimbursable transfers from other Federal agencies	2,740	36,779
	1,901,440	871,006
Deductions:		
Net cost of operations and adjustments to costs of prior years	1,937,595	1,558,194
Less—change in inventories of research materials, work in process and materials leased	141,030	221,773
	1,796,565	1,336,421
Nonreimbursable transfers to other Federal agencies	25,017	42,589
Funds returned to U. S. Treasury	166	9,182
	1,821,748	1,388,192
AEC EQUITY, JUNE 30	8,402,513	8,322,821
TOTAL LIABILITIES AND AEC EQUITY	8,717,625	8,602,519

The notes on the following page are an integral part of the Balance Sheet.

NOTES TO THE BALANCE SHEET

1. For security reasons inventories of weapons are not included in assets in this report.

2. The balance sheet does not include 64,751,316 troy ounces of silver loaned to AEC by the Treasurer of the United States for use as electrical conductors in plants. Based on market quotations at June 30, 1957, this silver had a value of $58.4 million.

3. In addition to the liabilities shown on the balance sheet, AEC had at June 30, 1957:

a. Commitments related to the procurement of source materials estimated at $5 billion.

b. Contingent liabilities related to contracts for the supply of electric power for the Oak Ridge, Paducah, and Portsmouth production facilities. If cancellation notice had been given at June 30, 1957 the estimated liability would have amounted to $339 million.

c. Contingent liabilities as guarantor of loans made by the Export-Import Bank to South African uranium producers of $104 million, less accumulated guarantee fees.

d. Contingent liabilities as guarantor of loans under the Defense Production Act of 1950 to the extent of $7.4 million.

e. Contingent liabilities for claims against the Federal Government or AEC contractors of approximately $19.6 million.

f. Commitments for accrued annual leave of AEC employees of $5.3 million.

g. Commitments applicable to future periods represented by unpaid obligations of $766 million.

UNITED STATES ATOMIC ENERGY COMMISSION
COMPARATIVE STATEMENT OF OPERATIONS

[In thousands of dollars]

	Fiscal year ended	
	June 30, 1957	*June 30, 1956*
Production costs:		
Procurement of source materials	$402,280	$281,045
Production of nuclear materials [1]	787,750	728,873
Weapons development and fabrication	337,183	280,765
	1,527,213	1,290,683
Development of nuclear reactors:		
Experimental power reactors	56,697	45,795
Power demonstration reactor program	1,499	85
Army reactors	2,956	978
Aircraft propulsion	86,719	52,033
Naval propulsion [2]	99,551	48,499
Other	28,742	22,505
	276,164	169,895
Chemistry, metallurgy and physics research	58,860	51,282
Cancer, medicine and biology research	33,148	30,126
Controlled thermonuclear power development	11,128	7,066
Vocational and educational training	5,903	1,702
Community operations:		
Expenses	27,885	29,417
Less—Revenues	18,988	20,463
	8,897	8,954
AEC administrative expenses	38,499	38,195
Security investigations	8,442	7,526
Cost of materials sold and other expenses	15,294	17,151
Less—Income:		
Sales of source and special nuclear materials	2,198	3,295
Sales of heavy water	4,388	5,059
Sales of isotopes	2,866	2,297
Miscellaneous	5,939	3,956
	15,391	14,607
Net cost of operations [3]	1,968,157	1,607,973
Credits applicable to prior years' costs—net	(30,562)	(49,779)
Net cost of operations—less credits applicable to prior years' costs	1,937,595	1,558,194

[1] Includes retirement of obsolete facilities of $29,402,000 in 1957.

[2] Includes retirement of obsolete facilities of $20,497,000 in 1957.

[3] Includes costs incurred for procurement and production of source and special nuclear materials and weapons parts and assemblies. Includes depreciation of $263 million in 1957 and $260 million in 1956.

AUDITOR'S REPORT

We have examined the balance sheet of the Atomic Energy Commission as at June 30, 1957, and the accompanying statement of operations for the fiscal year then ended.

These statements are a consolidation of financial statements of the ten AEC Operations Offices, the Washington Office, and their integrated contractors. In the AEC-wide audit examination thereof, the system of control and related procedures affecting the principal activities including the accounting systems of the AEC and its integrated contractors were reviewed, and without performing detailed audits of transactions, examinations or tests of accounting records and supporting evidence were made by methods and to the extent contemplated by the AEC internal audit program and considered necessary in the circumstances. With respect to the values of production inventories and source and special nuclear materials appearing in the balance sheet, the scope of our audit program did not provide a verification of those values or of the material quantities represented thereby. It should be noted, however, that there exist within AEC separate programs of surveillance over the aforementioned materials, which include the review of the quantitative accounting for and periodic physical inventory of such materials.

Subject to the foregoing statement, and based upon the opinions furnished by the Chief Auditor of each Operations Office, with respect to its integrated contractors, it is my opinion that the balance sheet and accompanying statement of operations, together with the notes thereto, fairly present the assets, liabilities, and equity of the Atomic Energy Commission as at June 30, 1957, and the operating costs for the fiscal year then ended, in conformity with applicable AEC policies, contractual provisions, and generally accepted accounting principles.

Charles F. Schaub

Assistant Controller for Auditing.

SEPTEMBER 1957.

SOURCE AND USE OF AEC FUNDS

[In millions]

	Fiscal year 1957	Fiscal year 1956
Cash balance, July 1	$1,409	$2,215
Funds provided by:		
Congressional appropriations—net	1,899	834
Working fund advances and appropriation transfers	74	44
Community revenues	19	20
Decrease in working capital	41	—
Other sources	19	61
Total available	3,461	3,174
Funds used for:		
Operations:		
Procurement of source materials	402	281
Production of nuclear materials	569	543
Weapons development and fabrication	304	247
Development of nuclear reactors	238	152
Chemistry, metallurgy, and physics	54	47
Cancer, medicine, and biology	31	28
Controlled thermonuclear power development	11	7
Vocational and educational training	6	2
Community expense	17	18
AEC administrative expense	38	37
Security investigations	8	8
	1,678	1,370
Plant and equipment	317	300
Work for others	85	54
Increase in working capital	—	30
Funds returned to U. S. Treasury	—	9
Other uses	4	2
Total used	2,084	1,765
Cash balance, June 30	1,377	1,409

U. S. GOVERNMENT INVESTMENT IN THE ATOMIC ENERGY PROGRAM

From June 1940 through June 1957

	Amount (in millions)	
Appropriation payments net of reimbursement:		
National Defense Research Council	$0. 5	
Office of Scientific Research and Development	14. 6	
War Department (including Manhattan Engineer District):		
Fiscal year 1943	77. 1	
Fiscal year 1944	730. 3	
Fiscal year 1945	858. 6	
Fiscal year 1946	366. 3	
Fiscal year 1947—part	186. 0	
		$2, 233. 4
Atomic Energy Commission:		
Fiscal year 1947—part	146. 1	
Fiscal year 1948	477. 6	
Fiscal year 1949	627. 3	
Fiscal year 1950	534. 3	
Fiscal year 1951	920. 5	
Fiscal year 1952	1, 669. 4	
Fiscal year 1953	1, 812. 7	
Fiscal year 1954	1, 930. 5	
Fiscal year 1955	1, 861. 9	
Fiscal year 1956	1, 633. 5	
Fiscal year 1957	[1] 1, 931. 6	
		13, 545. 4
Total payments—net		15, 778. 8
Unexpended balance of appropriations, June 30, 1957 [2]		1, 284. 8
Unexpended balance of appropriations transferred to other Federal agencies		37. 8
Total appropriated funds		17, 101. 4
Less:		
Collections paid to U. S. Treasury	$52. 8	
Property and services transferred to other Federal agencies without reimbursement, net of such transfers received from other Federal agencies	54. 7	
Cost of operations including depreciation and obsolescence from June 1940 through June 30, 1957	8, 591. 4	
		8, 698. 9
AEC equity at June 30, 1957		8, 402. 5

[1] Reduced by $58.8 million representing the balance of Allocated Working Fund Advances to other Federal agencies at June 30, 1956, transferred to Appropriation Transfers in fiscal year 1957.

[2] Appropriations of $2,324 million for fiscal year 1958 were approved on Aug. 28, 1957.

AEC PLANT AND EQUIPMENT

BY LOCATION

June 30, 1957

[In thousands]

Location	*Facility and operating contractor*	*Completed plant and equipment*	*Construction in progress*	*Total*
CALIFORNIA:				
Berkeley	Radiation Laboratory: University of California.	$26,036	$1,472	$27,508
Livermore	University of California.	32,661	4,149	36,810
Salton Sea	Salton Sea Base, Sandia Corp.	6,900	5	6,905
Canoga Park	Research equipment, North American Aviation.	*1,836	382	2,218
CONNECTICUT:				
Middletown	Connecticut Aircraft Nuclear Engine Lab., Pratt & Whitney.	*2,312	—	2,312
New Haven	Linear accelerator, Yale University.	—	*1,801	1,801
COLORADO:				
Grand Junction	Ore processing pilot plant, National Lead Co.	1,312	—	1,312
	Uranium handling and sampling facilities, Lucius Pitkin, Inc.	1,509	20	1,529
	Exploration and general maintenance facilities, Swinerton & Walberg.	4,993	299	5,292
	Total Grand Junction.	7,814	319	8,133
Rocky Flats	Rocky Flats Plant, Dow Chemical Co.	67,185	654	67,839
DISTRICT OF COLUMBIA:				
Washington	Research equipment, Naval Research Laboratory.	*2,424	3	2,427
FLORIDA:				
Clearwater	Pinellas Plant, General Electric Co.	8,112	—	8,112

See footnote at end of table.

AEC PLANT AND EQUIPMENT—Continued

Location	Facility and operating contractor	Completed plant and equipment	Construction in progress	Total
ILLINOIS:				
Lemont	Argonne National Laboratory, University of Chicago.	86, 144	1, 704	87, 848
Chicago	Argonne Cancer Research Hospital, University of Chicago.	4, 227	—	4, 227
INDIANA:				
Dana	Dana heavy-water plant, E. I. duPont de Nemours & Co., Inc.	100, 645	—	100, 645
IDAHO:				
Idaho Falls	National Reactor Testing Station:			
	Argonne National Laboratory.	1, 640	492	2, 132
	General Electric Co.	16, 507	5, 027	21, 534
	Phillips Petroleum Co.	75, 383	20, 058	95, 441
	Westinghouse Electric Co.	15, 542	15, 445	30, 987
	Total Idaho Falls	109, 072	41, 022	150, 094
IOWA:				
Ames	Research laboratory, Iowa State College.	6, 736	78	6, 814
Burlington	Iowa ordnance plant, Mason & Hanger.	25, 610	69	25, 679
KENTUCKY:				
Paducah	Paducah gaseous diffusion plant, Union Carbide Nuclear Co.	767, 476	1, 266	768, 742
MARYLAND:				
Germantown	AEC Headquarters	—	7, 423	7, 423
MASSACHUSETTS:				
Boston	Research equipment, Edgerton, Germeshausen & Grier.	*2, 790	—	2, 790
Cambridge	Reactor research and development facilities, Nuclear Metals, Inc.	1, 207	—	1, 207
Winchester	Raw materials development laboratory, National Lead Co.	1, 349	—	1, 349
MINNESOTA:				
Minneapolis	Linear accelerator, University of Minnesota.	*1, 609	—	1. 609

See footnote at end of table.

AEC PLANT AND EQUIPMENT—Continued

Location	*Facility and operating contractor*	*Completed plant and equipment*	*Construction in progress*	*Total*
MISSOURI:				
Kansas City	Kansas City Plant, Bendix Aviation Corp.	14, 831	1, 432	16, 263
St. Louis	Destrehan Street Plant, Mallinckrodt Chemical Co.	21, 567	404	21, 971
Weldon Spring	Weldon Spring Plant, Mallinckrodt Chemical Co.	30, 084	14, 105	44, 189
NEVADA:				
Mercury	Nevada Test Site, Reynolds Electrical and Engineering Co.	15, 180	565	15, 745
NEW JERSEY:				
New Brunswick	New Brunswick Laboratory, Atomic Energy Commission.	1, 780	—	1, 780
NEW MEXICO:				
Albuquerque	South Albuquerque Works, ACF Industries, Inc.	9, 456	132	9, 588
Albuquerque	Sandia Plant, Sandia Corp.	55, 362	608	55, 970
	Total Albuquerque	64, 818	740	65, 558
Los Alamos	Los Alamos Hospital, Los Alamos Medical Center, Inc.	2, 919	—	2, 919
	Los Alamos Scientific Laboratory, University of California.	123, 002	1, 604	124, 606
	Community and general maintenance facilities, The Zia Co.	123, 862	221	124, 083
	Total Los Alamos	249, 783	1, 825	251, 608
NEW YORK:				
Buffalo	Buffalo Plant, ACF Industries, Inc.	*6, 445	228	6, 673
Upton	Brookhaven National Laboratory, Associated Universities, Inc.	59, 021	9, 370	68, 391

See footnote at end of table.

AEC PLANT AND EQUIPMENT—Continued

Location	*Facility and operating contractor*	*Completed plant and equipment*	*Construction in progress*	*Total*
NEW YORK—Con.				
Hicksville	Fuel processing facility, Sylvania Corning Nuclear Corp.	1, 545	16	1, 561
Niagara Falls	Boron production plant, Hooker Electrochemical Co.	8, 148	10	8, 158
Schenectady	Knolls Atomic Power Laboratory, General Electric Co.	46, 988	13, 945	60, 933
Rochester	Research laboratory, University of Rochester.	3, 913	42	3, 955
New York	Computing and other research equipment, New York University.	*1, 009	—	1, 009
OHIO:				
Lockland	Lockland Plant, General Electric Co.	*3, 560	124	3, 684
Portsmouth	Portsmouth gaseous diffusion plant, Goodyear Atomic Corp.	742, 885	10, 005	752, 890
Miamisburg	Mound Laboratory, Monsanto Chemical Co.	26, 276	846	27, 122
Fernald	Fernald Feed Materials Center, National Lead Co.	107, 081	1, 092	108, 173
Luckey	Beryllium production plant, Brush Beryllium Co.	2, 731	—	2, 731
PENNSYLVANIA:				
Pittsburgh	Bettis Plant, Westinghouse Electric Corp.	31, 763	4, 109	35, 872
Shippingport	Pressurized Water Reactor, Duquesne Light Co.	—	40, 053	40, 053
SOUTH CAROLINA:				
Aiken	Savannah River Plant, E. I. duPont de Nemours & Co., Inc.	1, 177, 806	57, 155	1, 234, 961
TENNESSEE:				
Oak Ridge	Transportation system, American Industrial Transport, Inc.	1, 314	—	1, 314
	School system, Anderson County Board of Education.	11, 046	1	11, 047

See footnote at end of table.

AEC PLANT AND EQUIPMENT—Continued

Location	*Facility and operating contractor*	*Completed plant and equipment*	*Construction in progress*	*Total*
TENNESSEE—Con.				
	Community services, Management Services, Inc.	80, 007	445	80, 452
	Oak Ridge Hospital, Oak Ridge Hospital, Inc.	1, 423	—	1, 423
	Research laboratory, Oak Ridge Institute of Nuclear Studies.	2, 267	22	2, 289
	Oak Ridge gaseous diffusion plant, Union Carbide Nuclear Co.	840, 643	3, 060	843, 703
	Y–12 Plant, Union Carbide Nuclear Co.	406, 664	15, 719	422, 383
	Oak Ridge National Laboratory, Union Carbide Nuclear Co.	70, 067	4, 702	74, 769
	Total Oak Ridge	1, 413, 431	23, 949	1, 437, 380
TEXAS:				
Amarillo	Pantex Plant, Mason & Hanger.	18, 950	66	19, 016
UTAH:				
Monticello	Uranium ore processing mill, National Lead Co.	5, 494	18	5, 512
WASHINGTON:				
Richland	Hanford Works, General Electric Co.	933, 690	18, 977	952, 667
	Community services, General Electric Co.	99, 046	1, 438	100, 484
	Total Richland	1, 032, 736	20, 415	1, 053, 151
West VIRGINIA:				
Huntington	Huntington pilot plant, International Nickel Co.	4, 316	—	4, 316
MARSHALL ISLANDS:				
Eniwetok	Eniwetok Proving Grounds, Holmes & Narver.	26, 110	657	26, 767
ALL OTHER:				
Various	All other facilities	216, 283	49, 699	265, 982
	Total	6, 596, 679	311, 217	6, 907, 896

*Equipment only.

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