UNITED STATES ATOMIC ENERGY COMMISSION

Twenty-second Semiannual Report

OF THE

ATOMIC ENERGY COMMISSION

July 1957

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

LETTER OF SUBMITTAL

WASHINGTON, D. C.,
31 July 1957.

SIRS: We have the honor to submit herewith the Twenty-second Semiannual Report of the United States Atomic Energy Commission, as required by the Atomic Energy Act of 1954.

Respectfully,

UNITED STATES ATOMIC ENERGY COMMISSION,
WILLARD F. LIBBY.
HAROLD S. VANCE.
LEWIS L. STRAUSS, *Chairman.*

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

CONTENTS

APPENDIXES

FOREWORD

During the first 6 months of 1957, the Nation's atomic energy programs have made steady progress in developing a variety of power reactors, in setting governmental policies to aid the growth and operation of an atomic energy industry, in promoting the free world's utilization of atomic energy for mankind's benefit, and in developing nuclear weapons for defense. Advances were made in all major programs.

Power Reactors and Industrial Development

Power Reactors

Private industry's actions and plans for development of nuclear power progressed during the January–June reporting period, and the Atomic Energy Commission's experimental and demonstration power reactor programs moved further toward creating a wide technological base for economic production of electricity from nuclear fuels.

The first United States reactor designed exclusively to produce civilian electric power, a pilot plant for large commercial reactors, was dedicated by the Commission on February 9 at Lemont, Ill.,[1] and since that date has supplied up to 5,000 kilowatts of electricity to Argonne National Laboratory. The early performance of this Experimental Boiling Water Reactor indicated that it probably could produce twice its design heat output.

A second pilot plant reactor, the Sodium Reactor Experiment, achieved criticality in April and began experimental operation at Santa Susana, Calif. Its operation is expected later to feed 6,500 kilowatts into the lines of the Southern California Edison Co. on an experimental basis.

The Army Package Power Reactor achieved criticality and later began producing electricity at Fort Belvoir, Va. This type of reactor is expected also to help meet civilian needs for small and "portable" nuclear powerplants.

Other experimental reactors, including the Organic-Moderated Reactor Experiment, and the Homogeneous Reactor Experiment No. 2, were expected to achieve criticality during the 6-month reporting period following this one.

[1] This reactor achieved criticality November 30, 1956, see p. 41, Twenty-first Semiannual Report to Congress (July–December 1956).

The full-scale 60,000-plus kilowatt Pressurized Water Reactor at Shippingport, Pa., was scheduled to go into operation this year.

A contract was signed for design and construction of a reactor powerplant for the first nuclear-powered merchant ship.

Industrial participation increased both under the Commission's Power Demonstration Reactor Program and in independent plans for construction of reactors.

Two formal proposals were received from private industry to build central station power reactors—one in Florida, one in the Midwest—in response to a third invitation issued in January by the Commission under its demonstration plan. In this and similar invitations, the Commission undertakes in selected cases to supply research and development work, or to make other contributions, in exchange for full technical and economic data on new and promising types of reactors.

In other developments under the demonstration program, a contract was signed with the Power Reactor Development Co. for a 100,000-kilowatt reactor in Michigan, this being the second contract under the program. In connection with still another proposal, a contract was signed for development work on a new type of reactor proposed for construction in Alaska.

Full-scale construction got under way this spring on the Commonwealth Edison Co. 180,000-kilowatt powerplant near Joliet, Ill., and on the Consolidated Edison Co. 275,000-kilowatt combined nuclear and conventional plant at Indian Point, N. Y. The 5,000-kilowatt reactor plant of the General Electric Co. and Pacific Gas & Electric Co. at Pleasanton, Calif., was completed and was scheduled to begin operation soon. These three reactors are being financed exclusively from private sources.

Three additional industrial groups announced independent plans to build four full-scale atomic powerplants: one in California, two in the Ohio River Valley, and one at an undetermined site. This brings to 10 the number of power reactors which private organizations are building or have announced plans to build.

Summary of Reactor Activity

During this reporting period, 11 nuclear reactors built in the United States achieved criticality for the first time. Two of these were the Sodium Reactor Experiment and the Army Package Power Reactor reported above. Six of the remaining 9 reactors were for research and training purposes—one of these was operating in The Netherlands—and three were critical experiments.

In the same 6 months period construction was begun, major components were ordered or construction permits were issued, for a total of 22 reactors in the United States. The 22 included one Commission power reactor experiment, 11 military power reactors, two research reactors, two testing reactors, and six critical experiments. All these reactors except two critical experiments previously were tabulated as in the planning stage. Licenses were issued for export of seven research reactors.

The largest expansion took place in the category of new reactors planned: Intent to build 35 reactors in the United States, of which 7 would be exported, was announced during the reporting period. Of the total, 24 would be research and training reactors (6 for export), 2 would be testing reactors, and 3 critical experiments. Six of the 35 reactors were announced as full-scale civilian power reactors (1 for export); 4 of these were announced by industry as independent projects.

A complete list of nuclear reactors built, building, or planned in the United States as of June 30 is printed in Appendix 12.

Industrial Developments

The Commission took important steps toward enhancing the economic position of the developing private atomic energy industry:

Pending establishment of commercial facilities operating at reasonable prices, the Commission undertook to process used fuel elements from reactors in this nation and in other countries which have agreements for cooperation with the United States. The Commission published the bases of charges for this service.

The Commission also announced guaranteed purchase prices for fissionable materials generated in reactors here and in cooperating countries.

During this reporting period, insurance companies announced the formation of three syndicates or pools to provide liability protection up to $60 million per installation for operators of such nuclear facilities as nuclear reactors. The Commission supported before Congressional committees legislation for Government provision of supplemental liability protection and made recommendations on bills on this issue. The Commission also reported to the Congress a study undertaken to estimate the damage that might result in the remote possibility that a nuclear accident should occur.

The issuance in January of a regulation setting up requirements for protection of health and safety in licensed nuclear operations rounded out the basic pattern of regulation for the atomic energy industry.

The Trend in Licensing and Permits

Increasing industrial and private research activity was evidenced by applications for permits to construct nuclear reactors, and licenses to operate reactors. The number issued during the last 6 months was at an all-time high with three construction permits issued for five research reactors. Three permits authorizing construction of critical nuclear assemblies also were issued.

During the same reporting period, 7 applications were received for construction of 18 research reactors. One application covered manufacture of 12 research reactors of the same type for sale in this country and abroad; in the previous period, the same manufacturer requested a permit to build 5 of these reactors. The Commission published notice in June of its intention to issue a permit for these 17 reactors. At the end of the reporting period, 20 applications were pending for construction of a total of 32 research reactors, 1 power reactor, and 2 critical assemblies.

Radioisotopes

Radioisotope users in the United States during the same period increased from slightly over 3,600 to 4,109, a rise of about 12 percent. Radioisotopes were contributing to the economy by an annual saving of some $400 million in industrial uses alone, a Commission survey indicated. Various new and broadened uses of radioisotopes by industry are reported in the section on Civilian Application in this report.

Distribution of Information

The Commission in February accelerated the review of technical documents classified as confidential or secret in order to speed the distribution of industrial information made available when the new declassification guide was issued last December. The guide is intended to bring into the open literature and the realm of open technical discussion the technology necessary for industrial applications, and the basic data for fundamental research. Military applications of atomic energy, of course, remain classified and closely guarded.

The accelerated review covered some 18,700 documents, of which 9,100 were made available to the public on an unclassified basis, and were entered in abstracts and other lists of technical material for sale to the public. Some 5,300 other documents and technical reports were downgraded from secret to confidential, and hence made more

easily available to persons granted permits for access to restricted data for industrial and commercial usages.

Requests for permits to have access to confidential or secret restricted data continued to be received at a rate of 36 a month and, as of June 30, a total of 1,327 was in effect.

Sales of confidential and secret documents to those permitted to receive them mounted steadily, and total sales as of June 30 reached 22,393 confidential, 4,772 sold this year, and 5,668 secret reports, with 1,980 of these sold this year.

Six classified libraries, open to access permittees, were established by the Commission in locations across the Nation, and 11 more unclassified libraries were authorized bringing the total to 77.

A management survey to evaluate Commission technical information services found that the services offered were generally satisfactory to access permit holders.

Education and Training

The Commission's Education and Training program, as part of the national effort to increase the supply of scientists and engineers, was well developed as of this reporting period, two years after its inauguration. Grants of $3.3 million were made to help equip college and university laboratories; a new research and teaching reactor suitable for campus use—the Argonaut—was demonstrated; fellowships were offered to 117 students; capacity was doubled in graduate schools operated by the Commission installations and universities combined; and high school programs again included summer institutes for teachers and a special traveling-teacher program for pupils and teachers.

On Edison's birthday, 4,400 high school students accompanied by their teachers visited by invitation eight Commission laboratory and production installations. More than 2,000 information kits a month were being sent on request to students and teachers.

A survey of training and education programs among Commission contractors showed that more than 13,000 scientists and technicians participated in training conducted, sponsored, or assisted by 24 contractors.

Exhibits and Films

Nearly 3 million persons have seen Atoms for Peace exhibits put on tour by the Commission during the previous reporting period, and the three large exhibits and eight truck-housed exhibits were booked for many months ahead.

Four new films were added to 12 regional motion picture libraries maintained by the Commission and, during the January-June reporting period, films were loaned for more than 7,500 showings to an estimated 415,000 persons.

International Activities

The United States continued during this reporting period its rapid progress toward increased international cooperation on the peaceful uses of atomic energy.

Agreements for Cooperation

Four new agreements for cooperation went into effect—with Australia, Guatemala, Norway, and Switzerland—making a total of 36 in force, of which 7 included power reactors. In addition, negotiations were completed on 14 agreements (6 included power), and discussions were held on 6 other agreements, all of which would cover power. A total of 56 agreements had been discussed or was in force with 49 nations and amendments to 8 of these agreements were in force or being discussed.

As of June, 2 reactors manufactured in the United States were operating in other countries, licenses to export 8 other reactors from the United States had been issued, and 17 more were planned, including 8 power reactors—a total of 27 reactors installed or projected.

International Agencies

With approval of ratification on June 18 by the United States Senate, 12 countries had approved the Statute of the International Atomic Energy Agency. When 18 nations including, besides the United States and the Soviet Union, one more major atomic energy power, i. e., Canada, France, or the United Kingdom, have given formal notice of approval, the Statute goes into effect.

Six European nations formed the European Community for Atomic Energy and projected plans for construction by 1967 of nuclear reactors to produce 15 million kilowatts of electricity in the countries that are members of Euratom: Belgium, France, the Federal Republic of Germany, Italy, Luxembourg, and The Netherlands. Representatives of Euratom visited United States atomic energy installations and those of other countries, and the Commission has offered assistance to the Community.

Establishment of an Inter-American Nuclear Energy Commission within the Organization of American States to serve as a consultation

and coordination center on the peaceful uses of atomic energy was approved by the Inter-American Committee of Presidential Representatives.

Educational Activity

Two symposia on peaceful uses of atomic energy were held for representatives from the American states with the assistance of the Commission.

At a regional conference in Puerto Rico, attended by 1,200 persons, the Spanish-language nuclear center to be established at the University of Puerto Rico with the cooperation of the Commission was described.

Leading scientists, engineers and Government officials from the American nations attended a symposium at the Commission's Brookhaven National Laboratory which explored the present and future of nuclear technology and peaceful applications in the Americas.

With the current enrollment of 48 students from 25 countries in special courses in atomic energy technology conducted for the Commission, 211 students from 41 nations had received instruction.

Five additional technical libraries were approved during this reporting period for presentation by the United States, raising to 52 the total to be placed in other countries or with international organizations.

Emphasis continued on programs for interchange of technical information between the United States and other nations, including planned participation in two major international conferences. The Commission also determined that it would give financial support to selected unclassified international conferences on scientific subjects relating to atomic energy.

Commission headquarters received unclassified visits from 674 foreign nationals of 59 countries, its installations, visits from 615 nationals of 62 countries.

Operations and Other Major Activities

Raw Materials

Rates of uranium production both in the United States and in other areas of the free world continued to mount, and reached a point where the United States has a 10-year uranium supply in sight, that is, the supply from sources now under contract, and from estimated increases in domestic production, will provide for the military and civil power development programs as projected for the next 10 years, and for the United States international commitments. In the United

States alone, the annual rate of production was expected to approximate 14,000 tons of uranium oxide by the end of 1958, with some 22 mills processing more than 18,000 tons of ore daily.

Production

Construction of new production facilities has kept abreast of the expanding supply of raw materials and the output of special nuclear materials during the January–June reporting period equalled or exceeded the total of the preceding 6 months and met the requirements of military and civil programs.

Another Commission plant for producing feed materials will go into production next year, and a privately financed plant to supply feed materials under contract to the Government was to be constructed near the Paducah, Ky., gaseous diffusion plant.

Weapons

The Commission continued production of a variety of nuclear weapons, including weapons for defense, in accordance with Presidential directive.

Expansion of research and development and production facilities proceeded according to schedule.

Weapons tests were conducted at the Nevada Test Site, the first on May 28, in accordance with the Commission policy of periodically using this site for experiments or tests involving relatively low-yield nuclear detonations. The Commission arranged for on-site observation of designated tests by representatives of United States news media, by State and local civil defense organizations, and by news and civil defense representatives from other countries which have special defense arrangements with the United States.

Military Reactors

The USS *Nautilus* was refueled after this first nuclear-powered submarine cruised more than 62,000 miles, some 36,000 while fully submerged. In a May cruise on the second loading of nuclear fuel, the *Nautilus* traveled more than 3,000 miles without surfacing.

The land-based prototype of the USS *Seawolf's* reactor was shut down. The *Seawolf* ran her sea trials and a Naval board recommended that this submarine, powered with a sodium-cooled reactor, be accepted for restricted service, but that the reactor ultimately be replaced with a *Nautilus*-type powerplant.

The *Skate*, first of a new class of five nuclear submarines planned by the Navy, was launched at Groton, Conn., on May 16.

Design and development work continued on other naval reactors, including a powerplant for a cruiser, and one for a destroyer.

A contract was let for design and construction of a gas-cooled powerplant reactor for the Army.

Construction of test and service facilities began for the aircraft reactor program.

The Commission continued studies relating to the application of nuclear power to rocket and ramjet engines.

Research

In the *reactor* field, in addition to those experiments near completion and reported earlier, development work went forward on a number of reactors, including the fast breeder reactors, and molten plutonium and other liquid metal-fueled reactors.

The Commission carried forward its program to improve reactor safety with two reactor experiments at the National Reactor Testing Station in Idaho, and a third in California.

The Engineering Test Reactor was scheduled for completion this summer for use chiefly in the Commission's reactor development program.

Development work continued on new types of fuel elements, including plutonium-alloy elements and some containing 20 percent of uranium 235—the top enrichment generally permitted for shipment to other countries under agreements for cooperation.

A varied program on improved chemical processing of irradiated fuel elements, and on disposal of various types of radioactive wastes, was continued.

In the *physical and life sciences* research continued to produce important contributions to basic knowledge.

Discoveries in high energy physics led to challenging new theories of fundamental interest in understanding nuclear forces. The structure of liquid metals and their fundamental nature were explored.

A large machine called a "Stellerator" was authorized to advance studies on the control of thermonuclear reactions. Unclassified background knowledge about research in this field is summarized in this report.

The Commission program to advance design and use of "electronic brains" in atomic research is described.

Biomedical, biophysical, and biochemical studies of the effects of radiation on living systems, the treatment of these effects, and protection against them, are summarized in this report.

Three additional projects in the study of the effect of radiostrontium in fall-out material from nuclear weapons tests are reported.

The report reviews the status of the Rongelap residents, returned to their home island some three years after accidental exposure to test fall-out, necessitated their evacuation.

The Commission took part in presentations made before the Joint Committee on Atomic Energy in extensive hearings during May and June on fall-out from weapons tests and presented, as requested, facts and analysis concerning the effects of fall-out with particular reference to the continuance of weapons tests.

The Department of Defense and the Commission published in July a 579-page handbook providing a comprehensive summary of current knowledge on the effects of nuclear weapons. "The Effects of Nuclear Weapons" [2] contains the results of observations and experiment in laboratory work and nuclear test detonations since 1950, and brings up to date "The Effects of Atomic Weapons" issued in that year.

Communities

Housing lots, and commercial properties were on sale in the atomic energy communities of Oak Ridge, Tenn., and Richland, Wash.

In Oak Ridge, where the first offering was made in July of last year, 87 percent of the 4,360 residences have been purchased, and 15 percent of the lots.

Residential properties in Richland were offered for sale in June after a delay occasioned by residents' objections to the appraised values initially placed on the properties. Of 228 residential lots offered, 11 percent were sold.

In Los Alamos, N. Mex., gates and guards were removed from the approaches and, after some 13 years of restricted access, it became an open town. Air space over Los Alamos still is controlled.

New Headquarters

With its new office building nearing completion in Germantown, Md., some 23 miles northwest of Washington, D. C., the Commission planned to move its headquarters there during November.

Safety and Fire Protection

The accident record for all Commission activities showed an increase during 1956, but the days absent for all injuries were fewer. Industrial property losses, chiefly resulting from one fire, were above usual

[2] See p. 117, Twentieth Semiannual Report to the Congress (January–June 1956).

Commission experience and for the first time were about as high as national averages for the best class of industrial risks.

Personnel

On June 17, the President nominated John F. Floberg to a 5-year term on the Commission, replacing Commissioner Thomas E. Murray whose term expired June 30; and nominated John S. Graham to fill the unexpired term of the late Commissioner John von Neumann, ending June 30, 1959.

William Mitchell resigned as General Counsel of the Commission effective June 15.

Eger V. Murphree was appointed April 17 to the General Advisory Committee to fill the term of Dr. Eugene P. Wigner, resigned, which ends August 1, 1958.

Dr. Harold A. Fidler, Manager of the Commission's San Francisco Operations Office, was one of 10 Federal employees to receive this year's National Civil Service League Career Service Awards. W. Kenneth Davis, Director of the Commission's Division of Reactor Development, received an Arthur S. Flemming award.

During 9 months of fiscal year, 1957, the Commission made 101 awards for superior performance, one for a special act or service, for a total of about $24,000.

Commissioner von Neumann

Commissioner John von Neumann died on February 8 after a long illness. At its first meeting afterward, the Commission adopted the following resolution:

"With a profound realization of the loss that we have suffered in the death of our well-loved colleague, John von Neumann, we meet today in sorrowful recognition of the irreplaceability of his talents and of the tragedy to us as individuals, to the Commission, and to the Nation.

"A man blessed with extraordinary intellectual gifts, preeminent in his generation in the sciences, the value of his contributions to the work of this Commission is truly incalculable. His disciplined mind simplified the most difficult problems and enabled wise decisions to be reached. His human qualities, personal charm, his warmth, sense of humor and his wide sympathy endeared him to every member of the organization, and the particular place he made for himself in our affections cannot be filled.

430209—57——2

"To his widow and the members of his family whose grief and affliction we share, we, his colleagues, extend our heart-felt sympathy."

Fuel for Research and Power Reactors

An additional 59,800 kilograms of uranium 235 was designated by President Eisenhower during the January–June reporting period for use over a number of years in peaceful applications of atomic energy, bringing to 100,000 kilograms the total earmarked for these purposes. The uranium 235, to be sold or leased, will be divided equally between users in the United States and in other countries. The announcement was made July 3 by the President on the recommendation of the Commission's Chairman, with the concurrences of the Secretaries of State and Defense.[3]

The additional quantities made available are 30,000 kilograms for lease in the United States for all licensed civilian purposes, principally for power reactors; and 29,800 kilograms for sale or lease to individual nations or groups of nations which have entered Agreements for Cooperation with this country.

These amounts are in addition to the 40,000 kilograms of uranium 235 designated on February 22, 1956,[4] and the 200 kilograms designated earlier.[5] At current prices, as established by the Commission last November, the value of the 100,000 kilograms of uranium is about $1.7 billion.

The President's statement called attention to an earlier promise, made at the time of the first major designation of nuclear material, that more supplies would be made available for sale or lease as necessary for additional nuclear power projects.

The President stated his gratification that the advance toward nuclear power and scientific and technical knowledge was proceeding at a pace which required providing additional supplies.

The Commission's Chairman stated that the Commission's recommendation to the President was due to the progress of the development of nuclear power in this country and abroad. Of the 20,000 kilograms of uranium previously designated for use in this country, approximately 17,000 kilograms already have been allocated under licenses, and other licenses are being considered. Plans with nations which have concluded or are negotiating power agreements with the United States call for more than the 20,000 kilograms previously designated for foreign lease or sale. Under these licenses or agreements, uranium 235 is allocated not only for the initial loading of a reactor, but also

[3] Text of the President's and Chairman's statements, and additional details issued simultaneously, appear in Appendix 13 of this report.

[4] See pp. vii–ix, and 252–54, Twentieth Semiannual Report to the Congress (January–June 1956).

[5] See p. 12, Eighteenth Semiannual Report to the Congress (January–June 1955).

the estimated consumption during the period of the license or agreement, and pipeline requirements for fabrication, processing, etc.

The uranium 235 is made available only under conditions prescribed by the Commission, either in this or other countries, and is subject to prudent safeguards against diversion of the materials to non-peaceful uses. The fact that the Presidential determination of uranium 235 allocated equal amounts for domestic and foreign users does not necessarily create a pattern for any future designations of nuclear materials.

MAJOR ACTIVITIES IN THE ATOMIC ENERGY PROGRAM, JANUARY–JUNE 1957

Raw Materials

Production of uranium ore and concentrates from free world sources continued to increase during the first half of 1957. Construction of new ore processing facilities in the United States and in other countries will produce further increases. The United States reached the position where a 10-year uranium supply is in sight, that is, the supply from sources under contracts and from estimated increased domestic production will provide for the military and civil power development programs as projected for the next 10 years, and for the United States international commitments.

Domestic Activities

Domestic production of uranium ore and concentrates continued to increase during the reporting period. The United States was the free world's leading uranium producer and gave evidence of maintaining this position for some time to come, with a predicted rate of production in excess of 10,800 tons of uranium oxide (U_3O_8) per year by the end of 1957. By the end of 1958 the annual production rate should approximate 14,000 tons of uranium oxide.

Ore Production

Uranium ore production in the United States totaled about 1.62 million dry tons during the last 6 months as compared to 1.66 million dry tons during the last half of 1956 and 1.34 million dry tons during the first 6 months of 1956. It is expected that mine production will continue to rise and ore stockpiles will gradually be reduced with completion of new processing facilities already under construction or planned.

No significant new uranium producing area was discovered in the United States, and the number of producing mines remained about the same. Production from existing mines continued to increase, however, and additional ore reserves were developed in several producing areas, notably the Ambrosia Lake area, N. Mex., and the Wyoming Basins.

New leasing procedure. A regulation establishing procedure for issuing prospecting permits and mining leases on lands administered

by Federal agencies which do not have authority to lease the lands was published in *The Federal Register* on March 5 (10 C. F. R. Part 60, Section 60.9). The Bureau of Land Management, Department of the Interior, will assist the Atomic Energy Commission in administering the new procedure. The Bureau will receive and process applications on behalf of the Commission, and the Commission will approve and issue permits and leases. Applications are to be filed in the Bureau's Land Office for the State in which the land is situated. Permits and leases will not be issued under this regulation for lands administered by the United States for national park, monument, or wildlife purposes.

Bonus payments. More than $10.5 million has been disbursed in bonus payments since establishment in March 1951 of the Commission's Initial Production Bonus Program. This bonus program provides for a graduated bonus of up to $35,000, depending upon the quantity and grade of ore, for the initial production and delivery of acceptable uranium ore from new mining properties. Payments have been made to 1,066 operators for production from 832 mining properties. Transfers of ownership or leases are responsible for the number of operators being greater than the number of properties.

Milling Operations

Production of uranium oxide (U_3O_8) concentrates during the first half of 1957 totaled 4,200 tons as compared to 3,400 tons for the last half of 1956 and 2,600 tons for the first 6 months of 1956.

As of the end of June, 12 mills were in operation with a total capacity of 9,210 tons of ore per day, and 10 more were under construction or planned, with contracts signed for the purchase of concentrates. A list of mills operating as of June 30 follows:

Location	*Company*	*Tons of ore per day*	*Cost of mill (approximate)*
Tuba City, Ariz	Rare Metals Corp. of America	250	$3, 600, 000
Durango, Colo	Vanadium Corp. of America	430	813, 000
Grand Junction, Colo	Climax Uranium Co	350	3, 088, 000
Naturita, Colo	Vanadium Corp. of America	350	1, 000, 000
Rifle, Colo	Union Carbide Nuclear Co	280	1, 600, 000
Uravan, Colo	Union Carbide Nuclear Co	1, 100	5, 000, 000
Grants, N. Mex	The Anaconda Co	3, 000	19, 358, 000
Shiprock, N. Mex	Kerr-McGee Oil Industries	500	3, 161, 000
Edgemont, S. Dak	Mines Development, Inc	300	1, 900, 000
Moab, Utah	Uranium Reduction Co	1, 500	8, 250, 000
Monticello, Utah	Government-owned	600	5, 000, 000
Salt Lake City, Utah	Vitro Uranium Co	550	5, 500, 000
Subtotal		9, 210	58, 270, 000

Mills under construction or under contracts, as of June 30, follow:

Location	*Company*	*Tons of ore per day*	*Cost of mill (estimated)*
Gunnison, Colo	Gunnison Mining Co	200	$2, 025, 000
Maybell, Colo	Trace Elements Corp	300	2, 208, 000
Rifle, Colo	Union Carbide Nuclear Co	1, 000	8, 500, 000
Grants, N. Mex	Homestake-New Mexico Partners.	750	5, 325, 000
Grants, N. Mex	Homestake-Sapin Partners	1, 500	9, 000, 000
Grants, N. Mex	Kermac Nuclear Fuels Corp	3, 300	16, 000, 000
Mexican Hat, Utah	Texas-Zinc Minerals Co	775	7, 000, 000
Ford, Wash	Dawn Mining Co	400	3, 100, 000
Fremont Co., Wyo	Lucky Me Uranium Corp	750	6, 900, 000
Split Rock, Wyo	Western Nuclear Corp	400	3, 600, 000
Subtotal		9, 375	63, 658, 000

The two categories of mills, operating and projected, will together handle a total of 18,305 tons of ore a day. The total is 280 tons less than indicated in the tables because the new Union Carbide mill at Rifle, Colo., will replace the one now operating. Total cost of all the mills is estimated at $122 million.

Much of the new production from mills under construction or planned will come from the Ambrosia Lake district of New Mexico and from the States of Wyoming and Washington. These three new areas contain about 50 percent of the presently estimated ore reserves of the United States. As the new mills are completed, concentrate production will increase rapidly. By the end of 1958 domestic production should approximate a rate of 14,000 tons of uranium oxide per year. The annual value of the uranium production of the Western States for 1958 should be approximately $236 million.

The Commission signed contracts with two companies to purchase uranium concentrates from pilot plant operations. The Cotter Corp. 50-ton-a-day pilot plant will be located near Canon City, Colo. Ramapo Uranium Corp. operated a pilot plant at Warwick, N. Y., to determine the economic feasibility of producing uranium concentrates from its ore, using a gravity separation process.

Ore-buying stations. Two ore-buying stations and sampling plants closed during the first half of 1957.

The station at Marysvale, Utah, was closed March 15. Most mines tributary to Marysvale are currently selling their ore directly to Vitro Uranium Co. at Salt Lake City, Utah.

The ore-buying station near Globe, Ariz., was closed on June 30. Ore production and reserves in the district did not indicate a reasonable prospect for an economic milling operation.

The station at White Canyon, Utah, will be closed in the near future. The opening March 1 of Texas-Zinc Minerals Corp. ore-buying station at Mexican Hat, Utah, preparatory to completion of the mill now under construction, provided a market for ores produced in the area. The remaining three ore-buying stations at Grants, N. Mex., and Crooks Gap and Riverton, Wyo., will be closed as new ore-processing plants come into production and purchase ore direct from producers. Commission ore-buying operations at Monticello, Utah, are in connection with the Commission-owned mill.

Uranium from phosphates. Small tonnages of byproduct uranium concentrates continued to be produced from Florida phosphate rock during the reporting period.

Domestic Exploration

During the period of this report, private activity continued to be concentrated on development work within previously discovered areas. Uranium ore reserves in the United States continued to increase, and at the end of this reporting period were estimated at approximately 67 million tons containing about 174,000 tons of uranium oxide. The average grade of these reserves is about 0.26 percent uranium oxide or 5.2 pounds of uranium oxide per ton of ore.

Private organizations carried out all physical exploration and drilling during the period. The Commission's geologic program consisted of evaluating private development, current reserves, and prospective rates of production in support of the immediate production program, and geological studies and evaluations to support long-range planning.

Foreign Activities

Uranium reserves in the free world from which production can be obtained at present prices amount to approximately 1 million tons of uranium, of which three quarters are in Canada, South Africa, and the United States. Prospects are considered favorable for developing at least an additional 1 million tons in these countries and in the Belgian Congo, France, Australia, and Portugal.

Europe, whose requirements for uranium for power reactors will be large and are expected to develop quickly because of the need to supplement high-cost power from conventional fuels, is in a relatively poor position with respect to presently known reserves on the continent. The major source in Western Europe is France, which estimates its reserves at between 50 and 100 thousand tons of uranium. France

hopes to raise its production from the present 400 tons per year to 3,000 tons per year by 1975.

South Africa

Production from South Africa increased during the period and by the end of June was at a rate of 5,400 tons of uranium oxide per year. The seventeenth and final processing plant authorized in the program was completed and began operating in May.

An official South African announcement in January stated that uranium oxide production for 1956 totaled 4,400 tons and that the production at the end of 1956 was at an annual rate of 5,000 tons. It was estimated that the production rate at the end of 1957 would be 6,000 tons a year.

The South African uranium-bearing gold reefs represent the greatest known uranium reserve in the western world, according to present official estimates which place reserves at more than 1 billion tons of ore containing some 370,000 tons of uranium oxide. At the present projected rate of production, these reserves would last for more than 50 years. This figure does not represent the total potential of this area. However, production of uranium is dependent to a large extent upon gold production, because the ore averages only about one-half pound of uranium oxide per ton.

Canada

Canadian reserves of uranium ore, officially estimated in December 1956 at 225 million tons containing about 240 thousand tons of uranium oxide, constitute the second largest presently known reserves in the western world. Canadian ores average slightly more than 2 pounds of uranium oxide per ton, considerably higher than the South African, but only about half the average grade of deposits in the United States.

Production in Canada was at a rate of 3,300 tons of uranium oxide a year at the end of 1956, and it has been announced that it will reach a rate of 14,000 to 15,000 tons a year by mid-1958. Canadian production can be maintained at the presently planned rate for 15 to 20 years on the basis of the official reserve estimate. However, the Canadian production potential is much greater than the official reserve figure would indicate, since it may be assumed that reserves will be greatly expanded in presently known districts.

During the last 6 months, the two mills of Algom Uranium Mines in the Blind River area of Ontario reached their rated capacities of 3,000 tons of ore a day each: the Quirke Lake mill, which started op-

eration in October 1956; and the Lake Nordic plant, which began operating in January 1957. The Consolidated Denison mill, with a rated capacity of 5,700 tons per day, started production in June. The mill of Pronto Uranium Mines reached a steady operating rate of 1,500 tons per day. Seven additional plants, with a total rated capacity of about 21,000 tons per day, were under construction.

In the Bancroft area of eastern Ontario, the 1,000-ton mill of Bicroft Uranium Mines, which commenced operation in October 1956, reached rated capacity. The 750-ton mill of Faraday Uranium Mines Limited, which began production in April, was being expanded to treat an additional 500 tons per day from Greyhawk Uranium Mines. Dyno Mines Limited continued construction of a 1,000-ton-per-day treatment plant.

In the Beaverlodge area of Saskatchewan, expansion of the Gunnar mill to a capacity of 1,650 tons of ore per day was completed. The expansion of Eldorado's Beaverlodge mill was well advanced, with mill operation at a rate of about 1,750 tons per day. Production of concentrates has started from Lorado Uranium Mines Limited 700-ton-per-day custom mill. This is the first privately operated custom uranium mill in Canada.

Eldorado's Port Hope refinery was producing metal grade uranium oxide for shipment to Commission plants at an average rate of about 345 tons per month.

Australia

Low-grade mechanical concentrates from the Radium Hill mine in South Australia continued to be treated at a normal rate at the Port Pirie chemical plant. Uranium concentrates continued to be produced according to schedule from the Rum Jungle operations in the Northern Territory.

Production in Australia should increase markedly beginning in 1959 when milling operations are scheduled to start at a third deposit, the Mary Kathleen, near Mt. Isa in Queensland. The United Kingdom has contracted to purchase uranium from this property. Australia has vast areas geologically favorable for uranium, but exploration to date has been limited.

Portugal

Portuguese operations continued at a normal rate during the first 6 months of 1957.

Belgian Congo

The Shinkolobwe mine in the Belgian Congo continued to produce uranium at a normal rate during the period.

Exploration Activities

During the first half of 1957, the Commission continued to cooperate in exploration programs for uranium in Australia, Brazil, and Peru. A preliminary visit was made to Argentina at the request of the Argentine Government for consultation on exploration problems. Cooperative exploration projects with Chile and Colombia are under consideration.

Process Development

The main effort in the program of raw materials process development during the first half of 1957 was in operation at the Grand Junction, Colo., pilot plant and in the Winchester, Mass. Laboratory. Additional studies were conducted by the Columbia University School of Mines; the U. S. Bureau of Mines Experimental Station in Salt Lake City; the Mackay School of Mines of the University of Nevada; the Dow Chemical Co. research laboratory in Pittsburg, Calif., and Oak Ridge National Laboratory, Oak Ridge, Tenn.

During this period, tests were made in the Grand Junction pilot plant to demonstrate the amenability of particular ores to conventional processing and to derive data necessary for contract negotiation. The ores under study were from the Ambrosia Lake area in New Mexico, from Wyoming, and from southern Oregon. It appeared that either acid or alkaline leaching might be considered for most Ambrosia Lake ores, subject to confirmatory pilot-plant tests when samples are available from additional underground workings. If acid leaching is used, solvent extraction for recovering dissolved values may be attractive as an alternate to ion-exchange resins. The acid-leach solvent-extraction process is applicable to ore from southern Oregon.

Another item in the pilot-plant program was work to develop a process suitable for recovery of uranium from uraniferous lignite. Earlier laboratory work showed that this material should be amenable to a process including roasting to destroy organic matter, followed by conventional acid leaching and solvent extraction. Solvent extraction is superior to ion exchange for recovery of dissolved values, because impurities cause less interference in this process. The pilot-plant demonstration checked bench-scale results on selected ore

samples taken from major deposits in North and South Dakota. Detailed reports covering this work were made available to interested parties. The economics of lignite processing pose a number of problems because the process includes roasting and high acid consumption.

The Winchester laboratory, which makes the preliminary study necessary to pilot-plant demonstration, continued its investigation of new ideas for reducing costs and improving efficiency in uranium ore-processing. A study of the characteristics of new solvents offered by chemical manufacturers, and an evaluation of solvent extraction relative to resin ion-exchange as applied to the recovery processes of various established processing mills, were among important projects. Continued effort on analytical work to improve procedures resulted in a number of cases of improved accuracy, quicker results, and lower costs. The results of all this work, both laboratory and pilot-plant, were made available to the public promptly.

At the Columbia University School of Mines work on methods for recovery of uranium from Chattanooga Shale was being completed. This project was undertaken to develop preliminary process and cost data on the utilization of this enormous potential of uranium.

Two methods have been under study. One method involves the chlorination of the whole mass of shale and volatization of the chlorides of uranium, iron, aluminum, potassium, and some other metals. Subsequent process steps would reclaim chlorine for re-use and would recover valuable byproducts, as well as uranium. This phase of the work was substantially completed. It indicated a possible method for future consideration.

The other method concerned acid-leaching by conventional but specially adapted procedures, followed by recovery of dissolved uranium values by solvent extraction.

At the Bureau of Mines Experimental Station in Salt Lake City, the work on process development studies continued. Certain phases of this work in the past largely influenced the process selection and engineering design in several privately owned ore-processing plants. The Bureau continued routine testing of the amenability of ores to various processes and to special and specific tests in unit processes.

At the University of Nevada, Mackay School of Mines, a concentrated effort was continued to overcome the obstacles which lie in the way of concentrating the uranium values in ore by flotation or by other methods. No significant new discoveries were reported.

At the Dow Chemical Co. research laboratory in Pittsburg, Calif., fundamental studies of the chemistry of uranium, particularly in solvent extraction, were carried out. Final reports are in preparation; the Dow contract will be concluded; the Winchester Laboratory and Oak Ridge National Laboratory will carry forward the work.

Solvent extraction, as a method for selectively recovering uranium from leaching liquors, is a relatively new process in extractive metallurgy. The leaching liquors from some ores may be more economically treated by solvent extraction than by ion exchange, and it appears that this process will be of value as an alternate. The use of solvent extraction in the recovery of uranium from ores is an outgrowth of the use of solvents in feed materials plants. The original work on development of suitable solvents for use in uranium ore processing was done by Oak Ridge and by Dow Chemical. The development of processing techniques and their application have been studied by the Bureau of Mines at Salt Lake City, the Winchester Laboratory, and the Grand Junction pilot plant. As a result of this research work, three privately-owned ore processing mills have adopted solvent extraction as more efficient than previous methods.

Production of Special Nuclear Materials

During the first 6 months of 1957, production of special nuclear materials equalled or exceeded the quantity produced in the previous period and met the requirements for the military and civilian application programs. The various production facilities operated satisfactorily without major incident.

Construction of Plants

Completion date for construction of the new Weldon Spring, Mo., feed materials production center was changed from November 1957 to April 1958. As of June 30, construction was ahead of the revised schedule. The first unit, a sampling plant, was completed on February 8. The refinery began startup operations during May.

On February 4, the Allied Chemical and Dye Corp. announced selection of Metropolis, Ill., as the site of its plant to process 5,000 tons of U_3O_8 a year under contract with the Commission. The plant will produce uranium-hexafluoride feed for the nearby Paducah, Ky., gaseous diffusion plant.

Industry Participation

On April 1, proposals for the purchase of 4,000 tons of uranium-magnesium fluoride slag per year for 5 years, were received from: General Chemical Division, Allied Chemical and Dye Corp., New York, N. Y.; Hazen Metallurgical Corp., Denver, Colo.; The Spencer

Chemical Co., Kansas City, Mo.; Vitro Corp. of America, New York, N. Y.

Under the terms of the proposals, the recovered uranium will be resold to the Government.

The Commission last year announced a program to invite proposals for the construction and operation of facilities for radiochemical processing of irradiated fuel elements to be made available by the Commission. The facilities would also be capable of processing civilian power reactor fuel. In March a preliminary draft of such an invitation was sent to interested industrial firms for their consideration and comment.

The administrative and management aspects of this preliminary draft were discussed at an information meeting held in Washington on April 25. The meeting was attended by 47 representatives from 35 industrial firms and organizations. By the end of June 17 replies to the draft proposal had been received and the replies were being studied. Additional comments were expected from firms that requested more time to consider the proposal.

Pending establishment of commercial radiochemical processing facilities, the Commission announced February 18 that it had adopted a basis for providing these services to operators of private nuclear reactors (see Civilian Application).

Military Applications

During the period of this report emphasis continued on research and development activities designed to improve and increase the United States arsenal of nuclear weapons. Development programs continued on weapons employing new design principles which can be used more effectively for defensive purposes. Work went forward on methods of reducing the radioactive contamination resulting from weapon detonations.

Production continued during the reporting period in accordance with a Presidential directive on a variety of nuclear weapons, including weapons for defense against attack.

Weapons Testing

In accordance with Commission policy to use Nevada Test Site periodically for experiments or tests involving nuclear detonations of relatively low yield, the Commission on January 25 announced "Operation Plumbbob," the test series being conducted at Nevada Test Site during this year. The operation began in March and will

continue through the summer. The first test shot was fired May 28.

Objectives of Operation Plumbbob include development and exploratory tests which will lead to development of weapons for defense against attack; proof tests of weapons scheduled for production; development of more efficient weapons; development of weapons with minimum fallout; and weapons effects tests in which the Department of Defense and the Federal Civil Defense Administration will participate.

Operational safety criteria for Operation Plumbbob are basically the same as those for Operation Teapot held in 1955. Each test detonation was carefully evaluated as to necessity and as to safety before it was included in the schedule. Devices to be tested were designed to have the lowest practical yield which will be sufficient for necessary research and development. Every effort was made to improve ways and means of detonating shots to reduce off-site fall-out. Improvements include: additional arrangements for forecasting of wind speed and directions; improved methods of predicting fall-out, blast intensity and location; increased height of detonation towers and use of balloons instead of towers.

Technological developments brought to the fore the possibility of using captive balloons for tests which permit some leeway in positioning the nuclear device. These balloons can be used effectively up to 2,000 feet above ground level. Several tests in the Plumbbob series will utilize this technique.

Another possible technique of reducing test fall-out would be that of firing shots deep underground so that the radioactivity would be contained. To study the feasibility of this arrangement, conventional high explosives were fired in underground tunnels at Nevada Test Site thus providing data on underground contamination and on ground shock transmitted off-site. In the Plumbbob series, an underground nuclear test is planned.

In addition to the series of nuclear tests, there will be further experiments related to assuring the safety of various weapons and experimental devices in event of accident or fire during handling or storage.

To assist general public understanding, particularly of the safety measures employed and of civil defense work, several Plumbbob tests are being opened to on-site observation by representatives of United States news media and Federal, State and local civil defense organizations, and by news and civil defense representatives from other countries of the free world which have special defense arrangements with the United States.

As in the past series at Nevada Test Site, the Nevada Test Organization was jointly staffed by the Commission, the Department of

Defense, the Federal Civil Defense Administration, and by their laboratories and contractors. Using the experience of past tests, the Commission and cooperating agencies developed and refined measures to assure public safety. These are described in Appendix 10.

Weapons Facilities

Expansion of the research and development and production facilities reported in the July–December 1956 report proceeded according to schedule.

Work continued on revisions and additions to laboratory facilities at Los Alamos Scientific Laboratory, Los Alamos, N. Mex., necessitated by nuclear and thermonuclear reactor programs and the nuclear propulsion program, as well as the continuing work on research and development of weapons. The original $125 million construction program initiated in 1948 neared completion, with construction of the last major building expected to begin this summer.

Construction was completed in January on a ballistics test range located to the northwest of the Nevada Test Site in southern Nevada. It is used for determining the ballistic characteristics of inert weapons shapes dropped from aircraft.

The Atomic Energy Commission exercised an option to purchase the General Electric Co. recently completed Pinellas Peninsula Plant. The plant is located between St. Petersburg and Clearwater, Fla., and was built to produce electronic equipment for the Commission. General Electric will continue to operate the plant under a contract with the Sandia Corp.

International Activities

The growing program of international cooperation, under the President's Atoms for Peace program, was focused during the reporting period on activities pursuant to the agreements for cooperation in atomic energy development with other nations, and on activities related to the establishment of an International Atomic Energy Agency. Assistance was offered in connection with the establishment of the European Community for Atomic Energy (Euratom). Emphasis was placed on developing the program for interchange of technical information between the United States and other nations. Close liaison was maintained with the Department of State and other government agencies in these activities.

Increasingly, since the beginning of the program for international cooperation other nations have shown an interest in developing

specific atomic energy projects. Discussions have been held with 49 nations and to date negotiations have been concluded on 50 agreements for cooperation. Thirty-six of these agreements are in force, the remaining agreements await completion of statutory procedures. (See table, Agreements for Cooperation, In Effect and Pending.)

As of June 30, two reactors manufactured in the United States were in operation in other countries, licenses to export 8 others from the United States had been issued, and 17 more were planned, including 8 power reactors.

430209—57——3

AGREEMENTS FOR COOPERATION, IN EFFECT AND PENDING

Country	Agreements in effect		Agreements pending	
	Type	Effective date	Negotiations concluded (type)	Under consideration (type)
1. Argentina	Research	July 29, 1955		Research and power.
2. Australia	Research and power	May 28, 1957		
3. Austria	Research	July 13, 1956		
4. Belgium	Research and power	July 21, 1955		
5. Brazil	Research	Aug. 3, 1955	Research and power	
6. Canada	Research and power	July 21, 1955		
7. Chile	Research	Aug. 8, 1955		
8. China, Republic of	Research	July 18, 1955		Research and power.
9. Colombia	Research	July 19, 1955		
10. Costa Rica			Research	
11. Cuba			Research	Research and power.
12. Denmark	Research	July 25, 1955		
13. Dominican Republic	Research	Dec. 21, 1956		
14. Ecuador			Research	
15. France	Research and power	Nov. 20, 1956		
16. Germany, Federal Republic of	Research	Apr. 23, 1956	Research and power. Research, City of West Berlin	
17. Greece	Research	Aug. 4, 1955		
18. Guatemala	Research	Apr. 22, 1957		
19. Iran			Research	
20. Iraq			Research	
21. Ireland			Research	
22. Israel	Research	July 12, 1955		

23. Italy	Research	July 28, 1955	Research and power	
24. Japan	Research	Dec. 27, 1955		
25. Korea	Research	Feb. 3, 1956		
26. Lebanon	Research	July 18, 1955		
27. The Netherlands	Research	Dec. 30, 1955	Research and power	
28. New Zealand	Research	Aug. 29, 1956		
29. Nicaragua			Research	
30. Norway	Research and power	June 10, 1957		
31. Pakistan	Research	Aug. 11, 1955		
32. Peru	Research	Jan. 25, 1956	Research and power	
33. Philippines	Research	July 27, 1955		Research and power
34. Portugal	Research	July 21, 1955		
35. South Africa			Research and power	
36. Spain	Research	July 19, 1955		Research and power
37. Sweden	Research	Jan. 18, 1956		
38. Switzerland	Research	July 18, 1955		
	Research and power	Jan. 29, 1957		
39. Thailand	Research	Mar. 13, 1956		
40. Turkey	Research	June 10, 1955		
41. United Kingdom	Research and power	July 21, 1955		
42. Uruguay	Research	Jan. 13, 1956		Research and power.
43. Venezuela	Research	July 21, 1955		

Agreements for Cooperation

New Agreements

During the January–June reporting period, discussions looking toward comprehensive agreements for cooperation in atomic energy research and power projects were conducted with Argentina, Republic of China, Cuba, the Philippines, Spain, and Uruguay. Negotiations were concluded with Brazil, Italy, Peru, and the Union of South Africa for research and power agreements. In addition, negotiations were completed with the Federal Republic of Germany for a research and power agreement, and also for an agreement to permit cooperation with the City of West Berlin in a research reactor project. Including these five agreements, negotiated during this reporting period, a total of 14 new agreements was pending, completed except for certain legal or formal steps in this country or in cooperating countries. Also among this group was a power agreement with the Netherlands and research agreements with Costa Rica, Ecuador, Iran, Iraq, Ireland, and Nicaragua.

Four new agreements became effective: a power agreement with Switzerland effective January 29, one with Australia effective May 28, and one with Norway effective June 10; a research agreement with Guatemala effective April 22. These agreements brought the total in force to 36—29 in research and 7 in research and power.

Amendments to Agreements

An amendment was being negotiated to the existing agreement with France to permit larger amounts of fuel to be transferred to that country.

Amendments to four research agreements became effective, with Denmark February 14, with the Federal Republic of Germany February 18, with Sweden March 12, and with Thailand June 19. An amendment to the Portuguese research agreement on June 11 was placed before the Joint Committee on Atomic Energy of the Congress where it must lie for 30 days. It will become effective then after an exchange of notes between Portugal and the United States. These amendments include new provisions clarifying the responsibilities of the signatories with respect to use of information, of special nuclear material, or of fuel elements transferred under the agreements. An additional provision will permit transfer of materials, including limited quantities of special nuclear materials, for use in defined research projects. The amendments to the Danish, German, and Swedish agreements permit transfer to these countries of 12 kilograms of

uranium 235 for use as fuel in research reactors, instead of the 6 kilograms provided in most research agreements.

The agreement with Belgium was amended, effective January 18, to permit broader exchange of information on methods of producing and utilizing reactor materials, and on fabrication of reactor components. Amendments to the agreements with Canada and the United Kingdom, effective January 18 and March 4 respectively, permit exchange of restricted data on reactors for propulsion of naval vessels, aircraft or land vehicles for military purposes. The Commission continued discussions with Belgium, Canada, and the United Kingdom to establish exchanges of data under the new amendments.

When the City of West Berlin expressed an interest in developing an atomic energy program, the Commission requested, the Congress passed, and the President signed an amendment to the Atomic Energy Act of 1954 to make possible cooperation with Berlin through an agreement for cooperation covering this enterprise with the Federal Republic of Germany acting on behalf of Berlin. (Public Law 14, 85th Congress, 1st Sess., April 12, 1957.) Discussions on the agreement were begun.

Assistance in reactor projects. During the reporting period, the Commission made commitments on financial assistance on research reactor projects [1] to three nations, each to receive a total of $350,000 on completion of the proposed research reactor project: *Japan*, in the construction of a heavy water-moderated and cooled reactor of the CP–5 type; *Portugal*, in construction of a 1-megawatt pool research reactor; *Venezuela*, in construction of a 3-megawatt pool research reactor.

Previous requests for financial assistance on research reactor projects had been received from Belgium, the Federal Republic of Germany, Israel, and Greece. These countries will submit project proposals for review by the Commission. The United States may make grants up to $350,000, or half the cost if that is less, for a research reactor project.

Activities Under Agreements

Activities in atomic energy during the last 6 months in countries with which the United States has signed agreements for cooperation are summarized in the succeeding items.

Unclassified visits to Commission installations were arranged for 615 foreign nationals from 62 countries. To Washington headquar-

[1] See pp. 14–15, Twenty-first Semiannual Report (July–December 1956).

ters, unclassified visits were arranged for 674 foreign nationals and embassy personnel from 59 countries.

A total of 105 scientific and technical personnel from Belgium, Canada and the United Kingdom visited Commission installations and headquarters for classified discussions: 1 from Belgium, 53 from Canada, 51 from the United Kingdom, and 54 classified conferences were held in the United States: 5 with Belgians, 22 with Canadians, and 27 with representatives of the United Kingdom. Reciprocal conferences abroad attended by United States representatives included 32 in Canada, 22 in the United Kingdom.

The United States made arrangements to send special study groups to assist other American nations in developing or expanding national nuclear energy programs. These study groups were instituted as an outgrowth of visits made by two Atoms for Peace Missions to other American countries in 1956.[2]

Argentina. During April, Argentina was visited by a study group of seven who represented industry, universities, the Commission, and the Department of State, and included consultants in nuclear physics, agriculture, radio-chemistry, metallurgy, and medicine.

The Argentine Atomic Energy Commission which is actively developing an atomic energy program leading to the construction of an Argonaut reactor in Buenos Aires, sent two scientists to Argonne National Laboratory for discussions on this reactor project.

Belgium. In cooperation with Belgium, the Commission held in Brussels, Belgium, during the week of May 20 an unclassified symposium on chemical processing of irradiated fuel. Invitations to the symposium were issued by the Belgian Government to scientists of two regional atomic energy groups, the Organization for European Economic Cooperation (OEEC), and the European Atomic Energy Community (Euratom). The meeting was attended by 108 representatives from 14 countries: 24 from the United States, 37 from Belgium, and 47 from 12 remaining OEEC countries. Technical papers were presented by representatives of the Commission and its contractor organizations, and informal group discussions were held.

Arrangements were made for seven Belgian engineers of the *Syndicat d'Etude de l'Energie Nucleaire* (SEEN) to visit Argonne National Laboratory for 2 months to study the Experimental Boiling Water Reactor. Later the group will go to Shippingport, Pa., for a 2-month's study of the Pressurized Water Reactor.

[2] See p. 19, Twentieth Semiannual Report to Congress (January–June 1956), and p. 16, Twenty-first Semiannual Report to Congress (July–December 1956).

Brazil. Three members of the study group visiting Argentina went to Brazil for discussions on implementation of the agreement with Brazil and to visit the Sao Paulo reactor site. Work on the 5-megawatt pool research reactor being constructed at the University of Sao Paulo has advanced rapidly. Brazil reported that the reactor was scheduled to go critical in early September. Discussions began with the Commission regarding a proposed fuel lease arrangement for the Brazilian reactor.

Canada. Arrangements were completed for Canadian representatives to hold classified discussions with United States scientists as follows: at the Hanford plant, Richland, Wash. on the design of underwater shearing equipment and examination facilities; at Savannah River, S. C., on the joint United States-Canadian Sheath program; at Argonne National Laboratory, Lemont, Ill., on boiling heavy-water power reactors, technology of fuels and related problems.

United States representatives visited Canada for classified meetings on: uranium metal and uranium salt experiments; cooperation in the plutonium recycle program (see Reactor Development); and design of the Canadian (NPD) Reactor; the joint program on improving the processing of normal uranium metal, including studies of irradiation effects; and the joint program for the testing of fuel materials under power reactor conditions.

A new joint program was established to facilitate cooperation in the field of heavy water power reactor development between technical groups at Hanford, Argonne, Savannah River and Chalk River, including exchanges on recycling plutonium in such reactors.

Denmark. Three contracts were signed on April 16 with Denmark for the transfer of fuel as follows: (*a*) lease of fuel for use in the operation of 500-watt solution reactor at the Danish research center in Risoe; (*b*) lease of fuel for use in the operation of a 5-megawatt research reactor at Risoe, (both reactors are being manufactured by American corporations); and (*c*) sale of a quantity of metallic uranium not to exceed two grams to be incorporated in a single fission counter tube manufactured by an American firm, and to be used in the operation of the 500-watt solution reactor. Approximately 8.8 kilograms of contained uranium 235 was covered by these arrangements.

Federal Republic of Germany. In addition to three reactors [3] being constructed for the Federal Republic of Germany by American firms, a 10-megawatt power demonstration reactor was planned. This reactor will be built by an American and a British firm for the Rhine-

[3] See p. 22, Twenty-first Semiannual Report to Congress (July–December 1956).

Westphalian Electrical Co. The existing agreement for cooperation with Germany does not at present cover power reactors, but a power agreement has been negotiated.

Greece. The Greek Atomic Energy Commission signed a contract with an American firm to construct a 1-megawatt pool reactor. Financial assistance was requested from the United States.

India. The United States sent representatives to the formal inauguration on January 20 of the Indian Atomic Energy Establishment and research reactor in Trombay. Representatives included Dr. John C. Bugher, Director, Division of Medical Education and Public Health, Rockefeller Foundation; Dr. Lloyd Berkner, President, Associated Universities, Inc., which operates the Commission's Brookhaven National Laboratory, Upton, Long Island, N. Y.; and Maj. Gen. K. D. Nichols (USA retired) former General Manager of the Commission, and District Engineer of the Manhattan Engineer District.

Ireland. Two members of the Irish Atomic Energy Committee visited the United States during April and May to be briefed on civilian uses of atomic energy. Although Ireland has not established an atomic energy program, one is contemplated for the development and training of personnel in nuclear energy technology. Ultimately, the hope is to develop nuclear power to supplement existing sources of electricity. A research agreement for cooperation with Ireland was awaiting approval of that nation's parliament.

Japan. A second lease arrangement was signed on May 20 with Japan to provide for transfer of fuel material for use in a CP–5-type research reactor to be constructed by an American firm. The reactor is scheduled to go into operation in 1958.

At the invitation of the Commission's Chairman, the newly appointed Chairman of the Japanese Atomic Energy Commission, Koichi Uda, visited Washington and atomic energy installations in June.

During May a team of technical experts from the Commission and its contractors attended an unclassified conference in Japan on the peaceful uses of atomic energy. The conference was sponsored by the Japanese and American Atomic Industrial Forums. Representatives included approximately 89 Americans, about 1,000 from Japan, and 48 others from Asian countries besides Japan.

After the conference, this group visited the Philippines and the Republic of China to study atomic energy programs there and to aid

those countries in formulating plans for the future development of their programs.

The Netherlands. On February 15, the Netherlands Government signed a lease for the transfer of special nuclear material (approximately 4.7 kilograms of contained uranium 235) for use as fuel in a pool reactor being constructed by an American firm.

The reactor was installed near Amsterdam for use at the International Exhibition in the summer of 1957, and later would be removed to a permanent location at the University of Delft.

Philippines. Meetings were held during February and March with representatives of the Philippine Government to discuss plans for construction of a research reactor. In 1955, the Commission at the instance of the Department of State, approved the gift of a research reactor to the Philippine Government, subject to Congressional approval and completion of an agreement for cooperation, which became effective July 27, 1955. Congressional authorization was received for $500,000 for this project (Public Law 141, 84th Cong., 1st Sess., July 11, 1955). Representatives of the Philippines visited various Commission installations, and held discussions with private manufacturing firms to determine the type of research reactor suitable for their use.

Portugal. The Portuguese Nuclear Energy Board selected an American firm to construct a 1-megawatt pool research reactor.

Spain. A fuel lease was signed with Spain on April 9 for 35 fuel elements containing an aggregate of approximately 5.1 kilograms of contained uranium 235 for use in the 3-megawatt pool research reactor being constructed for the Spanish program.

Turkey. An official of the Turkish Government made a 3-month tour of Commission installations to study the various kinds of reactors. Discussions were held with United States firms on building a pool research reactor.

United Kingdom. In February, two Commission representatives visited the United Kingdom for classified discussions at Harwell on controlled thermonuclear research. A classified conference in this field was also held in Berkeley, Calif., February 20–23 (see Physical Research). Technical discussions continued between the two countries on a variety of programs related to reactors and separations processes. The Chairman of the United Kingdom atomic energy

authority visited the Commission in June for discussion of cooperative programs established under the United Kingdom agreement. Under the amendment to that agreement permitting certain exchanges of information on military reactors, Commission and Navy officials in May visited England for discussions.

Venezuela. A project for construction of a 3- to 5-megawatt pool research reactor by an American firm was submitted by Venezuela to the Commission in June. The reactor is scheduled for completion in July 1958. Consideration will be given by the Commission to Venezuela's request for financial assistance on the project.

Training and Education

Asian Nuclear Center. The Commission provided the Department of State and the International Cooperation Administration with continued technical assistance and advice in connection with the United States proposal to help in establishing an Asian Nuclear Center.

Activities Among the American States

Puerto Rico center. From January 24 through January 28, a regional symposium on the peaceful uses of atomic energy was held in Puerto Rico in cooperation with the Commission and the Oak Ridge Institute of Nuclear Studies (ORINS), Oak Ridge, Tenn. The symposium was arranged to provide students and faculty members with a better picture of atomic energy developments and the potentialities of the University in nuclear science education. More than 1,200 college students, faculty members and professional people from Puerto Rico and guests from Central and South American countries attended.

In an address at the symposium, Chairman Strauss stated the "broadened program will provide the University of Puerto Rico with unique training and research facilities. And because these facilities will be truly outstanding—the most up-to-date in concept and design—and because instruction will be in Spanish, the University of Puerto Rico may well become a training center of interest to many countries of the hemisphere . . . I can tell you that we will cooperate enthusiastically in that expansion."

Joint planning studies were initiated by the University and the Commission for the proposed Nuclear Training Center consisting of a research reactor and research and training facilities to be constructed by the Commission at the Rio Piedras and Mayaguez campuses and operated by the University.

During February, a group of Commission and contractor personnel, and several consultants in the fields of biology, medicine, and agriculture, visited the University to study the programs being carried out in these sciences.

In March, the Commission made a grant of $155,340 to the University for the purchase of equipment and materials to be used in the educational and training program of the College of Agriculture and Mechanic Arts on the Mayaguez Campus. These facilities will include an exponential assembly for nuclear engineering education. In addition, a grant of $61,610 was made to the University for the purchase of equipment and materials for the initiation of a radioisotope technique training course at the Rio Piedras campus.

Turrialba institute. The Commission cooperated with the Inter-American Institute of Agricultural Sciences at Turrialba, Costa Rica, in a program which included (*a*) irradiation of seeds of four principal crops of Latin America: rubber, Manila hemp, cacao and coffee, (*b*) projected installation of a "gamma field" at the institute with a cobalt 60 source of radiation for experiments on growing plants, (*c*) provision for exchange of scientists between the United States and the institute and (*d*) a projected training program in use of radioisotopes. The institute performs agricultural research of benefit to all countries of Central and South America and has facilities for carrying out research employing both isotopes and ionizing radiation.

Inter-American Symposium. One hundred and one leading scientists, engineer and government officials from the American nations met at Brookhaven National Laboratory, May 13–17, to participate in the first Inter-American Symposium on the Peaceful Application of Nuclear Energy. The Symposium was conducted by Brookhaven National Laboratory, and was jointly sponsored by the Commission, the Department of State, and the International Cooperation Administration.

Groundwork for the Symposium was laid last fall by Dr. Milton Eisenhower at a meeting of the Inter-American Committee of Presidential Representatives in which the 21 American Republics participated. These States were: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, United States, and Venezuela.

Speaking at the Symposium, Dr. Eisenhower reviewed the purpose of the conference, stressing the contribution which atomic energy can make to the future of the American states. "What is called for above all else, I think, is cooperation," Dr. Eisenhower said, "coop-

eration by all in a steadfast resolve to use the atom for the benefit of ourselves and all mankind. This is the great significance of this Symposium: Here begins a new era of Inter-American cooperation on the very frontiers of new knowledge. We are here on the verge of what can be the most amazing and rewarding period in history.

"You who are participating in this Symposium will help to determine whether rich promise becomes a living reality."

The primary purpose of this first bilingual atomic Symposium—all papers and discussions were simultaneously rendered in English and Spanish—was to explore present and future uses of atomic energy in the Americas. Special attention was given to practical efforts to accelerate development of atomic energy programs that would include useful research and seek applications that were economically and industrially valuable.

The first 2 days of the Symposium were devoted to general sessions, followed by 3 days of concurrent sessions on atomic energy management, biology and agriculture, medicine, and physical sciences and technology.

Papers on various aspects of the civilian nuclear energy program, legal and administrative problems, the role of the atom in industry, medicine and agriculture, biology, metallurgy, and raw materials sources, etc., were prepared and presented by scientists of the United States and other American states.

In the sessions on medicine, papers surveyed and discussed the newest diagnostic and therapeutic uses of radiation and covered specifically also such topics as teletherapy, brachytherapy, and the nuclear reactor as an instrument in medical therapy.

In the biology and agriculture sessions, uses of radiation directly, and of radioisotopes as tracers, were discussed. In plant research there was discussion on the use of radioisotopes in the study of biochemical syntheses, plant nutrition, and fertilizer problems.

In entomological research, papers were presented on the use of radioisotopes in improving methods for controlling insect pests and in studying the ways in which plants utilized foods for energy and growth.

In the physical sciences, problems in construction and operation of reactors, radiological hazards and criteria for selection of research reactor sites were discussed extensively.

Following the Symposium, the visiting groups toured governmental, university and industrial facilities where atomic energy is being put to use.

The Inter-American Symposium was unique among international meetings in that it covered all phases of a broad field as applied to the specific needs of a particular area of the world. Reactions from partici-

pants were extremely favorable and the consensus was that the Symposium offered a useful opportunity for scientists, engineers, and atomic energy officials of the Americas to exchange information and ideas.

Special Atomic Energy Schools

International school at Argonne. The fifth course of the International School of Nuclear Science and Engineering at Argonne National Laboratory began February 6. Enrollment included 48 students from 25 other countries and 13 from the United States. Since the beginning of this training, 41 nations have been represented with 211 foreign and 76 United States students participating.

The sixth course will begin on September 18, and applications from candidates for the course were reviewed during June.

Oak Ridge courses. Beginning with the 1957 Radioisotope Tracer Techniques Course at the Oak Ridge Institute of Nuclear Studies, the Commission has approved a quota of foreign students equal to 30 percent of the total enrollment for the six regularly scheduled courses to be conducted. These 4-week courses are divided among laboratory work, lectures on laboratory experiments, general background lectures, and seminars on special topics in atomic energy applications of radioisotopes.

Technical Libraries

The Commission approved presentation of five additional unclassified technical libraries on atomic energy during the reporting period. These are for Colombia, Ireland, Mexico, the Organization for European Economic Cooperation (OEEC), and the City of West Berlin, bringing the total donations of libraries to 67—62 to 50 foreign nations, 4 to international organizations and 1 to the city of West Berlin.

Other International Activities

International Atomic Energy Agency

As previously reported,[4] the Statute of the International Atomic Energy Agency was unanimously approved at the 82-nation conference in New York last October. A total of 80 nations, including the United States, has signed the Statute. The Agency will come into being when 18 states (including 3 of the 5 leading nations in atomic energy) have

[4] See p. 12, Twenty-first Semiannual Report to Congress (July-December 1956).

deposited their ratifications. Guatemala was the first nation to deposit its ratification, followed by Switzerland, the Union of Soviet Socialist Republics, Byelorussia, Romania, Pakistan, Austria, Afghanistan, the Union of South Africa, Norway, Sweden, and Turkey.

The Statute was forwarded to the United States Senate by the President on March 22 with the President's recommendation that the Senate give favorable consideration to it. Hearings were held before the Foreign Relations Committee during May and the Commission Chairman strongly supported approval in testimony before the Committee. The Senate on June 18 approved United States ratification of the Statute.

The Preparatory Commission created by the Statute met in New York to plan the organization and work program of the Agency. The Department of State and the Atomic Energy Commission advised and supported the United States representative on the Preparatory Commission. Recommendations of the Preparatory Commission generally conform to the United States' views and have, in the main, been unanimously supported. The first General Conference of the International Agency will begin in Vienna October 1.

European Atomic Community

On March 25, in Rome, representatives of Belgium, France, the Federal Republic of Germany, Italy, Luxembourg, and the Netherlands signed a treaty establishing a European Atomic Energy Community (Euratom) which is now before the various parliaments for ratification. The treaty provides the institutional framework for a concerted venture by the 6 nations to enable them to solve the problem of the growing shortage of coal and oil by the use of nuclear energy for the production of power.

Under the treaty, ownership of nuclear fuel would be vested in the Community. The treaty provides for cooperation in research and development, the establishment of common facilities, and a control system to apply appropriate safeguards over the use of nuclear materials.

Early in February, at the invitation of the Department of State and the Commission, three Euratom representatives visited the United States to discuss plans for the nuclear power program. These three—Franz Etzel of Germany, Louis Armand of France, and Francesco Giordani of Italy—visited Commission installations at Oak Ridge and Shippingport. They subsequently visited installations in Canada and the United Kingdom. On their return to Europe, they issued "A Target for Euratom." The report proposed that Euratom adopt as its goal an installed nuclear power capacity of 15 million kilowatts by 1967.

The Department of State and the Commission announced the wish of the United States to cooperate with the Community and to provide both technical and material assistance in achieving its bold atomic energy objectives. As a first step, a Commission team of technical experts visited Luxembourg in March and April to advise on certain technical aspects of the Euratom report later issued.

Chairman Strauss characterized the report as "another step forward in international cooperation to promote the peaceful uses of atomic energy." With establishment of the Community, and if the target of 15 million kilowatts is adopted, the prospect exists for cooperative experience to be gained in designing, building and fueling Euratom's nuclear powerplants which would be mutually beneficial to the Euratom nations and the United States.

Inter-American Atomic Group

Working groups established by the Inter-American Committee of Presidential Representatives included an atomic energy group under the chairmanship of Guillermo Sevilla-Sacasa, Nicaraguan Ambassador to the United States, and composed also of representatives from Argentina, Brazil, Chile, Cuba, Mexico, the United States, and Venezuela. The group urged establishing an Inter-American Nuclear Energy Commission within the Organization of American States and adding nuclear activities to the program of the OAS's existing technical agencies. These recommendations were approved by the Committee of Presidential Representatives.

1958 International Conference on Peaceful Uses

During May the Advisory Committee to the Secretary General of the United Nations met in Geneva, Switzerland, to discuss plans for the 1958 International Conference on the Peaceful Uses of Atomic Energy. The United States was represented by Dr. I. I. Rabi, to whom the Commission supplied staff assistance. Other members of the committee included Brazil, Canada, France, India, the Union of Soviet Socialist Republics, and the United Kingdom. The Secretary General of the United Nations presided.

The Secretary General determined that the 1958 scientific conference would be held in Geneva, Switzerland, September 1 through 13, 1958. A detailed agenda, wide in scope with emphasis on atomic power, was agreed upon and submitted to the Secretary General as a call for papers to be presented at the Conference.

Within the Commission, an Office for the International Conference was established to direct and coordinate the planning and organization of the United States presentation, including an exhibit.

U. S. Exhibit at Paris Trade Fair

The Office of International Trade Fairs, Department of Commerce, featured an atomic energy exhibit at the 1957 Paris Trade Fair, May 25–June 10. The Paris Fair was attended by some 4 million persons and offered the first opportunity for the United States to present an atomic energy exhibit in that city.

At the request of the Department of Commerce, the Commission provided technical assistance in planning the exhibit and loaned an electronic master-slave manipulator, designed by the Argonne National Laboratory. Dr. Francois Kertesz, Oak Ridge National Laboratory, Oak Ridge, Tenn., served as a scientific adviser at the United States exhibit.

Support for Special Conferences

The Commission undertook to give financial support to selected unclassified international conferences on specialized scientific subjects relating to atomic energy. The objectives of the program are:

a) Expanding knowledge among United States scientists of recent scientific advances.

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 the Atoms for Peace Program.

The first conference receiving support under this program was the International Conference on Neutron Physics scheduled to be held at Columbia University in September 1957.

U. N. Committee on Effects of Radiation

The third session of the United Nations Scientific Committee on the Effects of Atomic Radiation was held in Geneva, Switzerland, April 8–18 with Dr. Shields Warren as United States representative.

The meeting discussed the genetic effects of atomic radiation, radiation measurement and environmental contamination, and preparation of an outline planning for the "final report" to be submitted to the General Assembly next year.

The United States undertook to provide assistance in establishing fall-out collection stations to 5 nations, Austria, Colombia, Denmark, Japan, and Viet Nam, in addition to the 9 reported in the Twenty-first Semiannual Report (p. 24).

Disarmament

Commission representatives were advisors to the United States Delegation at meetings of the United Nations Disarmament Commission, held in London in April and May.

Civilian Application

Further growth during the last 6 months in the activities of private enterprise in peaceful uses of atomic energy was manifested throughout the field. The volume of licensing of nuclear research facilities during the period substantially exceeded that for any prior half-year. Applications were received for 18 research reactors and one critical experiment facility. In addition, applications for licenses to export 10 research reactors to 7 countries were received.

Radioisotopes continued to maintain their role as one of the most important civilian applications of atomic energy. The number of organizations, public and private, using radioisotopes increased by 12 percent during the last 6 months and totaled 4,109 at June 30. New uses of radioisotopes in industry, medicine, and agriculture were constantly being reported.

New applications for permits allowing access to restricted data concerning atomic energy technology were received at an average rate of 36 per month. As the January–June reporting period ended, 1,327 permits were in effect, an increase of 182 since December 31, 1956. In addition, applications for renewal of the first expiring access permits are now being received.

The regulation (10 CFR Part 20), promulgated January 29, 1957, established the Commission's standards, applicable to licensees, for protection against radiation.[5] Additional regulations applicable to licensed activities, as well as modifications to existing regulations, will be formulated and issued as need may be indicated by continued experience.

Further studies were made in the field of insurance for nuclear facilities and for public liability for possible damage arising out of the

[5] See p. 120, Twenty-first Semiannual Report to Congress (July-December 1956). Text printed in Appendix 7 of this report.

430209—57——4

operation of the facilities. Recommendations on legislation to provide Government indemnity, in excess of that obtainable from private insurance underwriters, were submitted to the Congress.

The important interests which State governments have in atomic energy regulation continued to receive careful attention. Cooperation between the Commission and the States has proved mutually advantageous and, in order further to foster this relationship, the Commission recommended to the Congress in June certain legislative means to help clarify the respective roles of the Commission and the States in the regulation of private atomic energy activities.

Licenses Requested and Issued

During the January–June reporting period, the Commission received the following license applications:

25 for production and utilization facilities;
84 operators licenses;
44 special nuclear material licenses;
3,003 byproduct material licenses;
1,075 source material licenses.

During the same period the Commission issued:

4 construction permits authorizing construction and modification of nuclear reactors;
4 licenses authorizing the operation of nuclear reactors;
3 construction permits authorizing construction of critical experiment facilities;
1 license authorizing operation of a critical experiment facility;
27 operators licenses;
34 special nuclear material licenses;
3,213 byproduct material licenses, including 1,225 amendments; and
1,055 source material licenses.

A license for the use of byproduct material, that of the M. W. Kellogg Co., of New York, was temporarily suspended in April pending completion of an investigation into the circumstances attending an incident which resulted in the accidental release of some irradiated material in the company's Nuclear Products Division laboratory at South Houston, Tex.

Production Utilization Facilities

As of June 30, the Commission had issued 25 construction permits or facility operating licenses, including 4 for developmental power reactors, 14 for research reactors, and 7 for critical experiment facil-

ities. Seven construction permits had been converted to facility licenses. Nine export licenses had been issued authorizing shipment of 9 research reactors to foreign countries. Facility licenses applied for and actions taken during this period are listed in Appendix 8.

A hearing ordered by the Commission, in connection with a construction permit issued to the Power Reactor Development Co. of Detroit, Mich., authorizing construction of a nuclear power reactor at Lagoona Beach, Monroe County, Mich., commenced on January 8. The submission of the cases in chief was completed by both applicant and intervenors during the reporting period.

Operators Licenses

As of June 30, reactor operators' licenses had been issued to 54 persons; 27 of these were issued during the period covered by this report.

Special Nuclear Material

A total of 94 licenses for possession of special nuclear material had been issued as of the end of the reporting period, chiefly for research and development purposes. These licenses did not include material for production and utilization facilities. Licenses applied for or issued during the period are listed in Appendix 9.

Source Material

Source material licenses were issued or renewed for 1,055 licensees during the 6-month period. These included 336 to producers, 21 to processors, 71 to distributors, 208 to consumers, and 419 to exporters.

Radioisotopes

The contribution of radioisotopes to the national economy, as evidenced by cost savings benefits reported in a recent canvass of industry, indicated a total yearly savings on the order of $400 million. Atomic energy byproducts are one of the most important peaceful applications of atomic energy.

As of the end of June, 4,109 organizations were licensed to use radioisotopes, representing an increase of 12 percent since November 30, 1956. Many others who have received small quantities of radiomaterial under general license are not included in these figures.

Appendix 4 lists the types of radioisotopes for which licenses were issued and also the number of users by class and location.

Total shipments from the Commission's primary radioisotope distributor, Oak Ridge National Laboratory, amounted to 96,417 as of May 31, an increase of 7,008 shipments since November. Other Commission laboratories at Argonne, Brookhaven, the National Reactor Testing Station in Idaho, and Mound Laboratory make fewer but specialized shipments. In addition, a number of commercial suppliers buy bulk quantities of radioisotopes in single shipments from Commission production laboratories, process the material into radioactive drugs, chemical compounds, radiation sources, etc., and sell thousands of shipments each month to licensed users.

Physicians now use radioisotopes in diagnosing or treating the ailments of an estimated 1 million patients a year. Radioisotopes have been particularly useful in such diagnostic procedures as analysis of thyroid function, blood volume determination, tumor location, and liver function. In medical treatment, some of the chief uses are in hyperthyroidism, thyroid cancer, the blood diseases, polycythemia and leukemia, heart disorders, pleural and peritoneal accumulations of liquid, prostate cancer, external whole body irradiation, and eye lesions. More than 100 radioisotope teletherapy units now are in operation in the United States.

Radioactive materials are important tools for many types of agricultural studies. Major benefits that have resulted include (*a*) better placement and application of fertilizer, (*b*) new and improved growth regulators, herbicides, etc., (*c*) improved measures against plant diseases and fungi, (*d*) better knowledge of animal nutritional needs, (*e*) improved measures against animal diseases, (*f*) better insect control through sterilization, insecticides, and information on migration and hibernation, and (*g*) new or improved varieties of plants and breeds of animals.

In addition to domestic users, 787 export shipments to experimenters and utilizers in other countries were reported during the past 6 months. Procedures for export of nearly all radioisotopes were simplified in February 1956.[6] Now, exporters need only notify the Commission within 90 days after an export shipment is made. Export of radioisotopes such as polonium 210 and tritium (hydrogen 3) require special approval.

The first application for a license to export radioisotopes to Soviet Russia was received and approved. It covered a small amount of carbon 14 which will be used for cancer research at the Bio-Chemical Institute of the Academy of Science, Moscow.

[6] See p. 24 and pp. 203-11, Twentieth Semiannual Report to Congress (January-June 1956).

The demand for radioisotopes in a few instances has begun to exceed the available supply. The items principally involved are tritium and krypton 85. Industrial interest in cobalt 60 indicates that for it, too, demand may soon exceed supply. The Commission, in cooperation with industry, is preparing to meet these demands. One commercial firm recently announced plans to construct a dual-purpose private reactor which would produce cobalt 60 as is reported later in the section on Reactor Development.

New Industrial Uses

During the past 6 months, several new industrial uses of radioisotopes were reported. One was the development of a tiny experimental atomic battery to power a wrist watch. The battery which uses the radioisotope, promethium 147, is smaller in diameter than a dime, has a useful life of more than 5 years and an output of 20 microwatts. Although not yet available for everyday use, larger future models of the battery are expected to power portable radios, hearing aids, and equipment in guided missiles and space craft.

With this development five different types of atomic batteries have been announced. The batteries convert atomic radiation to electric current. Although the energy from the batteries is very small, they are useful for applications requiring tiny amounts of power. Their useful life depends upon the radioisotope used, but may be many years, and the batteries are virtually unaffected by temperature and humidity extremes.

In another potentially large-scale application, the radiation from atomic energy byproducts was successfully used for the first time in heatless vulcanization of an automobile tire without the addition of sulfur. The radiation-vulcanized tire reportedly wears longer and resists deterioration better than tires vulcanized by the heat method.

This was the first basic change in the "curing" of rubber since the discovery of vulcanization in 1839. In conventional vulcanization, sulfur and other chemicals are added to rubber and heated to more than 300 degrees Fahrenheit. This treatment realigns the molecules to provide greater stability against temperature changes and deterioration. In this process, the carbon atoms are linked through sulfur atoms and this is considered a "weak link" in vulcanization of rubber. The radiation method resulted in direct linkage of the carbon atomic chains in the rubber molecules.

Radioactive Gages

A major industrial use of radioisotopes is in cigarette density gaging. The average density of tobacco in a cigarette is an important factor in cigarette quality and costs, since tobacco represents about 90 percent of the production cost. A density gage using strontium 90 as a source permits automatic adjustment of tobacco feed and contributes to uniformity of production.

Radioisotope thickness gages are used in automatically controlling mill rolls to reduce thickness deviations and consequent rejects in strip steel. The gages can hold steel strip within 1 percent of specified thickness.

In the rubber industry, radioisotope gages open and close calender rolls to control the amount of rubber coating placed on tire cords, preventing overuse of rubber, improving utilization of manpower, and reducing production time.

Plastic and adhesive thickness gages similarly improve usages in the plastics industry where raw material costs are usually high. Thickness gages in the paper and allied products industries automatically control stuff gates to maintain accurate basic weight of paper produced and help achieve faster machine startup times after order change or break, and higher machine speeds, and also reduce the number of rejects.

Other Industry Uses

More than 500 organizations use radioisotopes in radiographic testing. Used on a much larger scale than was previously economically feasible, radiography by means of radioisotopes is reported to cost only ⅛ to 1/10 the cost by other methods. Reactor-produced cobalt 60, cesium 137 and iridium 192 are now used in much the same way that radium formerly was used. Cobalt 60, equivalent in radiation intensity to $20,000 worth of radium, can be delivered for about $100, and its gamma rays will penetrate thicker sections of steel than will those from radium. Small radioisotope sources of high radiation intensity permit flexibility of operation as compared with fixed X-ray installations.

In the oil industry, radioisotopes have many uses: tracer applications for such drilling and production operations as acidizing control and evaluation, injectivity profiles, interwell tracing, cement top location, cement channeling, casing seat channeling, casing leaks, permeability surveys, locating fractures, and locating lost circulation. The annual

rate of savings as estimated in December 1956 for all United States industries from various uses of radioisotopes were as follows:

Type of use	*Probable low* (In millions)	*Probable high* (In millions)
Cigarette density gages	$35. 1	$58. 6
Approximately 2,235 licensed [a]		
Metal thickness gages	18. 5	27. 8
Approximately 185 licensed		
Rubber and tire fabric thickness gages	7. 9	20. 0
Approximately 120 licensed		
Plastic and adhesive thickness gages	1. 6	4. 9
Approximately 108 licensed		
Paper and allied products thickness gages	18. 6	20. 0
Approximately 299 licensed		
Other thickness gages	2. 0	5. 9
Approximately 130 licensed		
Gages such as liquid level, moisture, H-C ratio, snow, etc	1. 8	5. 4
Approximately 300 licensed		
Radiographic testing	26. 0	58. 5
Approximately 500 organizations		
Oil well logging	16. 0	24. 0
Oil well stimulation	120. 0	180. 0
Pipeline oil flow	0. 5	0. 7
Petroleum refining	5. 3	10. 1
Other applied industrial tracing	12. 5	25. 0
Tool wear studies	0. 8	1. 2
Piston ring and similar wear studies	12. 0	18. 0
Corrosion studies	3. 0	4. 6
Other industrial research	12. 0	18. 0
Luminescent sources	1. 7	2. 7
Miscellaneous industrial applications	0. 5	0. 8
Total	$295. 8	$486. 2
Average		$391. 0

[a] All license figures as of Nov. 30, 1956.

Access to Classified Technical Information

An average of 35 permits was granted each month during the reporting period to private individuals and concerns interested in obtaining access to classified technical information on the peaceful applications of atomic energy. As of June 30, a total of 1,327 permits was in effect.

In January, for the first time since establishment of the Access Program, the number of permits issued for access to secret information exceeded the number issued for access to confidential information. This trend apparently reflects a shift from general interest to specific applications in civilian uses of nuclear energy.

Requests for amendments to access permits, principally to enlarge the scope of access, stood at about 16 per month, compared with 25 per month during the last half of 1956.

Purchase of Classified Reports

During the last 6 months, 4,772 confidential technical reports and 1,980 secret reports were purchased by permittees.

	Confidential reports	*Secret reports*
Total, December 31, 1956	17, 621	3, 688
Total, June 30, 1957	22, 393	5, 668

Statistics on Access Permits

The distribution of permits by geographic area, industry, and field of interest is given in the following tables along with comparative data for the permits in force as of the end of the previous year:

Geographic Distribution

	Dec. 31, 1956	*June 30, 1957*
New England	103	119
Middle Atlantic	413	467
East North Central	234	281
West North Central	72	79
South Atlantic	115	132
East South Central	25	34
West South Central	40	49
Mountain	37	43
Pacific	102	118
Hawaii, Alaska, and Puerto Rico	4	5
	1, 145	1, 327

BUSINESS OR OCCUPATION

	Jan. 1,* 1957	June 30, 1957
Aircraft and/or Components	19	21
Chemical—General	65	72
Chemical—Pharmaceutical	5	5
Chemical Processing Equipment	4	5
Coal Industry	4	4
Communications	1	1
Consultants	71	83
Educational Institutions	20	22
Electronic Industry	24	24
Engineering—Construction	47	51
Engineering—Consulting	56	70
Engineering—Design	19	25
Federal, State, and City Governments and Departments	43	53
Financial Organizations	20	22
Food Companies	3	4
Information Services	8	16
Instrument Manufacturing Companies	54	64
Insurance Companies	64	79
Lawyers and Public Accountants	25	30
Machinery—General Application	25	35
Machinery—Special Application	3	10
Metal Products Manufacturing	131	158
Mining and Refining	62	71
Motor Vehicles and/or Components	5	6
Paper and Pulp Companies	4	6
Petroleum and Petroleum Products	20	20
Printing and Publishing	9	10
Professors, Teachers, and Scientists	55	65
Railroads and Railway Equipment	9	9
Research—Medical	4	4
Research—General	42	44
Rubber and Rubber Products	5	6
Scrap and Waste Disposal	7	7
Shipbuilding and/or Components	17	20
Special Carriers and Warehousing	3	4
Stone, Clay, and Glass Products	14	16
Tobacco and Tobacco Products	1	1
Unions, Trade Associations, Chambers of Commerce & Manufacturers' Representatives	13	16
Utilities	151	153
Weapons, Explosives, and Propellants	8	10
Others not Elsewhere Classified	3	5
Total	1,145	1,327

* Categories revised Jan. 1, 1957, to conform with Bureau of Census Standard List.

FIELD OF INTERESTS

	Dec. 31, 1956	June 30, 1957
OPERATING ATOMIC FACILITIES		
Reactors for production of electric power	168	162
Reactors for other purposes, such as research, propulsion of ships, etc	47	59
Plants to refine uranium and thorium ore and process feed materials	76	80
Chemical plants for reprocessing spent fuel elements, etc	46	64
MANUFACTURE OF ATOMIC ENERGY PRODUCTS		
Entire reactors	100	90
Components, such as fuel elements, instruments, and pumps for reactors and related facilities	241	287
Materials for atomic energy applications such as zirconium, carbon, and special alloys	121	149
RELATED ACTIVITIES		
Utilizing radioactive isotopes for sterilization of food, radiochemistry research, etc	57	64
Design and construction of atomic energy facilities	79	98
General nuclear research	50	66
Consulting on atomic energy problems	172	215
Investing and lending capital	20	23
Evaluating insurance risks	59	82
Others not elsewhere classified	136	65

NOTE.—These figures include permit holders with more than one field of interest, resulting in a total greater than the number of permittees.

Personnel Clearances Under Permits

A total of 3,479 new clearances [7] was granted during the reporting period to persons cleared for access to restricted data, either as individuals with a need to know or as employees or members of authorized concerns. This was in addition to 483 clearances reinstated and 747 clearances extended. Active clearances totaled 20,270.

[7] Two types of clearances are obtainable under access permits: The limited clearance ("L") permits access to Restricted Data classified no higher than "Confidential;" the full clearance ("Q") permits access to Restricted Data classified "Confidential" and to specific categories of Restricted Data classified "Secret."

FOR ACCESS TO SECRET RESTRICTED DATA

Clearance actions	*Total as of Dec. 31, 1956*	*6 months Jan.-June 1957*	*Total as of June 30, 1957*
New clearances granted	4, 237	2, 108	6, 345
Clearances reinstated	1, 066	399	1, 465
Clearances extended	4, 396	633	5, 029
Total	9, 699	3, 140	12, 839
Clearances terminated	341	502	843
Active clearances	9, 358	2, 638	11, 996

FOR ACCESS TO CONFIDENTIAL RESTRICTED DATA

Clearance actions	*Total as of Dec. 31, 1956*	*6 months Jan.-June 1957*	*Total as of June 30, 1957*
New clearances granted	5, 556	1, 371	6, 927
Clearances reinstated	434	84	518
Clearances extended	1, 353	114	1, 467
Total	7, 343	1, 569	8, 912
Clearances terminated	287	351	638
Active clearances	7, 056	1, 218	8, 274

Access permits are issued for periods of 2 years, and the first permits given by the Commission began expiring in May of this year. Of 85 permits due to expire by June 30, the Commission has renewed 76 at holders' request.

Requests for new personal security clearance to have access to secret information totaled 2,070 during the reporting period. Similar requests relating to confidential information totaled 1,143 in the same period.

Technical Information Meetings

During this reporting period, the Commission sponsored seven technical information meetings designed to keep access permit holders abreast of the latest technological advancements in their particular fields of interest. Meetings were held as follows: February 5–7, Chicago, "Isotopic Analysis of Uranium;" February 20–23, Berkeley, Calif., "Controlled Thermonuclear Reactions;" March 5–7, New York City, "Material Control;" March 28–29, Chicago, "Argonaut Industrial and Educational Symposium;" May 1–2, Oak Ridge, Tenn., "Homogeneous Reactor Program;" May 21–24, Oak Ridge, "Information Services Available to Access Permit Holders;" May 27–28, Chicago, "Briefing on Boiling Water Reactor."

Foreign Activities of U. S. Companies

On January 18, Atomic Power Development Associates was authorized to communicate restricted data to Belgian employees of *Syndicate d'Etude de l'Energie Nucleaire* (SEEN). The two organizations have a contract under which the United States firm will train employees of SEEN assigned to developing a fast breeder reactor program for Belgium.

On March 11, the authorization to Atomic Power Development Associates under the United States agreement for cooperation with Belgium was amended to permit exchanges in the general field of fuel element fabrication as agreed between the two governments on March 4.

The authorization issued Giffels & Vallet, Inc., last November 28 to exchange with Atomic Energy of Canada, Ltd., restricted data on fuel element fabrication was amended on April 1 to permit an exchange on full-scale plants for fabrication of all types of fuel elements, including plutonium elements. This exchange was recently assented to by the two governments under their agreement for cooperation.

Regulations

The Commission's regulation prescribing "Standards for Protection against Radiation" (10 CFR Part 20), was published in *The Federal Register* on January 29 and became effective on February 28, 1957. It was amended in May to require licensees to notify the Commission promptly of radiation incidents involving the use of licensed materials. The text of the regulation and the amendment is given in full in Appendix 7. The regulation was summarized in the previous semiannual report to Congress.[8]

"Control of Source Material" (10 CFR Part 40). This regulation was amended to put Commission contractors who handle source material in the same licensing relationship with the Commission as contractors who handle special nuclear material.

"Rules of Practice" (10 CFR Part 2). Two proposed amendments to this regulation were published in *The Federal Register* for public comment as notices of proposed rulemaking. The first, dated April 11, would provide that in the case of issuance of a construction permit or facility license the Commission either would hold a hearing on its own initiative or would publish a notice of proposed action. This notice would specify a time, not less than 15 days, within which interested

[8] See p. 120, Twenty-first Semiannual Report to Congress (July–December 1956).

persons might request a hearing. The second, published June 8, would require persons who wish to participate in a facility export licensing case to file a petition to intervene within 30 days after publication of a *Federal Register* notice that a facility export application has been filed with the Commission.

Cooperation With State Regulatory Agencies

The Commission has continued its program of working closely with interested States in the field of atomic energy regulations. In addition to keeping the States informed of licensing actions in their areas, the Commission met with State regulatory groups to explore and discuss questions of mutual interest, including State participation in the inspection of Commission licensees. Similar discussions were held with legislative committees of certain States which are considering atomic energy legislation and, in connection with their studies, have solicited Federal views.

The Commission in June sent recommendations to the Congress for amending the Atomic Energy Act of 1954 to help clarify the respective roles of the Commission and the States in the regulation of private atomic energy activities.

As a result of its work with the States over the past 2 years, including that with the Advisory Committee of State Officials and with the Council of State Governments, the Commission is studying possible amendments to the Atomic Energy Act of 1954 which would clarify areas of responsibility and of further cooperation between the States and the Commission.

Materials and Services

Processing Spent Fuel Elements

In the absence of commercial plans for facilities to process fuel elements, the Commission on February 18 announced a policy which assures private reactor operators that the Government will provide the services if private industry has not assumed responsibility for this operation at reasonable prices by the time the service is needed. The policy statement included a basis for private operators to contract for Federal services at fixed charges and is applicable to similar services provided on irradiated fuel materials returned to the United States from abroad.[9] Commitments on charges for processing fuel from reactors in other countries under agreements for cooperation,

[9] See Vol. 22, p. 1591, *The Federal Register*, Mar. 12, 1957.

however, are on a year-to-year basis, whereas domestic commitments may be made a number of years ahead under the Atomic Energy Act of 1954 (Sec. 161. m.).

Principal features of the Commission policy are:

a) Contracts with private reactor operators may extend through June 30, 1967 on the basis of operating an assumed plant at a standard daily processing charge of $15,300. Adjustments in the charge may be necessary for types of fuel elements other than those now known to be planned for use, or for which processing costs may be substantially lower or higher. (The daily rate is based on an assumed plant costing $20.5 million to build with annual operating costs, including amortization, of about $4.6 million, handling about 1 ton of natural or slightly enriched uranium daily 300 days a year.)

b) Each contract will provide firm charges except that they will be subject to escalation on the basis of an appropriate price index to adjust for changes in costs of labor and materials.

c) Contracts will be subject to cancellation on 12 months' notice if the Commission finds that fuel element processing services are available commercially at reasonable prices.

d) The services will provide for the mechanical, metallurgical and chemical treatment of spent fuel elements and blanket materials and storage of resulting wastes.

e) The processing system would yield purified nitrate salts of uranium and plutonium. For conversion of plutonium nitrate to metal, a standard charge of $1.50 per gram has been established. Additional charges would be made for converting uranium nitrate salts to uranium hexafluoride, and established to cover process losses. Unless waived by the Commission, a use charge will be made for the special nuclear materials involved during the normal processing time.

The Commission will continue its efforts to encourage private industry to build and operate fuel processing facilities.

Plutonium Price Schedule

The Commission set prices to be paid for plutonium produced in the operation of licensed power and research reactors in the United States between February 1, 1957, and June 30, 1963. These prices supersede all previous guaranteed fair prices for this material.

For purchases between February 1, 1957, and July 1, 1962, the price will range from $30 to $45 per gram depending on the plutonium

240 content of the material. For the year July 1, 1962–June 30, 1963, a single price of $30 per gram will be in effect.

The Commission intends to extend annually, for 1 year, the period for which guaranteed prices of plutonium have been established so that at any one time the guaranty period will extend at least 6 years in advance.

In making such extensions, the Commission expects that the guaranteed fair price of plutonium will be reduced to a level based upon the fuel value of plutonium in commercial power reactors, with reductions dictated by considerations of the value of the material for its intended use by the United States, and giving such weight to the actual cost of producing the plutonium as the Commission finds to be equitable. The presently estimated fuel value is $12 per gram.

The Commission action is expected to facilitate the preparation of economic data required by regulatory bodies for nuclear power projects in the United States. In arranging financing and under rate-making and stock issuance procedures generally applicable in the public utility field, complete public disclosure of anticipated and actual expenditures and revenues is required.

The principal application of the new price schedule will be in the power reactor field because research reactors generally do not produce substantial amounts of plutonium.

Boron 10 Available

Kilogram quantities of boron 10 were made available for sale for use in civilian atomic energy activities. Since boron 10 has the nuclear property of readily absorbing neutrons without itself becoming radioactive, it is particularly suitable for use in nuclear reactor shielding and control mechanisms, and also can be employed in radiation-measurement instruments.

Natural boron is a mixture of two isotopes: boron 10 which constitutes about 19 percent of the natural element, and boron 11, which does not readily absorb neutrons. Boron enriched from 30 to 95 percent in boron 10 is offered and the Commission charge for 92 percent metal is about $3 a gram.

Insurance and Indemnity

The remote possibility that accidents might arise from the conduct of atomic energy activities and involve extensive property damage or personal injury poses a problem of liability which constitutes a major obstacle to private development of atomic energy. Early in 1955,

the Commission arranged for representatives of associations of property and liability insurance underwriters to study problems related to providing this type of coverage.

The insurance industry early concluded (*a*) that workmen's compensation insurance could be provided by existing insurance facilities, (*b*) that capacity for property insurance for atomic energy installations could be organized, and (*c*) that public liability insurance could be provided in relatively large amounts, but liability coverage might not be adequate for the claims which could arise from a serious nuclear accident.

These studies led to the formation in January of three syndicates or pools to provide insurance for atomic energy activities. One made up by stock companies would provide property insurance on the facilities using atomic energy, a second stock company pool would provide public liability insurance, and a third made up by mutual companies would provide both types of insurance. The total capacity for property insurance would amount to some $60 million per installation and an equal amount would be available per installation for public liability coverage. The syndicates will provide insurance for facilities such as reactors, fuel fabricating plants, and chemical processing plants. Activities involving only the use of byproduct or source materials, and relatively small quantities of special nuclear materials, will continue to be insured under general policies issued by individual companies. The liability insurance policies will cover the facility licensee and all others who may be liable.

It appears to the Commission that this insurance coverage will be adequate except in the public liability field. While coverage available for this insurance is more than four times the amount heretofore provided for any other industry, it still is inadequate to cover the remote possibility that damage or injury could occur that would be considerably in excess of this amount. To encourage private atomic energy developments, Government indemnification is necessary for organizations engaged in activities that may involve the possibility of extensive injury or damage.

Legislative proposals for indemnity, including recommendations submitted by the Commission, were introduced in the 84th Congress, Second Session, and a bill, S. 4112, was reported out to the Congress by the Joint Committee on Atomic Energy on this subject. No further action was taken on it by that Congress.

In the first session of the 85th Congress, the bill was reintroduced as S. 715 and H. R. 1981. At hearings before the Joint Committee on Atomic Energy, March 25, 26, and 27, the Commission and others presented testimony. The Commission's recommendations were

directed toward clarification of the proposed legislation and improving administration under the proposal and did not affect general objectives. In brief, the bills provide (*a*) that all facility licensees and certain materials licensees be required to provide insurance or other financial protection against public liability in an amount determined by the Commission; (*b*) that such licensees and their suppliers of materials, equipment, and services and any others who may be liable, be indemnified in the amount of $500 million over the financial protection required; (*c*) that Commission contractors may be placed on the same basis as licensees, and (*d*) that the liability of all those liable be limited for each accident to the amount of financial protection plus the $500 million indemnity. The revised version of the bills reported on May 9 by the Joint Committee (S. 2051 and H. R. 7383) incorporated several of the Commission's recommendations.

Study on Theoretical Accident

In addition, the Commission presented to the Joint Committee on Atomic Energy, at the time of the hearings, a study entitled "Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants."

This study constitutes a part of the Commission's continuing effort on a broad front to understand and resolve this problem of possible reactor hazards so that the atomic energy industry can expand with full confidence that there will be few reactor accidents and that such as do occur will have only minor consequences.

To produce such a study, it was necessary to stretch possibility far out toward its extreme limits. Some of the worst possible combinations of circumstances that might conceivably occur were included in the hypotheses in order that their consequences might be assessed. The study must be regarded only as a rough estimation of the consequences of unlikely though conceivable combinations of failure and error and weather conditions; it is not in any sense a prediction of any future condition.

This was a difficult study to make. There has fortunately been little reactor accident experience upon which to base estimates. Nuclear reactors have been operated since 1942 with a safety record far better than that of even the safest industry. More than 100 reactor years of regular operating experience have been accumulated, including experience with reactors of high power and large inventories of fission products, without a single personal injury and no significant deposition of radioactivity outside of the plant area. There have been a few accidents with experimental reactor installations as contrasted with

430209—57——5

the perfect record of safety of the regularly operating reactors. But even these accidents did not affect the public.

To make the study, the Commission enlisted the services of a group of scientists and engineers of the Brookhaven National Laboratory and of another group of experts to serve as a steering committee, who met with many additional expert advisors to test out judgments on the estimates arrived at.

The Commission is not aware of such a study having been undertaken for any other industry and believes that if a similar study were to be made for certain other industries, with the same free rein of the imagination, it might be startling to learn what the consequences of conceivable major catastrophic accidents in those other industries could be in contrast with the actual experience in those industries.

As to the probabilities of major reactor accidents, some experts consulted in the course of this study hold that numerical estimates of a quantity so vague and uncertain as the likelihood of occurrence of major reactor accidents have no meaning. They declined to express their feeling about this probability in numbers. Others, though admitting similar uncertainty, nevertheless ventured to express their opinions in numerical terms. Estimations so expressed of the probability of reactor accidents having major effects on the public ranged from a chance of 1 in 100,000 to 1 in 1 billion per year for each large reactor. However, whether numerically expressed or not, there was no disagreement in the opinion that the probability of major reactor accidents is exceedingly low.

To reduce the matter of assumed hazards to comparative numbers, the report took the most pessimistic assumptions used and applied them to an assumed case of 100 power reactors in operation in the United States. Under these assumptions, the chances of a person being killed in any year by a reactor accident would be less than 1 in 50 million. By contrast, the present odds of being killed in any year by an automobile accident in the United States stand at about 1 in 5,000.

The portion of the study dealing with consequences of theoretical accidents started with the assumption of a typical power reactor, of 500,000 kilowatts thermal power, in a characteristic power reactor location. Accidents were postulated to occur after 180 days of operation, when essentially full fission product inventories had been built up.

Three types of accidents which could cause serious public damages were assumed. Pessimistic (higher hazard) values were chosen for numerical estimates of many of the uncertain factors influencing the final magnitude of the estimated damages. It is believed that these

theoretical estimates are greater than the damage which would actually occur even in the unlikely event of such accidents.

For the three types of assumed accidents, the theoretical estimates indicated that personal damage might range from a lower limit of none injured or killed to an upper limit, in the worst case, of about 3,400 killed and about 43,000 injured.

Theoretical property damages ranged from a lower limit of about $500,000 to an upper limit in the worst case of about $7 billion. This latter figure is largely due to assumed contamination of land with fission products.

Under adverse combinations of the conditions considered, it was estimated that people could be killed at distances up to 15 miles, and injured at distances of about 45 miles. Land contamination could extend for greater distances.

In the large majority of theoretical reactor accidents considered, the total assumed losses would not exceed a few hundred million dollars.

Reactor Development

In the first half of 1957, two power reactor plants in the Government's Experimental Reactor Program, formalized only 3 years ago, were in operation. The Experimental Boiling Water Reactor (EBWR), which went critical late last year, began supplying 5,000 kilowatts of electricity for Argonne National Laboratory. The Sodium Reactor Experiment (SRE) at Santa Susana, Calif., became critical in April and began initial low power tests. After these are completed, heat from experimental operations will be sold and will produce 6,500 kilowatts of electricity for the lines of the Southern California Edison Co. In addition, the Army Package Power Reactor, a type that has civil as well as military potentialities, began producing 1,855 kilowatts of electricity at Ft. Belvoir, Va.

The Organic-Moderated Reactor Experiment (OMRE) at the National Reactor Testing Station and the Homogeneous Reactor Experiment (HRE–2) at the Oak Ridge National Laboratory were expected to become critical during the next reporting period. The Nation's first full-scale atomic powerplant, the Pressurized Water Reactor (PWR) at Shippingport, Pa., also was scheduled to achieve criticality this year.

Under its Power Demonstration Reactor Program, the Commission signed a second contract on a proposal made under terms of its first invitation for public and private groups to undertake building various types of power reactors. The Commission also received two responses to its third invitation, issued January 7, proposing powerplants in

Florida and the Midwest. Under this program, if the Commission accepts a proposal and negotiates a contract, it may support or undertake research and development required for the project, and may permit the use of special nuclear material at no charge. All technical and economic data developed are made available to the Commission for dissemination to the public. The third invitation, in generally broadening the scope of the program, suggested specific types of reactors for which proposals were especially sought, as is reported in detail later in this section of the report.

A contract covering research and development and preliminary design to demonstrate for the Commission the feasibility of a sodium-cooled, heavy water-moderated reactor system was entered into.

With two full-scale atomic powerplants and one smaller one under construction by private organizations, three additional industrial groups announced during 1957 their plans to build four nuclear reactors for commercial purposes, bringing to 10 the total announced as independent projects by industrial organizations in the United States.

The Commission signed a contract for designing and constructing the nuclear propulsion plant of the first nuclear-powered merchant ship.

Considerable progress was made in military reactor development. The reactor of the USS *Nautilus* was refueled after having driven the submarine more than 62,000 nautical miles without refueling. The USS *Seawolf* was accepted for restricted service but the Navy Board of Inspection and Survey recommended replacing her sodium plant with a Nautilus-type pressurized water reactor. The S1G land-based prototype reactor for the *Seawolf* at West Milton, N. Y., was shut down. Work continued on land-based prototype powerplants for two submarines and a large ship. Design and development work continued on nuclear propulsion plants for a cruiser and a destroyer.

The Commission's tabulation of "Nuclear Reactors, Built, Building, or Planned in the United States," including critical assemblies and zero power reactors, given in full in Appendix 12 shows the following changes during the 6-month period:

	December 31 1956	*June 30 1957*	*Increase or (decrease)*
Operated, later dismantled	17	24	7
Operated, or licensed to operate	74	84	10
Being built	46	66	20
Planned	94	93	(1)
TOTAL	231	267	36

Progress continued in general engineering and development activities supporting both civil and military reactor programs. Construc-

tion of the Commission's second large generalized test reactor, the Engineering Test Reactor, neared completion at the National Reactor Testing Station. Experimental plutonium fuel elements for the Materials Testing Reactor were fabricated and tested; subsequently they were added to the reactor core and used as fuel elements. Further progress was made in developing methods for safely disposing of radioactive wastes.

Civilian Power Reactor Program

The Nation made progress during the last 6 months in all principal aspects of the effort to achieve economic nuclear power. At the same time, sizeable increases in estimated construction costs for power reactors have become apparent. In the Commission's Experimental Power Reactor Program, operation of one reactor, attainment of criticality in another, and the approaching operation of others, was expected to supply improved technology and to provide some bases for better economic evaluations. In the Power Demonstration Reactor Program, plans for cooperation between the Commission and proposers of various types and sizes of demonstration protoytpe reactors made further advances. Though still in the early stages, the plans of industry to construct power reactors with private funds showed expansion.

Reactor concepts that are developed to technological readiness in the Commission's Experimental Program were expected to be advanced steadily toward inclusion in full-size powerplants, if not as independent undertakings by public and private groups, then under the Power Demonstration Reactor Program, or as direct Federal projects.

Experimental Power Reactor Program

Fundamental to progress toward economic nuclear power, the Commission's Experimental Power Reactor Program includes projects concerned with development, design, construction, and operation of the following reactors: pressurized water, boiling water, sodium-graphite, fast breeder, aqueous homogeneous, organic-moderated, liquid metal-fueled, and molten plutonium.

The Gas-Cooled Reactor Experiment being conducted as part of the Army Reactors Program has civil as well as military significance.

The concept underlying this multiplication of reactor experiments is that the present general low cost of electric power produced with the ample conventional fuels of this country affords the United States an opportunity, which it should exploit, to canvass all promising reac-

tor types so as to select those best suited to the various demands for nuclear powerplants that will provide reliable, safe, and economic power for use in the United States and in other countries.

With the exception of the Pressurized Water Reactor, reactor projects in the Experimental Program are not full-scale powerplants of a size which it is hoped to build ultimately for commercial production of nuclear power. Instead, they are reactor experiments undertaken on a scale large enough to provide definitive answers to technological questions. Ten such reactor experiments have been completed in the United States, four are under construction, and four more are planned.

Pressurized Water Reactor. Installation of components continued in the Pressurized Water Reactor plant at Shippingport, Pa., designed by the Westinghouse Electric Corp. as prime contractor to the Commission. The Duquesne Light Co., Pittsburgh, Pa., is building the non-nuclear portion of the plant and will operate the entire plant when it is completed. The initial capacity of the plant is expected to be in excess of 60,000 electric kilowatts.

The reactor pressure vessel which will contain the fuel core was set in its final position, two of four coolant pumps were installed, and the main generator was placed in position on the turbine-generator side of the plant. Tubing of the main condenser was completed. Auxiliary equipment switchgear and busses have been energized. Construction of the reactor service building was essentially complete.

During this reporting period, re-estimates showed that costs for the nuclear portion of the plant will be $55 million, as against $37.75 million previously estimated.

Experimental Boiling Water Reactor (EBWR). The Experimental Boiling Water Reactor at Argonne National Laboratory, which went critical late in the last reporting period,[10] was dedicated on February 9, when it began its first extended full-power tests. At the ceremony held at the Argonne National Laboratory, Chairman Strauss called attention to the fact that "The electrical kilowatts from this plant are not a byproduct—they are the prime product. . . . Thus, this occasion marks a milestone in the development of the peaceful atom—another important step toward the fulfillment of President Eisenhower's promise to the world that the United States will . . . 'devote its entire heart and mind that the miraculous inventiveness of man shall not be dedicated to his death but consecrated to his life.' . . .

"This, therefore, I think is the year when we begin to see something of the results of our comprehensive nuclear power program—the year when our research and development begins to pay off with Argonne's

[10] See p. 41, Twenty-first Semiannual Report to Congress (July–December 1956)

Experimental Boiling Water plant leading the parade. 1957 may well come to be regarded in the future as the year of the coming of the age of nuclear power, for before this year is out we will have in operation at least five and perhaps six power producing reactors turning out some 87,000 kilowatts of electricity and all of it for peaceful uses."

The EBWR, the first United States civilian reactor designed exclusively for generation of electricity to go into service, supplies 5,000 kilowatts of electricity to the Argonne Laboratory. It was designed as a pilot plant for larger commercial power reactors. The reactor was completed on schedule at a cost of $6.1 million, including all building and the initial core but not the research and development work.

The performance of the EBWR indicated that it probably can produce satisfactorily twice the design reactor power of 20 megawatts (heat). A further increase in power may be achieved principally by forced circulation of the coolant. Future operating plans call for substituting heavy water for the light water now used as the reactor's coolant and moderator.

Boiling Reactor Experiment No. 4 (BORAX-IV). Power excursion tests were started in January with the boiling water reactor, BORAX–IV, at the National Reactor Testing Station in a series of experiments by Argonne National Laboratory designed to study reactors of this type further. Steady-state boiling tests at atmospheric pressure were carried out during February with power levels as high as 2.6 megawatts. Oscillations in reactivity levels were evident at higher power, but the general evidence indicated that the reactor was much more stable than anticipated.

BORAX–IV is a modification of the previous reactor, designated BORAX–III, accomplished by substituting aluminum-clad uranium oxide-thorium oxide fuel elements. Its principal purpose is to test the stability and safety of such fuels.

Argonne Boiling Reactor Facility (ARBOR). Design work by Argonne National Laboratory continued on the Argonne Boiling Reactor Facility (ARBOR).[11]

Sodium Reactor Experiment (SRE). On April 25 the Sodium Reactor Experiment went critical. During the initial start-up the reactor was operated at a power level of about one kilowatt of heat. No electricity was generated. The design capacity of the SRE is 20,000 kilowatts of heat. It was built by Atomics International, a division of North American Aviation, Inc., at Santa Susana.

Numerous tests were begun to determine the nuclear characteristics of the reactor and to establish the satisfactory operation of all reactor

[11] See pp. 41–42, Twenty-first Semiannual Report to Congress (July–December 1956).

components. After these tests, the power level of the reactor will be increased gradually.

Heat will be purchased on an experimental basis by Southern California Edison to supply 6,500 kilowatts of electricity, from a generator installed by the company at no cost to the Government.

Fast breeder reactors. A replacement core highly enriched with uranium 235—the third core for the Experimental Breeder Reactor No. 1 (EBR–1)—was under manufacture at Argonne National Laboratory in order to put the reactor back into operation late in 1957. The second core of this reactor, which was damaged during a series of transient experiments in November 1955,[12] was removed from the reactor at the National Reactor Testing Station (NRTS) and shipped to the Argonne National Laboratory for detailed examination. The replacement core was designed to control inward-bowing of the fuel elements under certain conditions of coolant flow. Bowing is believed to have been a cause of the nuclear instabilities observed in operation of the reactor with the previous core.

Mockups of several full-sized components for Experimental Breeder Reactor No. 2 (EBR–2), and a one-quarter scale model reactor tank, were operated at Argonne. These mockups included several large sodium pumps, fuel-handling equipment, shut-down-cooling systems, and fuel-reprocessing equipment. Such component and equipment tests have demonstrated the technical feasibility of remote handling mechanisms and other novel features of the EBR–2 design. The H. K. Ferguson Co., Cleveland, completed preliminary architect-engineering studies. Current estimates of costs total $29.1 million for construction at NRTS of the entire reactor plant, including an integrated fuel reprocessing system. This project was under the direction of the Argonne National Laboratory.

Molten plutonium reactor. Fabrication of Los Alamos Molten Plutonium Reactor Experiment No. 1 (LAMPRE–1), a small-scale reactor with molten plutonium as fuel, continued at Los Alamos Scientific Laboratory. The main effort was directed toward developing methods of fabricating tantalum, a material able to withstand corrosion from molten plutonium.

Homogeneous reactors. Preoperational testing of the Homogeneous Reactor Experiment No. 2 at the Oak Ridge National Laboratory was resumed following a shutdown period in December (reported previously [13]) that was caused by chloride-induced stress-corrosion crack-

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

[13] See p. 43, Twenty-first Semiannual Report to Congress (July–December 1956).

ing of stainless steel tubing in the leak-detector system. Nonnuclear tests with water and uranyl sulfate solutions at 280 degrees centigrade and 1700 pounds per square inch were performed for more than 1200 hours during January, February, and March. The results were satisfactory. Natural uranium was circulated at full design conditions for more than 500 hours.

A complete inspection of the leak-detector tubing and the flanges to which the tubing is attached was made in April. Parts revealed by the inspection to have been damaged by the chloride contamination were being replaced. When the replacement is completed, final checkout runs will be undertaken and the reactor was expected to go critical late this year.

Examination and evaluation of the Los Alamos Power Reactor Experiment No. 1 (LAPRE–1), which was abandoned in 1956, continued to assist in the development of Los Alamos Power Reactor Experiment No. 2 (LAPRE–2) expected to achieve criticality later this year. Main efforts on LAPRE–2, which in general is less complex than LAPRE–1, were on development of a corrosion-resistant heat-exchanger. Leaks in the heat-exchanger were the cause of the shutdown of LAPRE–1.

Organic-Moderated Reactor Experiment (OMRE). Construction of the Organic-Moderated Reactor Experiment was completed by Atomics International at the National Reactor Testing Station and the reactor was scheduled for critical loading in July. The reactor, which will produce 5,000 to 16,000 heat kilowatts (no electricity) will demonstrate whether or not organic materials such as diphenyls or terphenyls may be used as coolants and moderators for a power reactor.

Liquid Metal Fuel Reactor Experiment (LMFRE). Research and development work on portions of the LMFRE system continued at Brookhaven National Laboratory under the contract, signed by the Commission last November, with The Babcock & Wilcox Co., New York, to develop, design, and build a liquid metal-fueled reactor. The work under way included evaluation of graphite and other structural materials suitable for reactor fabrication, and development and testing of various reactor components for operation at the high temperatures to be encountered in the reactor.

Pressurized heavy water reactor program. A study including experimental research and development in the field of pressurized heavy water reactors for electrical power production was under way at the Savannah River plant. A preliminary survey of several possible arrangements for such a reactor system was completed. Work is

under way on natural uranium fuel element development and on important mechanical design features of heavy water power reactors.

Power Demonstration Reactor Program

Including the first two proposals formally submitted in response to the third invitation issued by the Commission for public and private organizations to participate in its Power Demonstration Reactor Program, a total of 12 proposals has been received. Under the first invitation [14] issued January 1955, three proposals were approved as bases for contract negotiations,[15] and two contracts have been signed,[16] one in this reporting period. Under the second invitation issued in September 1955 and calling for proposals for small-size nuclear powerplants,[17] four of the seven proposals received were approved as bases for contract negotiations.[18]

The seven accepted proposals, including those under contract and those on which contracts were being negotiated were:

Organization and Plant Location	*Type*	*Principal Contractor*	*Power (Electrical Kilowatts)*
Power Reactor Development Co.[a] Inc. (Monroe, Mich.).	Fast breeder	PRDC	100, 000
Yankee Atomic Electric Co.[b] (Rowe, Mass.).	Pressurized water.	Westinghouse Electric Corp.	134, 000
Consumers Public Power District (Beatrice, Nebr.).	Sodium graphite.	Atomics International.	75, 000
Rural Cooperative Power Ass'n. (Elk River, Minn.).	Boiling water	AMF Atomics Inc.	[c] 22, 000
Wolverine Electric Cooperative (Hersey, Mich.).	Aqueous homogeneous.	Foster-Wheeler Corp.	[c] 10, 000
Chugach Electric Assoc., Inc., and Nuclear Development Corp. of America (Anchorage, Alaska).	Sodium, heavy water.	Nuclear Development Corp. of America.	10, 000
City of Piqua, Ohio	Organic moderated.	Atomics International.	12, 500

[a] Contract signed March 26, 1957.
[b] Contract signed June 6, 1956.
[c] Represents total output of plant, about 20 percent of which will be non-nuclear.

Third invitation. In expanding the Power Demonstration Reactor Program on January 7 by issuing a third invitation for proposals to develop, design, construct, and operate nuclear powerplants, the Commission placed no limitations as to types or sizes, and no deadline

[14] See p. 41–43, Eighteenth Semiannual Report to Congress (January–June 1955).
[15] See p. 47, Nineteenth Semiannual Report to Congress (July–December 1955), and p. 39, Twentieth Semiannual Report to Congress (January–June 1956).
[16] See p. 39, Twenty-first Semiannual Report to Congress (July–December 1956).
[17] See p. 47, Nineteenth Semiannual Report to Congress (July–December 1955).
[18] See p. 40, Twenty-first Semiannual Report to Congress (July–December 1956)

for submission of proposals other than a requirement that plant construction be completed by certain fixed dates. The completion date was originally set as not later than June 30, 1962, and this still applies for all types of reactors except one. For reactors using a fluid-fuel system, the completion date was extended by a June 10 announcement of the Commission until at least June 30, 1963. This extension was made necessary by unforeseeable delays in the Commission's research and development program expected to produce basic data for reactors of this type.

The Commission expressed a special interest in reactors fueled by (*a*) natural uranium with a heavy-water moderator, and (*b*) aqueous solutions or slurries of either uranium or uranium- and thorium-bearing materials. Should industry not make acceptable proposals on these types of reactors, the Commission will request Congressional authority and funds to initiate them as Government projects. Similarly, and on the same conditions, the Commission expected from time to time to specify other types of reactors as ready for construction when technological progress appeared to warrant such announcement.

The assistance to be provided by the Commission under the third invitation is of three general types: (*a*) waiver of established charges for use of source and special nuclear materials over a specified period of time, (*b*) performance at no charge, or at a reduced charge in Commission laboratories of mutually agreed-upon research and development not reasonably available elsewhere, and (*c*) support of research and development required to advance the technology of projects which promise to make a significant contribution toward achieving economic, abundant, and safe nuclear power.

On April 30, the *Florida Nuclear Power Group,* consisting of the Florida Power Corp., the Florida Power and Light Co., and the Tampa Electric Co., submitted a proposal in response to the third invitation. The proposal contemplates constructing in west central Florida a natural uranium-fueled, heavy water-moderated, gas-cooled reactor of 136,000 electric kilowatts—a reactor of a general type specifically mentioned in the third invitation.

On May 15, the *Northern States Power Co.*, a utility operating in Minnesota, Wisconsin, North and South Dakota, proposed a boiling water reactor powerplant designed to generate 66,000 kilowatts of electricity. A number of other Midwest utilities indicate they would contribute to part of the cost of research and development for this project.

Contract activities. The contract executed by the *Power Reactor Development Co.* (PRDC) and the Commission on March 26 was the second for a reactor proposed in response to the Commission's first

invitation under the Power Demonstration Reactor Program. By this contract, the Commission undertakes to perform research and development at a cost to the Commission no greater than $4.45 million and to waive its normal use charges on the special nuclear material fuel for 5 years after the issuance of an operating license. In return, the Detroit company is to provide to the Commission complete information on construction and operation of its fast breeder reactor at Monroe, Mich., rated at 100,000 electric kilowatts. In a letter agreement signed at the same time, the Commission undertook to reprocess the company's spent fuel and blanket (breeding) material until commercial facilities became available to provide this service at a reasonable price. (See report on Commission's general announcement of this service in section on Civilian Application.)

Construction of the PRDC's steel reactor building began during this reporting period, on the 915-acre site near Monroe, Mich. Site development and foundation work were under way.

The *Yankee Atomic Electric Co.*, of Boston, Mass., continued research and development work on the 134,000 electric kilowatt pressurized water reactor which it plans to build at Rowe, Mass., by 1960. Assistance which the Commission will give to this project was defined in a contract signed in June 1956, the first contract concluded under the Power Demonstration Reactor Program.[19]

Contract negotiations continued during this reporting period with *Consumers Public Power District*, Columbus, Nebr., for its proposed 75,000 electric kilowatt sodium-graphite nuclear powerplant.

In connection with the joint proposal of the *Chugach Electric Association* of Anchorage, Alaska, and the *Nuclear Development Corp. of America* (NDA), White Plains, N. Y., the Commission contracted with NDA for research, development, and preliminary design work at an estimated cost of $2.2 million to demonstrate the feasibility of a liquid sodium-cooled, heavy water-moderated reactor system. This work looked toward construction and operation of a nuclear electric plant at Anchorage, Alaska, under a three-party agreement now being negotiated among the Nuclear Development Corp., the Chugach Association, and the Commission. The contract with NDA covers work under the first of three phases. Negotiations continued on a contract with Chugach and NDA which would cover the remaining phases of the project—final development and engineering design; and construction, startup, and operation.

Contract negotiations also continued with *Rural Cooperative Power Association*, Elk River, Minn.; *Wolverine Electric Cooperative*, Big Rapids, Mich.; and the *City of Piqua, Ohio.*

[19] See pp. 39–40, Twentieth Semiannual Report (January–June 1956).

Other Industrial Projects

Three additional groups announced during this reporting period their intentions to build four nuclear powerplants. These additions brought to 10 the number of projects announced by utility or industrial organizations as independent projects. Some are financed exclusively from private sources. Financial arrangements have not been completed in all cases.

Pacific Gas & Electric Co. announced plans to build alone or in partnership with other California utilities a large-scale reactor in California. PG&E obtained preliminary estimates from the General Electric Co. and the Westinghouse Electric Corp.

West Penn Group, including utilities which operate in the Ohio Valley and contiguous areas, announced plans to build by 1962 a small prototype reactor with an electric output of about 13,000 kilowatts. If the research work on the prototype developed satisfactorily, West Penn hoped to undertake well before 1962 the preparation of plans for constructing and operating a reactor of up to 200,000 electrical kilowatts.

Isotope Products, Inc., Buffalo, N. Y., with several other corporations announced plans to build a boiling water reactor for dual production of cobalt 60 and process steam, the steam to be supplied to a pulp and paper mill. The reactor was being designed by General Nuclear Engineering Corp., Dunedin, Fla.

The organizations and reactors in the independent projects announced earlier are:

Organization and Plant Location	*Type*	*Principal Contractor*	*Power (Electric Kilowatts)*
Consolidated Edison Co. of N. Y. (Indian Point, N. Y.)	Pressurized water.	Babcock & Wilcox.	[a] 275, 000
Commonwealth Edison Co. (near Joliet, Ill.).	Boiling water	General Electric.	180, 000
General Electric Co. and Pacific Gas & Electric Co. (Pleasanton, Calif.).	Boiling water	General Electric.	5, 000
Pennsylvania Power & Light Co. (Eastern Pennsylvania).	Aqueous homogeneous.	Westinghouse	150, 000
New England Electric System (New England).	Undetermined	Not Selected	200, 000
Carolinas–Virginia Nuclear Power Assoc's., Inc. [b]	Undetermined	Not Selected	10, 000–30, 000

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

[b] Virginia Electric & Power Co., Carolina Power & Light Co., Duke Power Co., and South Carolina Electric & Gas Co.

Full-scale construction of the *Commonwealth Edison* 180,000-kilowatt nuclear powerplant began in March, and of the 275,000-kilowatt *Consolidated Edison* combined nuclear and conventional plant in February. Completion was expected by 1960 in both cases. The 5,000-kilowatt plant of *General Electric and Pacific Gas & Electric Co.* was under construction and scheduled for completion this year.

Research and development work preliminary to initiation of construction was well advanced on the *Pennsylvania Power and Light Co.* project.

Plans of the other organizations listed were not yet detailed.

Maritime Propulsion Reactors

The Commission and the Maritime Administration formalized by a memorandum of understanding their administrative arrangements for carrying out a cooperative program for construction of the first nuclear-powered merchant ship and also for a longer-range development program aimed at achieving economically competitive nuclear propulsion for merchant ships.

First Nuclear-Powered Merchant Ship

A contract was executed on April 8 with The Babcock & Wilcox Co. of New York, for design and construction of the nuclear propulsion plant for the first nuclear-powered merchant ship. The contract stipulates that for a fixed price of $9.872 million, Babcock & Wilcox will furnish the basic propulsion system, including the reactor and components of the steam plant and auxiliary systems. The remainder of the Commission's responsibilities in this project, which include furnishing the containment vessel, shielding, and related items for the reactor, and installation of the propulsion system, were not included in the present contract and are to be provided by appropriate contractors at a later date.

The Maritime Administration awarded a contract to George G. Sharp, Inc., New York, to act as design agent for the ship itself. Sharp was expected to complete preliminary plans and specifications by August. The company engaged Walter Kidde Nuclear Laboratories, Inc. as consultant on nuclear phases of design.

A joint Commission-Maritime Administration Shipyard Survey Board completed its review of facilities and personnel at shipyards interested in constructing the first ship and qualified to do so. The survey will provide a basis for selecting a yard with which to negotiate a fixed-price contract.

Entry of Nuclear-Powered Ships Into Commerce

Work started during this reporting period on resolving the many unique operating requirements associated with entry of nuclear-powered ships into foreign and domestic commerce. The vessel now being planned is considered a forerunner of an eventual privately owned and operated American nuclear-powered merchant marine.

As part of this program, cooperative efforts were started with the Coast and Geodetic Survey, Department of Commerce, for harbor survey work, with the Coast Guard, Department of the Treasury, for establishing operating and design and construction codes and regulations, and with the Public Health Service, Department of Health, Education and Welfare, to ascertain appropriate health and safety regulations. In addition, marine insurance underwriters were studying anticipated insurance needs. Arthur D. Little, Inc., Cambridge, Mass., undertook to analyze the health physics and safety aspects associated with operating nuclear-powered merchant ships, and the Ralph M. Parsons Co., Los Angeles, was investigating shore and fuel handling facilities and preparing recommendations pertaining to these facilities as they relate to nuclear ships.

Economically Competitive Ships

Development work continued on an intermediate and long-range program leading to competitive nuclear powerplants for merchant ships. Preliminary design feasibility studies were completed on the following concepts—organic-cooled and -moderated; boiling water; and three gas-cooled systems with closed-cycle turbines: two helium-graphite systems, and a carbon dioxide hydride-moderated system. Consideration of these studies is expected to define a long-range effort on concepts that offer the maximum possibility of producing competitive power.

A contract was awarded to the Westinghouse Electric Corp. for the study of a supercritical water reactor, that is, one which would operate at extremely high pressures and temperatures.

American Radiator and Standard Sanitary Corp., Redwood City, Calif., with Stanford Research Institute, Menlo Park, Calif., as a subcontractor, was selected to study possible applications of nuclear energy within the next decade to the entire field of merchant ship propulsion, taking into consideration evolutionary trends of both conventional and nuclear systems.

In connection with this development work, private industry showed increased interest in the role nuclear energy will play in the future merchant marine. Several ship-operating companies indicated a

willingness to participate with the Government in a cooperative nuclear shipbuilding program.

Military Reactors Program

Naval Reactors Program

Submarine Thermal Reactor (S1W/S2W). The Naval Reactor Facility (S1W) plant at the National Reactor Testing Station (NRTS) continued operating during this reporting period to develop and test improved reactor devices and to train naval personnel.

USS "Nautilus" (SSN571). The submarine USS *Nautilus* was refueled at Electric Boat Division of General Dynamics Corp., Groton, Conn., after traveling 62,560 miles, 36,498 of which were fully submerged. To duplicate this performance a conventionally powered submarine of the same size would have required more than 2 million gallons of diesel fuel—enough to fill 217 tank cars making a train more than 1½ miles long.

The used core was shipped to the National Reactor Testing Station for examination.

The *Nautilus* put to sea again on April 11. Since then she has steamed more than 8,000 miles on her new core.

In May while traveling to the Pacific to participate in fleet activities, the *Nautilus* traveled the 3,049 miles from Panama to San Diego completely submerged. This is the longest distance any ship has ever traveled underwater without surfacing. An average speed of over 19 knots was maintained.

Submarine Intermediate Reactor. In March the Commission shut down the SIG land-based prototype of the USS *Seawolf* (SSN575) propulsion plant at West Milton, N. Y. This action resulted from the Navy's plan not to install sodium-cooled reactor propulsion systems in additional naval vessels and the fact that the experiments conducted for the *Seawolf* had been completed. The 225-foot steel sphere which housed the *Seawolf* prototype plant will be retained intact for future use in experimental operation of prototypes for other naval powerplants.

Following decision to shut down this reactor, the contract with the Niagara Mohawk Power Corp. for the sale of electric power produced by it was terminated on March 21.

Between July 6, 1956, and the termination date of the contract, sales totaled 765,160 kilowatt-hours of electricity, which, at 3 mills per

kilowatt-hour, amounted to $2,295.48. The power was generated by a 10,000-kilowatt turbine generator installed and operated by the General Electric Co. at no cost to the Government. Of 2,294,000 kilowatt-hours of electricity generated, only electricity found surplus to the needs of West Milton site operations was sold.

The USS *Seawolf*, powered by the S2G reactor plant, put to sea on January 21 for her first sea trials. On February 2, she completed her builder's trials, and on March 18–21 the Navy Department conducted Board of Inspection and Survey trials. As a result of these trials, the Board recommended that the *Seawolf* be accepted for restricted service and that the sodium plant be replaced with a pressurized water reactor plant of the *Nautilus* type. The *Seawolf* was commissioned March 30 at Groton, Conn.

Submarine Advanced Reactors. Design and development work on the Submarine Advanced Reactor propulsion plant (S4G) was continued at the Knolls Atomic Power Laboratory, Schenectady, N. Y., by General Electric. Construction of the prototype plant (S3G) continued nearby at West Milton, N. Y. A section of a submarine hull was erected. It will house the prototype reactor compartment and engine room.

Small Submarine Reactor (S1C). The Windsor, Conn., site of the Nuclear Engineering Laboratory of Combustion Engineering, Inc., was cleared for construction of a land prototype of a small submarine reactor propulsion plant. Design and development work on the prototype nuclear propulsion plant continued.

Large Ship Reactor (A1W). Construction of the A1W site facilities at the National Reactor Testing Station continued. Westinghouse Electric Corp. continued design and development work on the nuclear propulsion plant. Estimated construction costs for the reactor increased by $5.2 million to a total of $35 million.

Cruiser project (F1W). Design and development work continued at the Bettis Laboratory, Pittsburgh, Pa., on a nuclear propulsion plant for a cruiser. This will be the first United States Naval surface ship to be propelled by nuclear power. The ship has been named the *Long Beach* CG(N) 160 by the Secretary of the Navy, and will be built at the Quincy, Mass., shipyard of the Shipbuilding Division, Bethlehem Steel Co.

Destroyer reactor (D1G). In February, the Commission assigned to the Knolls Atomic Power Laboratory a project for developing a

430209—57——6

pressurized water nuclear propulsion plant for use in a surface vessel of the destroyer type. KAPL contracted with the Shipbuilding Division of the Bethlehem Steel Co. for machinery arrangement and propulsion plant design work.

Army Reactors

Army Package Power Reactor (APPR). The Army Package Power Reactor, a prototype of a pressurized water stationary nuclear powerplant developed by the Commission for the Department of Defense, achieved criticality on April 8 at the U. S. Army Engineer Center, Fort Belvoir, Va. A dedication ceremony was held on April 29.

Chairman Strauss stated at the ceremony that "Our paramount responsibility under the law is to make 'the maximum contribution to the common defense and security' . . . The joint effort which has produced this promising reactor supports that 'paramount responsibility,' for it means that the armed forces will have compact, efficient, and readily transportable powerplants for remote outposts where electrical energy would be unobtainable, except under conditions of extreme logistical strain."

Chairman Strauss went on to say that ". . . aside from its substantial contribution to the common defense and security, this Package Power Reactor is essentially an instrument of peaceful progress. And in this aspect it meets the second responsibility placed by the law upon the Commission that ' . . . the direction, 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.' "

The APPR is the first nuclear powerplant built or contracted for under a fixed-price contract. The plant, net output of which is 1,855 electric kilowatts, underwent tests by the builder, Alco Products, Inc., of Schenectady, N. Y., preparatory to an extensive performance run to demonstrate reliability. Field models of this reactor will provide steam for space heating in addition to electricity.

Details of design of the reactor are unclassified, which means that industry has complete access to its technology and can draw upon it for the development of commercial plants for use in this country and abroad.

Argonne Low Power Reactor. Final design of the Argonne Low Power Reactor was essentially completed during this reporting period. Construction work on this boiling water heterogeneous reactor continued at the National Reactor Testing Station. Fegles Construction Co., Inc., Minneapolis, Minn., the low bidder, was awarded the general

contract to construct the conventional portion of the plant, and completion was scheduled for 1958. Chicago Bridge and Iron Company was selected to fabricate and erect the steel tanks and structural steel. Estimated cost of construction of the total project was increased from $1.3 million to $1.98 million.

The Argonne National Laboratory continued development of the nuclear portion of this prototype of small plants intended to provide heat and electricity for remote military installations.

Food Irradiation Reactor. The Commission signed a contract on May 15 with Kaiser Engineers, Division of Henry J. Kaiser Co., for the research and development to permit refinement of a conceptual design of the Food Irradiation Reactor into a preliminary design.

Gas-Cooled Reactor Experiment. The Commission negotiated a contract on February 12 with the Aerojet-General Corp., Azusa, Calif., for design, fabrication, and initial operation of the Gas-Cooled Reactor Experiment (GCRE) at the National Reactor Testing Station. This experiment was intended to develop engineering data and to provide experience for the design and construction of gas-cooled reactors to meet military needs and possible civilian requirements for small central power stations. The contractor completed the preliminary design experiment and continued to perform supporting research and development.

Four gas-cooled loops at different facilities, which will serve to screen and test GCRE components, were in various stages of completion.

Advanced reactor systems. The General Motors Corp., Detroit, completed an engineering analysis of a nuclear-powered overland logistical cargo carrier. Gilbert Associates, Inc., Reading, Pa., completed a preliminary design study of a 20,000 electric kilowatt powerplant suitable for overseas installations.

The Raytheon Manufacturing Co., Waltham, Mass., completed a conceptual design of a liquid metal-fuel package reactor. The contract was extended at no cost to the Commission to permit additional experiments aimed at proving feasibility of the design.

Aircraft Reactors Program

National Reactor Testing Station activities. Reactor experiments relative to nuclear operation of turbojet engines continued at the National Reactor Testing Station performed by General Electric Co. under contract to the Commission.

Construction started on the Low Power Test Facility. In addition, construction of minor test and service facilities was initiated.

Connecticut Aircraft Nuclear Engine Laboratory (CANEL). The construction of facilities at CANEL proceeded satisfactorily and some portions of this complex were occupied. This laboratory, being built at Middletown, Conn., by the U. S. Air Force, will be used for research and development work for the Air Force and the Commission. The facility will be operated by the Pratt & Whitney Aircraft Division, United Aircraft Corp., East Hartford, Conn., under contract to the Air Force and the Commission.

Nuclear-powered rockets and ramjet engines. The Commission initiated feasibility studies relating to the application of nuclear power to rocket and ramjet engines.

General Engineering and Development

Testing Reactors

Engineering Test Reactor. Construction of the Engineering Test Reactor (ETR) at the National Reactor Testing Station continued during the reporting period with completion scheduled for this summer. Operating at 175 megawatts, the ETR will provide a flux of 4×10^{14} thermal energy neutrons and 1.5×10^{15} neutrons above thermal energy.

The reactor will have larger experimental spaces than earlier test reactors, most of them incorporated in the fuel section of the core. The ETR will be used primarily in the Commission's reactor development program. Kaiser Engineers, a division of the Henry J. Kaiser Co. is responsible for the architect-engineering work, for the overall design based on conceptual design studies by Phillips Petroleum Co., and for construction of the reactor. Nuclear design of the reactor core and facilities within the tank was by the Atomic Power Equipment Department of the General Electric Co. under contract to Kaiser. The reactor will be operated by Phillips Petroleum Co.

An ETR critical facility was completed on schedule at NRTS and achieved criticality in May. It will yield important operating information on experiments before actual ETR irradiations.

Materials Testing Reactor operations. Charges for all Materials Testing Reactor irradiations were reduced 12 percent, effective January 7. The reduction, the second since reactor startup, reflected efforts by Phillips Petroleum Co., the operating contractor, to reduce costs of

operation by more efficient utilization of the reactor, equipment, and manpower.

Fuel Element Development

Enriched fuel elements for reactors abroad. The Commission continued its program to develop fuel elements using uranium enriched to 20 percent in uranium 235, primarily for research reactors of other countries. During this reporting period two uranium-aluminum alloy elements were fabricated by the Oak Ridge National Laboratory and four by Babcock & Wilcox. The elements then were irradiated in the Materials Testing Reactor, and none of the inspected elements has yet shown any evidence of damage.

Negotiations were completed for procuring from Babcock & Wilcox a full core-loading of 20 percent enriched uranium 235 fuel elements for operation of the Materials Testing Reactor. Results from operation with these elements will be compared with the results obtained previously with highly enriched elements.

Plutonium fuel elements. Irradiation of four plutonium fuel elements and three plutonium fuel shim (movable) elements, fabricated from plutonium-aluminum alloy, was started in the Materials Testing Reactor to produce for research multigram quantities of higher plutonium isotopes and transplutonium isotopes, and to determine the damage caused by irradiation. The fuel shim elements will be irradiated for 2 years, the fuel elements for about 150 days. Results to date revealed no evidence of radiation damage, distortion, or fission breaks.

Additional plutonium fuel elements were being prepared at Oak Ridge National Laboratory and Los Alamos Scientific Laboratory, and the feasibility of operating the Materials Testing Reactor with a full core-loading of plutonium elements was being investigated.

Reactor Safety

Transient testing (i. e., testing the behavoir of reactors when subjected to variations in the rate of neutron production) continued at the National Reactor Testing Station on the Special Power Excursion Reactor Test (SPERT–1), an unpressurized tank type of water-moderated reactor which became critical in July 1955.

Design work was completed on SPERT–2, and construction continued on SPERT–3. These reactors, intended to yield safety information on operation of medium pressure and high pressure water reactors, respectively, were scheduled for completion in 1958.

Transient tests continued also with the Kinetic Experiment on Water Boilers (KEWB–1), a homogeneous water-boiler reactor operated for the Commission by Atomics International at Santa Susana, Calif.

The Commission's research and experimental programs on reactor safety were reported in detail in the Twenty-first Semiannual Report to Congress, pp. 139–151.

Research reactor dismantled. After more than a thousand successful operations, a small fast-neutron critical assembly known as Godiva was dismantled and retired at Los Alamos Scientific Laboratory after an accidental excursion on February 12 which disrupted the enriched uranium core and damaged support members. Godiva was so named because it was an unshielded, unmoderated spherical mass of uranium 235. Godiva was operated by remote controls, located about a quarter of a mile away, in order to prevent accidental exposure of personnel to radioactivity during routine tests. This practice has proved valuable in that, under abnormal conditions, such as this incident, no personnel were exposed to released radioactivity.

At the time of the accident the assembly was being used as a source of neutrons for instantaneous irradiation of experimental reactor fuels. The purpose of the experiment was to determine the behavior of this material after exposure to a sudden wave of neutrons. The thermal shock which resulted in the damage was caused by a nuclear power surge considerably higher than the expected power level.

Godiva was constructed about 6 years ago in order to make experimental investigations of the characteristics of unreflected assemblies of enriched uranium metal. It was modified later to explore chain reaction phenomena just above the prompt critical condition, i. e., the level of criticality in which the reaction is sustained by the neutrons emitted at the instant fission occurs without need for "delayed" neutrons which are emitted shortly after a fission occurs. It was found that the fast fission bursts produced under these conditions were self-limited by virtue of the thermal expansion of the uranium assembly.

The pulse of gamma and neutron radiation accompanies the fission burst. This radiation pulse was found to be extremely valuable in biomedical studies of radiation effects, evaluation of radiation damage to material, and calibration of measurements made in connection with nuclear bomb tests. The Godiva device therefore was adapted as a radiation source for such studies. As the work continued it was recognized that many improvements in convenience and control could be made and replacement equipment was under design at the time of

the accidental excursion. The new equipment was completed and placed in operation in June.

Chemical Processing

One large factor that may help reduce costs of electric power generated by nuclear reactors is a cheaper method of removing fission products from irradiated fuel elements and blanket materials. In an effort to reduce fuel cycle costs, the Commission continued its varied efforts to improve methods for chemical processing of irradiated fuel elements. Progress made in a number of projects during the reporting period is summarized here.

Aqueous processing. Work continued on the development of processes which will permit dissolution and preliminary treatment of fuel types of widely differing chemistries in existing processing plants. This work was directed toward reducing processing costs in the period before private enterprise enters this field.

Two promising processes are the "Darex" and "Zircex." Darex, under development by Oak Ridge National Laboratory and Phillips Petroleum at the Idaho Chemical Processing Plant, involves treatment of stainless steel-bearing fuels with nitric acid-hydrochloric acid mixtures. Zircex, being developed by Oak Ridge National Laboratory involves anhydrous hydrochlorination of zirconium-bearing fuels under conditions such that the zirconium can be separated as a volatile product. In both cases, the uranium stream can be converted to an aqueous uranyl-nitrate solution and fed to conventional liquid-liquid extraction systems.

Volatility processing. Considerable progress was made on the volatility process development studies under way at the Argonne and Oak Ridge National Laboratories. The Argonne National Laboratory demonstrated on pilot plant scale that single-cycle volatility processing will decontaminate irradiated natural uranium sufficiently so that the residual radioactivity is less than that of unirradiated natural uranium. Investigations continued on a volatility process for separating plutonium from fission product residues. Construction of the Oak Ridge volatility pilot plant involving a different processing approach was essentially completed.

Pyrometallurgical separations. Atomics International and Argonne National Laboratory continued cold mockup work on pyrometallurgical processes for recycling fuels from the Sodium Reactor Experiment and the Experimental Breeder Reactor No. 2.

Argonne worked on a process for separating and purifying irradiated uranium by dissolving fuel in molten zinc, followed by the formation and separation of an intermetallic uranium-zinc compound. Preliminary results indicated that this process for limited decontamination may be suitable for use in integrated facilities which contain an operating reactor, a chemical processing plant, and facilities for remote fuel-element refabrication. A possible advantage was that this process may permit the separating of certain fission products which most pyrometallurigical methods do not remove; that is those elements less electropositive than uranium.

Zirconium-uranium fuel reprocessing. Recovery of fissionable material from irradiated zirconium-uranium fuel of the type for Submarine Thermal Reactor, Mark I, Core I, was completed successfully for the first time in January at the Idaho Chemical Processing Plant. This process, developed at the Argonne National Laboratory, resulted in a high recovery of decontaminated enriched uranium. Continued development effort will be required, especially in handling and disposing of the highly corrosive waste solutions.

Other Research

Radiolanthanum program. Research and development efforts by Phillips Petroleum, drawing on initial process research at Oak Ridge National Laboratory, culminated in design, construction, and successful operation at the National Reactor Testing Station of a new facility to produce high purity radiobarium. The output is shipped to Los Alamos Scientific Laboratory for extraction of the radiobarium daughter product, radiolanthanum.

The very pure radiolanthanum has a specific radioactivity of many hundreds of curies per milligram, about 10,000 times as great as that of cobalt 60, and is used in biological research programs.

Production of radiobarium under a different process at Oak Ridge National Laboratory was discontinued.

Fluidized bed calcination. The calcination treatment of chemical reprocessing plant waste materials previously reported[20] was demonstrated successfully during the reporting period on a cold pilot plant basis by Phillips Petroleum. Runs planned to reach one-tenth of full level radioactivity on Idaho Chemical Processing Plant wastes were under way at Argonne National Laboratory. Work along similar lines was carried out also at Brookhaven National Laboratory. Suc-

[20] See pp. 60-61, Twentieth Semiannual Report to Congress (January-June 1956).

cessful demonstration of the feasibility of calcining highly radioactive wastes would be a significant preliminary step toward ultimate disposal.

Waste Disposal

Waste disposal problems and programs of the Commission were described in detail in the last semiannual report.[21] Progress continued during this report period in developing methods for handling gaseous, solid, and liquid wastes.

Gaseous wastes. Two years of meteorological records and investigations at the site of the Pressurized Water Reactor were being analyzed and interpreted. Arrangements were made for continued participation by the U. S. Weather Bureau through initial phases of actual operation of the reactor.

Solid wastes. The handling and disposal of solid wastes have at no time constituted a serious technical problem. The feasibility of contracting for a commercially operated facility for solid waste disposal to serve the northeastern United States was under study.

A preliminary survey of the mile-deep Pacific Ocean dumping area some 30 miles west of San Francisco, Calif. made by the Scripps Institute for Oceanography, La Jolla, Calif., tended to confirm that waste disposal there has produced no harmful effects. A similar survey of the Atlantic dumping area, 120 miles off New Jersey and also a mile deep, was planned in cooperation with the Coast and Geodetic Survey and Johns Hopkins University.

Liquid wastes—low level. Liquid wastes of low radioactivity, originating in laboratories or in operation of ore processing or fuel fabrication plants, can generally be disposed of successfully with systems and equipment already developed. Harvard University, in cooperation with the Massachusetts State Department of Health, studied on a pilot plant scale what happens to radioactivity dispersed in surface waterways. At Northwestern University, two full-scale studies using radioactive tracers were carried out on the Chicago Drainage Canal in cooperation with the Sanitary District of Chicago and the Illinois State Department of Health. Northwestern University, in cooperation with the Vicksburg Water Experiment Station, of the Corps of Engineers, Department of the Army, also carried out a tracer investigation on a scale model of the Savannah River.

[21] See pp. 151-161, Twenty-first Semiannual Report to Congress (July–December 1956).

Model studies will provide a valuable tool for proposed studies of the fate of radioactivity discharged into tidal estuaries—a type of study of direct interest to the nuclear-powered ship program. Such an investigation for New York Harbor was initiated with the Chesapeake Bay Institute of Johns Hopkins University and Coast and Geodetic Survey.

Liquid residues—high level. The Commission continued its efforts to develop more economical and more permanent methods than tank storage for handling and disposing of highly radioactive liquid residues from chemical processing plants. This remained the major technological problem in disposal. To date, approximately 65 million gallons of high-level liquid residues containing millions of curies of radioactivity have been placed in tank storage.

Planning was initiated for a facility at the Idaho Chemical Processing Plant to investigate on a prototype scale one method now under study for fixing residues in a stable, solid form preparatory to storage or burial in selected areas, i. e., conversion of aqueous residues to a solid oxide form by intense heating. Conversion to a solid oxide form of liquid wastes containing high salt concentrations, e. g., aluminum nitrate waste from processing uranium-aluminum alloy fuels, is in itself a method as well as a useful step in an ultimate disposal system. Such a system would also involve leaching of solid oxide with water or weak acid followed by fixation of the leachate in clay or some other material.

Based on the results of discussions with geological and geochemical groups representing the National Academy of Science, National Research Council, U. S. Geological Survey, industrial organizations and others, preliminary investigations were started on the possibility of direct disposal of highly radioactive liquids to salt formations. Other specific geologic formations also were proposed for investigation. Studies were conducted at Oak Ridge National Laboratory to utilize the decay energy available in the residues to produce temperatures required for self-sintering of a mixture of the waste material and natural earth in a specially prepared pit, thereby forming the material into an insoluble mass.

Declassification and Classification

Guides to Declassification

The new declassification guide to atomic energy information, dated December 5, 1956,[22] made possible declassification during the first 6 months of 1957 of large quantities of additional information useful in designing, constructing, and operating research, testing, and power reactors. At the same time, it insured protection of information essential to the common defense and security.

The reactor supplement of the new guide, which specifically declassified nearly all nonmilitary and nonproduction reactors, and declassified or downgraded many categories of information about specific military reactors, was further revised in February 1957. At that time, the Commission determined that even more information within certain further categories of data about classified military reactors could be declassified without adversely affecting the common defense and security. This determination opened to general use a large amount of reactor technology acquired in the programs on Army Package Power, and Naval propulsion reactors.

In permitting declassification of practically all the basic chemistry and practical technology dealing with preparation of reactor fuel and materials, and with processing spent reactor fuel to extract their fissionable, fertile, and fission-product content, the Commission retained classification on specific processing details as applied to the fuels of production and military reactors. Much of this information is too specialized for use in peaceful applications of atomic energy and the necessary restrictions on these data should not handicap industrial and research efforts.

To supplement the new guide, the Commission encouraged preparation of "local" classification guides concerning information on an individual material or device, or information generated at a particular installation, or in a certain program. The local guides must be based, of course, on the broad principles laid down by the declassification guide and before use must be approved by the Commission. Once in force, local guides will increase the number of technical documents which will be produced in unclassified form.

Reviewing Accumulation of Classified Documents

To make available for use as soon as possible the maximum amount of information releasable under the new declassification guide, the

[22] See pp. 54–55, Twenty-first Semiannual Report to Congress (July–December 1956).

Commission launched on February 11 an expedited review of documents, reports, and diagrams which had remained classfied under the previous version of the guide. A similar expedited review was undertaken after the previous revision of the guide, promulgated in April 1955.[23]

This year's accelerated review program canvassed 18,677 technical documents and reports which previously could not be declassfied. Under the revised rules, the Commission declassified an additional 9,076—48.6 percent of the documents reviewed. Besides these, 5,297 were downgraded from secret to confidential, or were confirmed in their confidential rating, and 4,304 required the classification of secret.

To conduct the accelerated review, the Commission assembled an expert review team of approximately 40 scientists, engineers, and classification specialists from its own staff and its contractors. Most members of the team worked in one- or two-week relays; a few stayed throughout the review—a total of 80 reviewers, exclusive of staff and secretarial aides. The review team was located at Oak Ridge, Tenn., under supervision of Commission staff drawn from its Division of Classification.

Team members reviewed papers on the basis of specialty, and in the light of the new declassification guide. Each reviewer made his recommendation as to the classification of a particular document, and indicated deletions, if any, required for declassification of the report or downgrading it to a lower classification. The Division of Classification staff carefully rechecked each recommendation. Reviewed documents then were transmitted to the Commission's Information Services for abstracting, announcement, reproduction and distribution as appropriate.

Information

As interest in the peaceful uses of atomic energy increased among the general public and research and industrial organizations, the Commission continued during the last 6 months to broaden its services to users of technical and general information.

In addition to the distribution of information through releases and other official publications, speeches by Commission officials, symposia, workshops and institutes for teachers and through professional papers of scientists and engineers associated with the program, the Commission continued a variety of special programs of information services.

Following are some highlights of these programs:

About 3 million persons viewed the traveling Atoms for Peace Exhibits which were established in the previous reporting period.

[23] See pp. 98-99, Nineteenth Semiannual Report to Congress (July-December 1955) and pp. 63-64, Twentieth Semiannual Report to Congress (January-June 1956).

New films were added to each of the 12 regional motion picture libraries maintained by the Commission and, during the report period, these libraries loaned films for over 7,500 showings viewed by an estimated 415,000 persons.

Information kits distributed to high school students and teachers in response to inquiries exceeded 2,000 a month during the early part of the reporting period (see Education and Training).

As teams of specialists reviewed the Commission's files of classified technical information in an accelerated program to declassify or downgrade reports and documents under the new declassification guide the Commission placed the newly declassified material in circulation.

Permits granting access to classified information for industrial and commercial purposes continued to be issued during the report period at a rate of 30 a month (see Civilian Application). The Commission conducted a workshop in the first of a series of meetings to assist access permittees in using its facilities and authorized six classified depository libraries in centers across the country.

During this reporting period, the Commission received the results of a survey of access permit holders' view of the adequacy of Commission information services to them and found that they generally were satisfied.

During the first 6 months of 1957 the Commission published the first four volumes of the Nuclear Technology Series designed to organize and compile technical information otherwise available only in many separate documents. Also, during this period, two Technical Progress Reviews were prepared, four additional unclassified libraries established and support of scientific translation services was continued.

General Information

Exhibits

As of May 30, the three 86-panel "Atoms for Peace" exhibits inaugurated by the Commission during the previous reporting period, had been shown in 20 states to some 2.2 million people. The five mobile, walk-through type exhibits had been shown in 560 communities and viewed by 323,805 people.

Other exhibits assembled for special showings were viewed by 283,600 persons and the eight "package type" exhibits had been shown in 86 locations to 116,955 persons. In addition, three high school demonstration units operated for the Commission by the Oak Ridge Institute of Nuclear Studies were shown at 441 schools and lecture demonstrations given to 333,394 high school students. Altogether the total attendance for all phases of the Commission's exhibit program between July 1, 1956 and May 30 this year was about 3 million.

Atomic exhibit. The walk-through type of Atoms for Peace Exhibit, of which the Commission has five on tour throughout the country.

Motion Pictures

During the reporting period, the Commission's 12 motion picture libraries, located at the 10 operations offices, in Washington, and in the Portsmouth, Ohio Area Office, loaned films for a total of over 7,500 showings viewed by an estimated 415,000 persons.

Through the libraries the Commission made available on loan copies of 56 nontechnical films and 12 technical films.

Among the technical films, 6 are available in French, Spanish and English versions and are circulated by U. S. Information Office posts in 21 foreign countries.

During this reporting period, the following technical films were added to the Commission libraries:

Gamma Irradiation Facility, a 20-minute color film, produced by Argonne National Laboratory, about the irradiation services which it offers for private and Federal research organizations;

Construction of the Experimental Boiling Water Reactor, a 10-minute black and white film produced by Argonne;

The Argonaut, a 15-minute color film, produced by Argonne, about the laboratory's training and research reactor;

Sodium Reactor Experiment Fabrication, a 20-minute color film produced by Atomics International, Commission contractor, about fabrication and testing of major reactor components for the Sodium Reactor Experiment which it is constructing.

Plumbing and Pipe Fitting Seminars

Lectures were given in Hartford, Conn., Springfield and Worcester, Mass., and Providence, R. I. during the reporting period to inform plumbing and pipe fitting trades about the effect of new developments in atomic energy upon trade activities. They were sponsored by local school systems in cooperation with unions.

Technical Information

Nuclear Technology Series

During the period of this report, the Commission published through the Government Printing Office the first volume of the Nuclear Technology Series, "Experimental Boiling Water Reactor," and was printing for early publication three others: "Atomic Energy Facts," "Neutron and Gamma Irradiation Facilities," and "Hot Laboratory Equipment."

The Commission also published "Corrosion and Wear Handbook for Water-Cooled Reactors," which is not part of the NTS series.

As the reporting period ended, NTS volumes in preparation included: "Processing of Uranium Ores," "Production of Uranium," "Production of Thorium," "Fuel Element Fabrication," "Principles of Radiation Damage to Reactor Fuels," "Engineering for Nuclear Reactor Fuel Processing," "Treatment and Disposal of High Level Radioactive Wastes," "Treatment and Disposal of Low Level Radioactive Wastes," "Research Reactors—Their Operation and Use," "Techniques of Conducting Radiation Effects Experiments," "Nuclear Radiations in Science and Industry," and "Management and Control of Nuclear Materials."

Additional volumes will be announced later.

Technical Progress Reviews

The first two of the Commission's Technical Progress Reviews, *Radiation Applications* and *Reactor Technology,* were prepared for

publication during the first half of 1957. Others in the series were expected to be published later in the year.

Unclassified Engineering Materials List

In January the Commission published its first *Unclassified Engineering Materials List* (TID–4100). This list described the engineering information materials which have been received and catalogued, and which are available from the Technical Information Service Extension, Oak Ridge. A loose-leaf form for the list was designed to facilitate inclusion of supplements to be issued from time to time as new materials are received and catalogued. Additional unclassified engineering drawings and related materials were being assembled from Commission sites and will be catalogued and announced in future issues of the *Unclassified Engineering Materials Lists.*

Translations

The Commission, in continuing its expanded program for producing translations of foreign scientific literature of value to the national atomic energy program, undertook the translation for publication and sale of a selected number of foreign scientific monographs and books. Some 13 monographic works on subjects such as "Quantum Electrodynamics," "Conference on Photosynthesis," "Theoretical Foundation of Isotopic Methods of Studying Chemical Reactions," and "Statistical Theory of Phase Transformations" were translated from Russian into English during this reporting period.

The Commission continued and enlarged its support of the joint translation program with the National Science Foundation and other Government agencies to make the foreign scientific periodical literature increasingly available.

Industrial Information Exhibit

An estimated 9,000 persons visited the Commission industrial information booth at the 1957 Nuclear Congress, Philadelphia, March 11–15. The visitors selected several thousand each of 16 Commission publications available in the booth. Among publications in heavy demand were three specially prepared booklets: *Licenses* (TID–4555), *Materials, Services, and Facilities Available from the Commission* (TID–4559), and *Training and Educational Assistance* from the Commission (TID–4560). Among other publications distributed were: *Experimental Power and Test Reactors* (TID–4562), price lists of Com-

mission publications, lists of technical films on atomic energy, reprints of Commission regulations, and fact summaries on power and other reactors.

Depository Libraries

The six classified depository libraries authorized by the Commission to improve the availability of classified information to access permit holders,[24] are located in Boston, Chicago, Idaho Falls, New York, Oak Ridge and San Francisco. At these libraries properly cleared individuals may consult classified reports on civilian applications of atomic energy.

Additional depository libraries for unclassified reports were established at Agricultural and Mechanical College of Texas, Alabama Polytechnic Institute, Kansas State College, Northwestern University, State College of Washington, Union College, University of Arkansas, University of Maryland, University of Missouri School of Mines and Metallurgy, University of Virginia, and Virginia Polytechnic Institute, making a total of 77.

Information Workshop for Permit Holders

The Commission inaugurated a series of technical information workshop meetings, the first being held at Oak Ridge, May 22–24. Designed to orient access permittees on Commission technical information services available to them, the workshop gave special emphasis to reference and bibliographical tools for searching the literature. On the final day, individual consultations were held with access permittees on specific problems.

The Commission also published in April a *Guide to Atomic Energy Literature for the Civilian Application Program* (TID–4575).

Survey of Services

The report by a management consultant firm engaged by the Commission to obtain the views of access permit holders regarding the adequacy and effectiveness of technical information services provided by the Commission was received and evaluated during this reporting period. The firm conducting the survey reported that access permit holders generally were satisfied with the technical information services provided by the Commission.

[24] See p. 59, Twenty-first Semiannual Report to Congress (July-December 1956).

430209—57——7

The findings were based upon questionnaires returned from a mailing to approximately 1,000 industrial firms, institutions, and individuals holding access permits as of October 1956, and personal interviews conducted with approximately 100 permit holders selected as representative of the total.

Topics covered in the survey included documentary and reference services provided by the Commission, technical information meetings held under Commission sponsorship, and visits of permit holders to Commission facilities. Access permit holders were asked to indicate the use made of various services, describe problems encountered in obtaining or using them, and suggest improvements.

The surveyors noted that the Commission had earlier taken measures to institute the major improvements suggested by the permit holders. The summary recommended continuance of the Commission activities to (a) evaluate periodically the program for the preparation of technical books; (b) conduct a continuing review of the system for reporting research and development results; and (c) devise improved techniques for orienting access permit holders in the use of the technical information services at their disposal.

Education and Training

During the last 6 months, the Commission's program as part of the national effort to increase the supply of scientists and engineers, enlisted increasing participation by educational institutions and interest on the part of college, university and high school faculty and students.

Begun in 1955,[25] the Commission's program which puts special emphasis on nuclear science technology, included during this reporting period provision of materials, facilities, equipment and services to colleges and universities, faculty training courses, provision of visiting lecturers, a broadened fellowship program, and enlargement of the temporary graduate-level schools at Argonne National Laboratory, and at Oak Ridge National Laboratory. An inventory of the effort of 24 major Commission contractors showed that training which they sponsored, conducted, or assisted, had been made use of by 13,000 scientists and technicians. In the high school field, institutes were scheduled for teachers, the traveling teacher program was continued, and training and information kits were provided. The Commission's traveling exhibits on peaceful uses of atomic energy (see Information section) were well attended. A special feature of the 6-month period was the opening of unclassified portions of eight major Commission

[25] See pp. 55-58, Nineteenth Semiannual Report to Congress (July-December 1955).

installations on Edison's birthday for excursion visits by 4,400 high school children and teachers.

Assisting Educational Institutions

Provision of Materials, Facilities, Equipment and Services

The Commission continued making direct financial grants to colleges and universities for the purchase of teaching aids, demonstration apparatus and laboratory equipment for laboratory courses in nuclear energy technology. Grants totaling $3,365,000 were awarded to 34 educational institutions during this reporting period. Included in these awards were funds for 10 educational and training reactors. Fourteen institutions received natural uranium and neutron sources for use in subcritical assemblies, and 9 others were approved for similar loans.

The Argonaut, a low-power, low-cost training reactor, went into operation at Argonne National Laboratory. An unclassified Argonaut Industrial and Educational Symposium with some 200 participants was held in March. Invitations were issued to representatives of interested industrial organizations and to educational institutions to acquaint potential suppliers and users of the Argonaut with its design, construction and application.

A model of the Argonaut training reactor was exhibited at the Universities of Florida, Nevada, Puerto Rico, and Texas each of which is considering acquisition of a training reactor for graduate nuclear energy programs.

Requests for loan of the model for exhibition purposes may be made through the American Museum of Atomic Energy, Oak Ridge, Tenn.

Library Facilities

The Commission provided nonclassified depository libraries on nuclear technical information to universities conducting broad graduate work in nuclear science and engineering. (See Information section.)

Faculty Training

The Commission scheduled five 2-month institutes in nuclear reactor technology for university faculty during the summer of 1957 to be given in cooperation with the American Society for Engineering

Education. The Brookhaven National Laboratory will repeat the basic course given in 1956. Advanced courses will be presented in reactor physics at the Oak Ridge National Laboratory, in metallurgy at the Ames Laboratory, Ames, Iowa, and in chemical separations at Hanford. A specialized course for faculty interested in the Argonaut training reactor will be conducted by the Argonne National Laboratory. Each institute will be able to train 20 to 30 faculty members.

Visiting Lecturers in Biology

Under a formal agreement, the Commission participated with the American Institute of Biological Sciences in a program to provide special lecturers in biology to colleges and universities throughout the country. Forty-one members of the staffs of Commission installations volunteered to give lectures at nearby institutions during visits of 3 to 5 days. Since the initiation of the program in March visits have been made to four colleges. Consultations with students were included.

University Training Programs

Fellowship Program

The Atomic Energy Commission has offered special fellowships in nuclear energy technology to 117 students for the academic year 1957–58.

The awards were the first made under the fellowship program announced on October 30, 1956, established to encourage more students at the graduate level to study nuclear energy technology, with particular emphasis on reactor development.

Selections for the 1957–58 academic year also were made under the Commission's other special fellowship programs comprising 84 appointments in radiological physics, 9 in industrial medicine, and 9 in industrial hygiene.

All the fellowships are administered for the Commission by the Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tenn., with the exception of those in industrial medicine which are administered by the University of Rochester Atomic Energy Project, Rochester, N. Y.

Graduate-Level Schools

The capacity of the Oak Ridge School of Reactor Technology at the Oak Ridge National Laboratory was increased from 120 to 240 students per year through a cooperative arrangement between the Oak Ridge School and 6 universities and colleges. The participating institutions are the Carnegie Institute of Technology, the Case Institute of Technology, Northwestern University, Union College, the University of California at Los Angeles, and the University of Florida. During the first 6 months of study universities provide unclassified refresher courses for all students in mathematics, physics, engineering, and chemistry. At Oak Ridge, the students study for 6 months on classified topics pertaining to nuclear reactors which require the facilities of Oak Ridge National Laboratory.

In February, the 5th session of the International School of Nuclear Science and Engineering of Argonne National Laboratory began (see International Activities).

High School Programs

Courses for High School Teachers

During this summer training course in radiobiology and the use of radioisotopes were scheduled for approximately 100 high school science teachers at Duke University, Harvard University, the University of New Mexico, Wayne State University, and the University of California at Los Angeles. This program is jointly sponsored by the Commission and the National Science Foundation, with the Commission providing the cost of equipment and teaching assistance and the Foundation providing student stipends and family support.

Continuing the program begun last year, the Commission will present participants who successfully complete the course with demonstration kits of equipment to be used in high school teaching. The kits contain sufficient equipment to enable the teachers to perform simple experiments and effectively demonstrate the principles of radiobiology and radiation physics to high school students. The kits have been enlarged and now contain a combination scaler and ratemeter, three Geiger counter tubes, absorber set, radioactive reference sources, sample holders, electroscope, spinthariscope, cloud chamber, X-ray film and developing kit, uranium ore samples, syringe and hypodermic needle, and surgeons' gloves.

Another educational series for the summer is the 2½-week institutes for high school science teachers living in the Chicago area, which will survey nuclear sciences with stress on physics, chemistry, reactor

principles, radiobiology and radiological (health) physics. Laboratory experiments will emphasize fundamentals and the construction of equipment from inexpensive materials readily available in the schools. In addition, facilities and instruments of Argonne National Laboratory will be visited.

For the third successive year, the University of California Radiation Laboratory, Berkeley, is offering refresher courses for science teachers from the San Francisco Bay area. The courses, for 25 teachers, review fundamentals of physics and chemistry and teachers have an opportunity to take active part in phases of the research program.

Traveling Teachers

The "traveling teachers" program was inaugurated in the summer of 1956, under the sponsorship of the National Science Foundation, with the support of the Atomic Energy Commission. The Oak Ridge Institute of Nuclear Studies conducted the program. A total of 186 schools was visited in all 48 States and the District of Columbia. The selected group of seven high school teachers traveled approximately 100,000 miles after spending the summer of 1956 in training at Oak Ridge. They spent 9 months visiting high schools throughout the country during the 1956–57 academic year. Each teacher has been provided with a 1957 station wagon and science-demonstration equipment consisting of easily transportable classroom aids in physics and chemistry.

The program was increased for the 1957–58 season and school year with a total of 10 teachers selected from among 287 science teachers who applied. Besides their regular visits to schools, the traveling teachers participate in science teacher and other professional meetings.

Visits to Commission Sites

More than 4,400 high school students, most of them enrolled in science courses, accompanied by their teachers, visited major Atomic Energy Commission laboratories and production facilities on February 11, marking the 110th anniversary of the birth of Thomas Alva Edison.

Eight of the Commission's key laboratories and production centers admitted the students to unclassified areas, affording them an opportunity to see the research and development work in the national program to advance peaceful uses of atomic energy with a view to stimulating their interest in careers as engineers or scientists.

Visits were made as follows:

Sandia Laboratory, operated by Sandia Corp.: 100 outstanding science students and their teachers from the Albuquerque High School.

Los Alamos Scientific Laboratory, operated by the University of California: 800 students from Los Alamos and nearby communities.

Hanford Operations, operated by the General Electric Co.: 675 science students from 11 school districts in the Hanford area.

National Reactor Testing Station, operated by the Commission's Idaho Operations Office: 850 chemistry and physics students from 16 high schools in the Idaho Falls area.

Brookhaven National Laboratory, operated by Associated Universities, Inc.: 200 science students from junior and senior high schools in Suffolk County, Long Island, N. Y.

Oak Ridge National Laboratory, operated by Union Carbide Nuclear Co. of Union Carbide Corp.: 1,100 science students from 78 high schools in the Oak Ridge area on February 11 and 12.

Savannah River Plant, Aiken, S. C., operated by E. I. du Pont de Nemours and Co., Inc.: 75 science students from Aiken, Barnwell and Allendale Counties, South Carolina, and Richmond County, Georgia.

Knolls Atomic Power Laboratory, Schenectady, N. Y., operated by General Electric Co.: 36 top science students selected from 18 high schools in the area.

A series of 15 educational tours has been conducted at Oak Ridge for high school and college student groups by the Commission, the Oak Ridge Institute of Nuclear Studies, and the Oak Ridge National Laboratory. The "Student Science Tour Day" program, arranged to stimulate student interest in the scientific field and in the future opportunities in atomic energy, has been attended by 2,400 students from 66 schools in 10 States in the 15 tours conducted through May 30.

Information Kits

Between January and June, 11,285 kits of published material had been distributed to elementary and high school students and teachers. This was more than double the number requested in the same period in 1956, when 5,066 kits were distributed. Two types of kits were assembled to provide answers to the large number of requests received for information on careers in atomic energy and on nuclear power.

A large increase occurred also in requests for material to be used in science fair projects. Because not much information concerning atomic energy is yet available in school textbooks, students and

teachers turned to the Commission for information on peaceful uses of atomic energy.

Demand for educational literature came also from students in Europe, Africa, Asia and South America who have written for publications and educational guidance. A marked increase in the number of letters from Puerto Rico followed the Commission-sponsored symposium conducted at the University of Puerto Rico (see International Activities).

Other Programs

Work Experience Program

On March 28, the Commission announced the establishment of a "Work Experience Program" under which privately employed nuclear scientists and engineers may obtain specialized work experience in Commission laboratories and plants as an aid in development and use of atomic energy for peaceful purposes. The primary purpose of the program is to advance people who have experience and training in nuclear science and technology.

Some contractors operating Commission-owned facilities made similar informal arrangements in the past. The program now has been put on a regular, systematized basis at all Commission installations.

Applications are considered on the basis of (*a*) whether the knowledge and training desired are available outside the Commission's facilities; (*b*) whether the employees to be assigned appear qualified to take full advantage of the work experience; and (*c*) whether the assignments can be arranged without undue burden on the regular work of the Commission facility.

Radioisotope Training

During the reporting period, four basic radioisotope-techniques courses were completed with 128 participants, 39 from foreign countries, at the Oak Ridge Institute of Nuclear Studies and another started with 32 participants. The courses, offered to scientists and physicians, cover instructions in the safe handling and use of radioisotopes.

Since the program's beginning almost 1,900 persons have received this basic training.

ORINS has received for various courses more than 3,000 students from every part of the United States and its territories and from 45 other countries.

Research Reactor Motion Picture Film

Work began on a motion picture film on research reactors which will explain what research reactors are and how used in different fields of activity. Design considerations will be discussed and the film will show existing research reactors.

Training Inventory

Preliminary results of an inventory of training and educational programs of Commission contractors showed that more than 13,000 scientists and technicians participated in training conducted, sponsored, or assisted by 24 Commission contractors. Nearly 70 percent were contractor personnel, the balance came 10 percent from private firms, 9 percent were university faculty members, 6 percent were students, and 6 percent came from other Federal agencies. Twenty percent of those programs were paid for by industry, educational institutions and others.

Participation by subject category of training was as follows:

Field	*Number*	*Percent of total*
Nuclear reactor technology	5, 283	39
Nuclear Science and Engineering	3, 796	28
Health and Safety	1, 278	9
Nuclear Materials	1, 178	9
Radioisotopes	746	5
Radiobiology	741	5
Nuclear Fuels	386	3
Radiation and Isotopes in Medicine	302	2

Approximately 3,000 people received training that could not be identified specifically with the subject categories itemized previously. In addition, certain contractors gave specific assistance to secondary schools to encourage interest in nuclear science and the atomic energy industry, e. g., guided tours of plants and facilities, lectures, models and other exhibit materials, films, etc. Further data were being collected through the Commission's four-part survey of scientific and engineering manpower (see Organization and Personnel).

Physical Research

High energy physics continued during the first 6 months of 1957 to command an important share of research effort in the atomic energy program. Challenging new theories of fundamental physics were being tested.

Declassification of further information in the field of controlled thermonuclear research was under study. A classified conference was held on this subject, during this reporting period, to which holders of access permits were invited for the first time. The Commission authorized design and construction of the Model C Stellerator, a large experimental device for research in controlled thermonuclear reactions, to be constructed at Princeton University. In this report, a summary of the background of controlled thermonuclear research is submitted.

The Commission sponsored broadened study on digital computers, the so-called "electronic brains" which are making increasing contributions to progress in atomic energy research and development.

Chemists in atomic energy programs undertook research that promised fundamental knowledge that would support progress in reactor design, and typical work is reported here. In metallurgy, new materials were investigated and a basic program was developed to obtain a better understanding of the structure of liquid metals and their fundamental nature because of their use in new reactor design.

Physics

Accelerators

Linear accelerator transferred. During this report period, transfer of the 32 million electron volt (Mev) proton linear accelerator at the University of California Radiation Laboratory to the University of Southern California was approved by the Commission. The transfer will release space at the Radiation Laboratory for expanding needs and will provide the University of Southern California with a machine for education, training, and research purposes. The transfer was made under Section 31b of the Atomic Energy Act of 1954 which authorizes the Commission to make grants or contributions to the cost of the construction and operation of reactors and other facilities and equipment to colleges, universities, hospitals and other institutions.

Cosmotron and bevatron shutdowns. The two most powerful particle accelerators in operation in the United States, the cosmotron at Brookhaven National Laboratory and the bevatron at University of California Radiation Laboratory, experienced emergency shutdowns during the last 2 weeks of January. Prior to these shutdowns both machines had achieved record beam outputs and were under heavy demand from many important research projects. Because of this, both laboratories assigned all available manpower to the repair jobs. To minimize the loss of total operating time, some planned improve-

ments that would have required future shutdowns were made during the emergency.

The *cosmotron* was shut down when a short circuit in a magnet caused a fire which damaged the magnet insulation. On disassembly, it was discovered that a fracture near the end of one magnet bar had caused the short circuit. It was known that heavy mechanical stress on these copper bars caused some mechanical motion but it was believed that the clamps holding the bars would prevent damage. Apparently, the motion work-hardened the copper and caused the fracture.

To determine whether other bars might fracture, the vacuum chamber was removed from an undamaged quadrant and the coil was excited separately to measure the deflections that occur. In addition, some bars were removed for metallurgical examination to determine whether microscopic cracks had developed. The bars that failed plus those bars showing wear were replaced with a redesigned bar having greater thickness at the bend and a larger radius of bend.

Along with repair of the magnet bars, new adjustable "kicker" bars and a new coil clamp were installed. The kicker bars wedge the back coil tightly against the back of the gap and are adjustable from outside the cosmotron magnet. The original kicker bars could be adjusted only by removing the vacuum chamber, a very time-consuming operation. The new coil clamp reduces the motion of the coil to less than one half the previous motion. The chance of a similar shutdown occurring was lessened greatly. Resumption of the research program was expected during July.

The *bevatron* at Berkeley, Calif., was shut down by a working loose of the rivets and the iron brackets in the shrouding that conducts cooling air to the magnet. The rivets apparently came loose after being stressed repeatedly by the pulsed magnetic field. The laboratory made a thorough study of the rivet failure and the rivets are being replaced with a non-magnetic type. The repair job, which involved disassembly of approximately three-quarters of the machine, was scheduled to be completed in July and the heavy research schedule resumed.

The recent installation of a "wipe-off" target increased the amount of research data that can be collected by the bubble chamber group at the bevatron. This target scrapes off approximately 5 percent of the main beam leaving the remaining 95 percent of the beam for other experiments. This arrangement makes it possible for the bubble chamber to record events with every pulse of the bevatron without hindering any other experiments.

New accelerators for universities. The Commission authorized the purchase and installation of research accelerators on four university campuses during this report period.

A high-voltage engineering model tandem-style Van de Graaff accelerator was authorized for the University of Wisconsin. This machine will be housed in a building provided by the University. It will open the energy range from 6 to possibly 12 Mev to exploration in a manner similar to that in which the lower energy range has been explored. Cyclotrons have been working in this range but with neither the resolution nor flexibility of which the tandem Van de Graaff is capable. The University of Wisconsin was selected because the research group is especially competent in the field of research with a Van de Graaff.

The Commission also authorized purchase and installation of a 3 Mev electrostatic generator at Johns Hopkins University. This machine will enable the research group at Johns Hopkins to continue making significant contributions to physical research that are of interest to the Commission. The nuclear physics group at Johns Hopkins University has a 1 Mev accelerator which was built before 1947 and now is obsolete. The machine has been operating less than 50 percent of the time, because of the necessity of repairing worn parts, and maintaining an inadequately built vacuum system.

In addition to these two machines, the Commission authorized purchase of two 3 Mev Van de Graaffs for installation at Case Institute of Technology and University of Maryland.

Case Institute will house the machine in a new building with greatly expanded space for research. The Institute will add several members to its nuclear physics staff and broaden the scope of its research program.

The University of Maryland can provide space for its new accelerator and for establishing a new center for nuclear physics research by minor modifications of space already available. The University has added several members to its staff for nuclear research work, and made arrangements for temporary use of accelerators at the Naval Research Laboratory and the Carnegie Institution of Washington.

Studies on 12.5 Bev proton accelerator. Argonne National Laboratory continued studies on design of a 12.5 Bev proton synchrotron, able to produce all presently known sub-nuclear particles. The magnet will be of the weak-focusing variety, with a guide field about 50 percent stronger than those used currently in other synchrotrons. As a result, a very substantial saving of iron can be effected as well as a reduction in the size and cost of the magnet shelter. Studies indicate that it will be possible to build this accelerator magnet more easily and

rapidly than any other magnet of the weak-focusing variety. The output of protons from this accelerator would be expected to be an order of magnitude greater than that of any other existing accelerator in this energy range. Detailed theoretical analyses of the orbit stability problems have been carried out in order to arrive at appropriate parameters.

Construction was completed on a prototype master oscillator for the proposed accelerator. A preliminary hook-up was made of the intermediate stage amplifier for the synchrotron. Drawings for the prototype model of the accelerating cavity are nearly completed. In addition, Argonne has ordered 980 kilograms of ferrite, which will be used to tune the prototype cavity.

Theoretical and experimental studies were being carried out on the problem of the radio-frequency voltage which must accurately follow the schedule demanded by the rising magnetic field. Preliminary engineering studies were under way on a variety of subjects such as vacuum chamber design, power and water requirements, foundation stability, magnet power supply, structure designs and cost estimates.

The theoretical group also continued studies of less conventional accelerators and of regenerative methods of particle extraction and injection.

Other accelerator design studies. In this reporting period, experiments in methods of radio-frequency acceleration were carried out using a model of the Midwestern Universities Research Association (MURA) radial sector Fixed Field Alternating Gradient (FFAG) accelerator. Previously this machine had used betatron acceleration.

The experiments showed that the methods proposed by MURA for accelerating and storing particles in FFAG accelerators were feasible. In view of these results, it would be possible to produce circulating beams of accelerator particles much larger than in pulsed accelerators. Such beams have applications in high energy physics, and MURA has proposed that they be used to perform experiments directly in the center of mass systems by causing collision of beams that have been accelerated in opposite directions.

A new FFAG accelerator model was being designed by MURA to produce such a high current in order to test various plasma effects predicted.

The fixed field alternating gradient system has a magnetic field configuration in which the magnetic field is kept constant in time during the acceleration process and the average magnetic field varies periodically with the field's angle to the machine's axis. Ions are injected in the weak region of the field, and accelerated to the stronger region. The configuration uses radio-frequency fields to achieve the

required focusing for particles as they are accelerated. This system is in contrast to that of a cyclotron in which the field is constant in time and does not vary with the angle, and from that of the cosmotron-bevatron-type of accelerator, the proton synchrotron, in which the field in addition to being a complicated function of space also varies in time. The main advantages of the FFAG system are that much higher flux densities of particles in a more strongly focused beam will be possible.

In this same period, experimental and digital computer tests were carried out on various linear and non-linear resonant effects on beam oscillations. Results of this test were in good agreement with theory. Therefore the inherent non-linear forces controlling beam oscillations in FFAG accelerators do not make the design and construction of such accelerators impractical.

Millimicrosecond Neutron Spectroscopy

Instruments have been built at many Commission laboratories for determining the energies of neutrons by directly measuring their velocity and hence their energy. The instruments, which are essentially new, measure the velocity by producing the neutrons, a batch at a time, and measuring the elapsed time for a given batch to traverse a measured distance from neutron source to neutron detector. The unit of time measurement ranges 5 to 10 thousand-millionths of a second and the elapsed times measured range from 2 ten-millionths of a second to a millionth of a second. Distances over which the velocities are measured range from 3 feet to 20 feet.

These new instruments are different from the neutron choppers used in connection with a nuclear reactor. In that case, the chopper interrupts a continuous beam of neutrons from the reactor. In the new instruments the neutrons are produced through a reaction with the ion beam of a Van de Graaff accelerator or synchrocyclotron. The neutron batches are produced by pulsing the beam of the accelerator. Adequate pulsed beam currents are thus available for neutron-producing reactions.

The instrument at Oak Ridge National Laboratory is being used to study how neutrons interact with nuclei, and to study neutrons produced in nuclear reactions. One particular application which is new is the utilization of the reactions that occur when a lithium 7 target is bombarded by a proton, resulting in beryllium 7 with discharge of a neutron ($Li^7+p \rightarrow Be^7+N$). This reaction is used as a source of unmoderated neutrons for "transmission spectrometry." This new approach employing unmoderated neutrons for time-of-flight is useful for studying neutrons in the 1 kev to 20 kev energy

range where it has been difficult to obtain accurate energy measurements.

New Emitters of Delayed Neutrons

At the Argonne National Laboratory a method was developed using a continuous flow of gas to make a very rapid chemical separation of either of the halogens, bromine or iodine, from other fission products of uranium 235 produced by irradiation with thermal neutrons. The method made possible the identification of certain emitters of delayed neutrons formed from halogen fission products which have a short half-life. As in all other delayed-neutron events, the half-life is the period required for the beta decay of the nuclide's immediate radioactive ancestor, the neutron being emitted at once after the formation by this process of the unstable neutron-emitting nuclide.

Two hitherto unrecognized delayed-neutron emitters were found in the experiment. One is krypton 88, formed by the beta decay of bromine 88 with a half-life of 15.5 sec. The other is xenon 138, formed from iodine 138 that decays with a half-life of 5.9 sec.

Krypton 88 and xenon 138 are the first nuclides with both even atomic number and even neutron number, formed in this way, that have been found to be unstable neutron emitters. A study of the mass-energy relations in these reactions indicated that such even atomic number-even neutron number nuclides are, however, as likely to be neutron emitters as are the even atomic number-odd neutron number nuclides previously identified.

Non-Conservation of Parity

Progress was made in the study of properties of elementary particles during this report period. The new discoveries were inspired by theoretical work done by two professors, Tsung Dao Lee of Columbia University, and Chen Ning Yang of the Institute for Advanced Study at Princeton University, while they were guests at Brookhaven National Laboratory. They developed a theory based on "non-conservation of parity"—parity being a concept involving space and time that is of importance in quantum mechanics—and they suggested certain definitive experiments that could test the predictions of this theory.

The experiments consisted of searching for a predicted difference in the number of particles emitted in the direction of polarization, and those emitted in the opposite direction, for certain cases of radioactive decay.

The principle of parity might be explained by an analogy: Assume that one motion picture camera is photographing a given set of actions and that another camera is simultaneously photographing the same set of actions as reflected in a mirror. If the two films are later screened, a viewer would have no way, according to the principle of parity, of telling which of the two was the original, and which was the mirror image. The recently completed experiments indicate that there is a way of determining which is which.

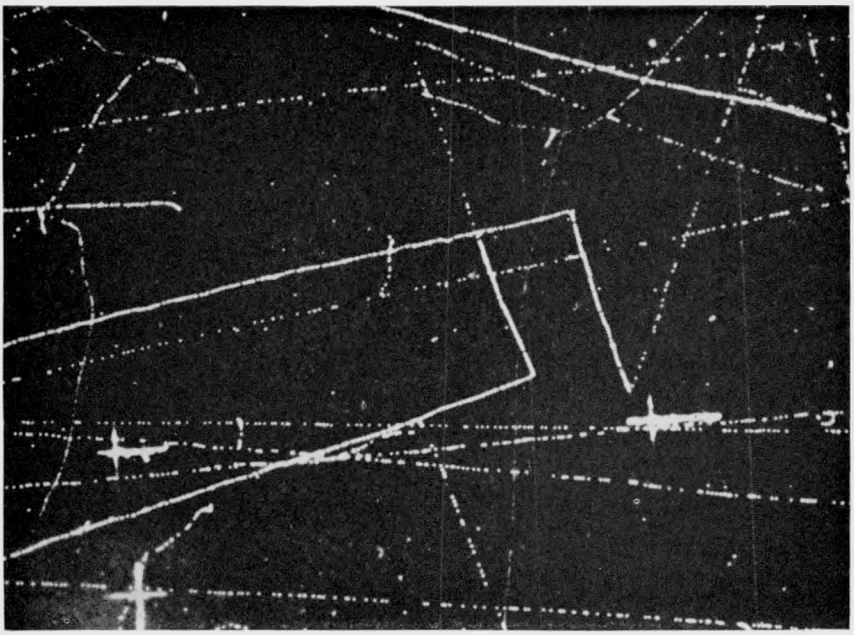
Contrary to the former theory, some subnuclear particles are not symmetrical in their reaction to nuclear events. Instead, they show a tendency in certain systems to prefer certain directions. This discovery does not appear to require a basic revision of nuclear theory but it may help to explain certain phenomena noted in the behavior of fundamental particles.

The quantum theory from which quantum mechanics evolved was developed in 1900 when the German physicist Max Planck proposed that energy must always be emitted or absorbed in tiny packets or quanta. Light, as a pure carrier of energy, therefore, must behave like a particle (or quantum) as well as a wave. Quantum mechanics explain in great detail the building up of an atom from its constituent parts, the nucleus and electrons, and, less completely, the building of the nucleus from its particles. The nature of the interaction between particles in the nucleus, to a large extent, is not well understood and this represents the central problem of physics today.

The Commission and its staff have followed closely the combined efforts of the theoretical and experimental physicists in this field. On April 1, eight leading physicists briefed the Commission and its staff on the significance and progress of their work.

The Brookhaven National Laboratory contributed to the experimental evidence for this important development as has work at other laboratories. The tracks of disintegrating mu-mesons from the cosmotron were observed in a liquid hydrogen bubble chamber and it was found that about 30 percent more electrons were omitted in a backward direction from the mu-meson than in a forward direction.

It was discovered, moreover, that the gamma radiation produced by electrons from a radioactive source when they are stopped in matter, the so-called "brehmsstrahlung," has a net circular polarization. This is a direct result of the newly recognized fact that these electrons have their spin axes preponderantly aligned generally parallel along their paths, but pointing in opposite directions. The theory of this interesting effect now is being worked out by theoretical physicists at Brookhaven.



Mesons. Fragment of a hydrogen bubble chamber photograph showing, among other tracks, two pi-mesons coming from the left, each decaying into a mu-meson (short heavy track at about 90°), and these decaying into an electron (thin dotted track). Examination of about 1000 of these events has shown that more of the electrons are emitted in the backward direction than in the forward direction, with respect to the motion of the mu-meson.

Meson Research

The analysis of cloud chamber experiments performed at the cosmotron at the Brookhaven National Laboratory which established the existence of a so-called "strange particle," the long-lived theta-two meson,[26] continued despite the machines' shutdown in late January. The photographs of cloud chamber events, taken before the shutdown were studied and two pictures of particular interest were found. One shows an interaction of a theta-two that produces a positive K meson, while the other one shows an interaction producing a negative sigma hyperon. According to a successful description of strange particles, K mesons and hyperons are distinguished from pi-mesons and nucleons by non-zero values of a new quantum number called "Strangeness." The theta-two meson is produced with positive strangeness. The same theoretical considerations which lead to the view that this meson exists lead naturally to the view that it has mixed positive and nega-

[26] See pp. 67-68, Twenty-first Semiannual Report (July-December 1956).

430209—57——8

tive strangeness. Since the positive K meson has positive strangeness and the sigma minus has negative strangeness, this predicition is now verified.

The "Strangeness" concept and "strangeness numbers" grew out of the discovery of a large number of new particles in the late 1940's whose lifetime, though short by ordinary standards, was so long on the nuclear time-scale as to be entirely inexplicable by any theory existing at that time. Physicists began to refer to these new particles as "strange" particles. In 1953 Dr. Murray Gell-Mann devised a scheme in which he numbered or labeled these new particles with a series of "strangeness numbers" so that it could be determined which particles would be produced under certain conditions and which particles would not be produced under the same conditions. To some degree this scheme is analogous to the periodic chart of the elements. It was found that strangeness is conserved when particles interact to produce new particles, but that it is not conserved when particles simply decay into other particles. The strangeness concept thus describes a new property of matter.

Another remarkable feature of the strange particles was that there were two positive K mesons (the tau and the theta) which differed by a quantum number which physicists called "parity," but which otherwise were very similar. General theoretical ideas, since discovered to have been erroneous, showed that these two K mesons could not have exactly the same lifetimes, even though qualitative experiment already had shown that their lifetimes were similar. At the University of California Radiation Laboratory, the lifetimes of the tau and the theta mesons were carefully measured to be the same within 4 percent.[27] It was the surprising equality of lifetimes which led Lee and Yang to suggest that ideas about parity might be wrong. It since has been shown by experiments of major importance that this indeed is the case and that parity is not "conserved" in slow decay processes, contrary to the opinion held by physicists for decades.

Further investigations of the production of strange particles were made at Brookhaven National Laboratory. Measurements of the production of strange particles by negative pi-mesons in a liquid hydrogen bubble chamber were interpreted to mean that hyperons and heavy mesons are produced within a small core at the center of the proton, which has a radius much smaller than that within which pi-mesons are produced.

High energy positive pi-mesons were passed through a bubble chamber and it was established that positive pi-mesons as well as negative pi-mesons can produce hyperons and heavy mesons in interactions with protons.

[27] See p. 68, Twenty-first Semiannual Report (July-December 1956).

The question of whether neutrons and protons are distributed uniformly throughout a nucleus such as lead was answered by measuring the absorption of 700 Mev positive and negative pi-mesons. At this energy, negative pi-mesons are absorbed mainly by protons and positive pi-mesons mainly by neutrons. Since positive and negative pi-meson absorption cross sections were found to be equal it is concluded that protons and neutrons are distributed similarly throughout the nucleus.

Computer Research

Recognizing that advances in the field of high speed electronic computation have had a large impact on atomic energy programs, the Commission authorized a program to encourage and foster research in the design, development, and use of modern, high-speed, digital computers.

The initial phase of the program includes a study by the Digital Computer Laboratory of the University of Illinois to test the design of a computer of greater capabilities than those presently available. The laboratory will thus put to test theories and research arising from the experience gained in operating the digital computer, ILLIAC, over past years.

The Rice Institute in Houston, Tex., will construct a modified version of the Los Alamos Scientific Laboratory computer MANIAC II. It is expected that this computer will be a nucleus for a center devoted to computer research.

New York University is operating a computing facility for the use of Commission contractors and to furnish a research team in applied mathematics to attack problems in the atomic energy field. In support of this work and to provide greater capacity the Commission has authorized the rental of an International Business Machines Corp. 704 computer to be installed in the expanded quarters of the university.

An applied mathematics division was formed at Brookhaven National Laboratory which will provide expanded computational services for the laboratory program. Construction of a digital computer of the MANIAC II class is well under way. A primary use of the machine will undoubtedly be in the high energy physic program for the studies of accelerator design, and for the analysis of experimental data and theoretical studies.

The typical modern digital computer has, as a central unit, a highly duplicating structure of some 5,000 vacuum tubes and associated electronic equipment which is capable of performing thousands of operations per second. In addition to the ordinary arithmetic operation, the computer is able to decide between possible courses

of action, basing the decision on the result of a previous calculation.

Since the machine can only assimilate numbers, the instructions which tell the machine what to do are coded from plain language or mathematical statements into numbers before they are inserted into the machine. These numbers are stored in the "memory" of the machine in some form, such as distribution of charges on a cathode ray tube, or directions of magnetization in magnetic materials. The instructions themselves can be the object of the machine manipulations so that the computer can modify its own instructions. The implications of this extra degree of freedom are far reaching and are the object of much research.

Much of the impetus of the present computer research arose from the genius of the late Commissioner John von Neumann. His ideas permeate the computer field and undoubtedly will do so for years to come. The present high state of the art is due, in no small measure, to his valuable contributions.

Controlled Thermonuclear Research

Commission representatives met with officials of the United Kingdom in June to undertake further studies of declassification of information on research in the field of controlled thermonuclear reactions. Basic scientific information is unclassified, and this report summarizes some of the background of the present research program of the Commission. Permits allowing access to classified information about controlled thermonuclear research are granted to certain qualified research and industrial groups, who have a need to know, and who might contribute to progress in the field.[28]

On February 20–23, approximately 460 persons attended a meeting at Berkeley, Calif., to review recent developments in controlled thermonuclear research. For the first time, holders of access permits, along with scientists from the United Kingdom and representatives of other interested Government agencies, were invited to attend the meeting with scientists representing the Commission's laboratories and contractors. At the same time, the Commission encouraged publication of unclassified articles in scientific journals and Commission reports to assist the public, including industry, in keeping abreast of those aspects of the program which can be described in open literature.[29]

[28] See pp. 29–30, Twenty-first Semiannual Report to Congress (July–December 1956).

[29] E. g. "Controlled Fusion Research—An Application of Physics of High Temperatures Plasmas"—Richard F. Post—*Reviews of Modern Physics*, Volume 28, No. 3, pp. 338–362, July 1956. "Series of Lectures on Physics of Ionized Gases—Los Alamos Scientific Laboratory"—Distributed to all authorized recipients of unclassified reports in October 1956.

The Commission, during this reporting period, approved design and construction of a multimillion dollar experimental device for research into controlled thermonuclear reactions. This action was taken subject to Congressional authorization and appropriation of necessary funds. The device, the Model C Stellerator, would be constructed at the Forrestal Research Center at Princeton University. It is exclusively for research and would make possible experimental work that cannot be performed with smaller machines.

Architect and engineering work for construction of supporting office and laboratory facilities is scheduled to begin at once. If Congress approves, construction of these facilities would begin this summer, construction of housing for the machine in 1958. Experimental work with the Stellerator could start in late 1960 or early 1961.

Objectives of Research

As announced previously, the Commission sponsors major experimental programs at Princeton University, Los Alamos Scientific Laboratory, and the University of California's Radiation Laboratory, Berkeley and Livermore, as well as smaller projects at Oak Ridge National Laboratory, New York University, and several other university and industrial sites. All these efforts are directed toward developing a method that will achieve a controlled release of energy from nuclear fusion so that the energy can be utilized for the production of electric power.

In the fission process, the nuclei of certain very heavy atoms such as uranium 235 or plutonium 239 are split, by the addition of a neutron, into two smaller fragments of roughly comparable size, plus several neutrons. These released neutrons can then be used to cause other heavy nuclei to undergo fission in continuing sequence, thereby maintaining a chain reaction. In each fission process, the total mass of the nuclei produced by fission is less than that of the original nucleus. The difference in the masses is converted into energy, principally into the kinetic energy of the fission fragments as they move apart. The temperature rise that results in the surrounding materials can be utilized through coolant flows in turbines and generators to produce electrical energy.

The mechanism of the fusion process is in many respects just the opposite to that of fission. In this process the nuclei of two light atoms, such as isotopes of hydrogen, are fused together to produce a single heavier nucleus plus either a proton or a neutron. As in the fission process, the difference in mass between the two fusing nuclei and the single nucleus they produce appears as kinetic energy of the product nucleus.

The nuclear reactions that are most promising for a reactor operated by controlled fusion are those involving two isotopes of hydrogen, deuterium (D) and tritium (T), and helium (He). These reactions are:

(*a*) $D+D \rightarrow He^3+n+3.25$ Mev Energy
(*b*) $D+D \rightarrow T+p+4$ Mev Energy
(*c*) $T+D \rightarrow He^4+n+17.6$ Mev Energy
(*d*) $He^3+D \rightarrow He^4+p+18.3$ Mev Energy

(The symbols He^3 and He^4 stand for isotopes of helium. The symbols p and n represent the proton and the neutron.)

Reactions (*a*) and (*b*) are of great interest because they involve only deuterium, which exists in ordinary water in sufficient concentrations to permit its isolation. These two are alternative reactions that occur with roughly equal probability. Reactions (*c*) and (*d*) are of interest because of their high energy yield and also because they involve reaction between products of reactions (*a*) and (*b*). Tritium now is obtained by being manufactured in a nuclear reactor.

The energy release per fusion reaction—3.25 to 18.3 Mev—is appreciably less than the 200 Mev released in fission. However, if the energy released per unit weight (for example, per gram of material) is calculated, the energy yield per unit in the fusion process is slightly greater than in the fission process. The real interest in the fusion process arises however, from the fact that, if a fusion reaction can be achieved under control, the world will have an energy source virtually without limit. There is enough deuterium in the ocean water—about 1 part of deuterium in 6 thousand of hydrogen—to provide all of mankind's power requirements for millions of years.

The Problem of Temperature

Formidable difficulties stand in the way of developing controlled thermonuclear reactors.

The first difficulty is producing the exceedingly high temperatures (hundreds of millions of degrees) required to give the particles sufficient energy for the fusion reactions to occur.

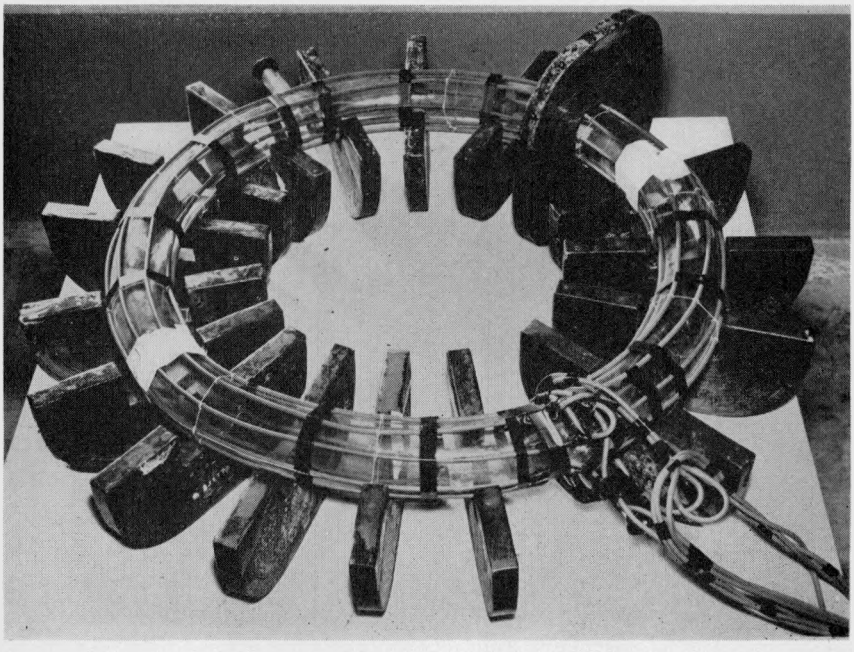
It has long been known that useful fusion power cannot be obtained by merely bombarding a target with any presently known charged particle. Even in very favorable cases, the chance of a nuclear reaction occurring before the charged particle is brought to rest is very small. However, when a hot gas is confined at temperatures of 100 million degrees or more, the probability of a nuclear reaction occurring becomes greater.

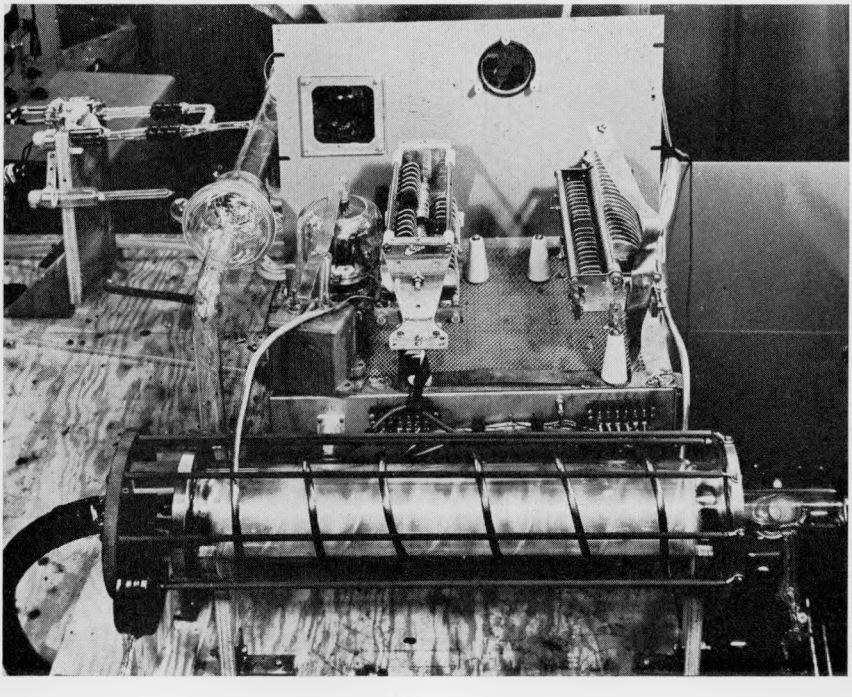
For nuclei to undergo fusion, they must be brought sufficiently close to one another so that their nuclear force fields may interact. Since the nuclei are all positively charged, they repel each other strongly. To overcome this force of repulsion they must be made to collide with one another at rather high velocities. Since the chances for the nuclei bouncing away from each other far exceed the chances of the fusion process occurring, the nuclei must be confined in some region and caused to approach one another many times, until fusion eventually does occur. This condition of having the particles in a confined region, and moving at high velocities with respect to one another, corresponds to having the deuterium at temperatures of 100 million degrees or more—temperatures, higher than those in the interior of the sun, which will vaporize all materials.

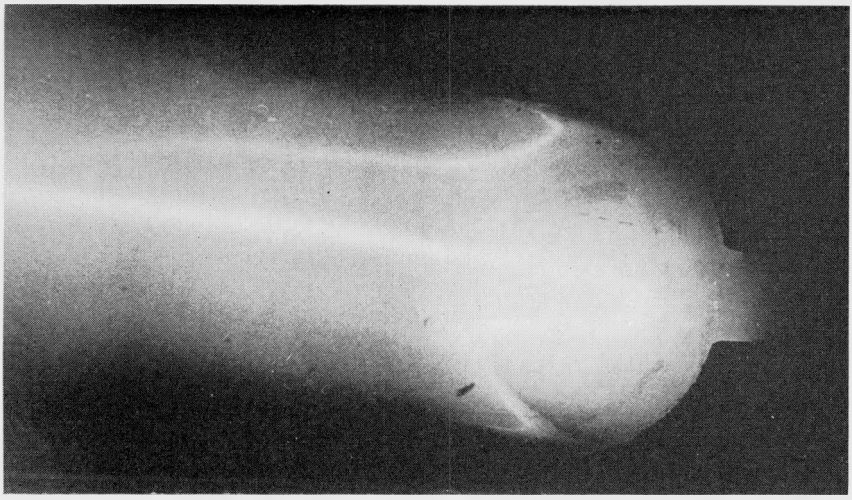
Only extremely light elements—those of low atomic number—can be considered as possible fuels in fusion reactions. Part of the reason for this is that the force of repulsion increases with the atomic number of the interacting nuclei—representing the number of positively charged protons in each nucleus. Hence the temperature required to overcome these forces of repulsion increases very appreciably with the mass number of the element used. It is for this reason that the isotopes of hydrogen are particularly interesting. Other elements with higher atomic numbers are not out of the question as possible fuels, but they would require even higher temperatures.

Another difficulty that confronts those developing a controlled thermonuclear device is making the reaction self-sustaining like a fission chain-reaction—that is, keeping the device at a temperature at which the system will remain in a steady state and not cool off.

At these extremely high temperatures, the only matter that can exist are wholly ionized gases, that is, the atoms which consist of a positive nucleus and surrounding negative electrons, are torn apart into positively-charged nuclei (or ions) and negatively charged electrons. Such a gas is called a "plasma." This plasma radiates energy at a very appreciable rate. No isolated plasma can remain at a high temperature if it gives off energy faster than it generates it. Under conditions of practical interest, when the temperature is increased, the rate of nuclear reaction rises more rapidly than the rate of radiation. Accordingly there is a minimum temperature below which the reaction cannot sustain itself by generating more internal energy than it radiates. This so-called "ignition temperature" turns out to be independent of the density of the plasma. For the deuterium-deuterium reaction this temperature is approximately 400 million degrees. For the deuterium-tritium reaction it is somewhat lower.







Plasma Experiments. Photograph on opposite page, taken at Commission's Los Alamos Scientific Laboratory, shows two types of equipment in which experimenters are working with ionized gases in an attempt to find methods to control a thermonuclear reaction. At top is a "Perhapsatron," a torus, or doughnut-shaped, tube in which ionized gas reactions are performed. Primary windings and iron cores of magnets used to heat the gas are shown around the tube. Below is another type of apparatus, the Columbus, a liner, rather than a circular apparatus, in which a "pinch effect" in krypton gas plasma is visible. The discharge of the gas in the glass tube (white line) shows how the plasma is "pinched" away from the walls of the tube, compressing the plasma. The Los Alamos photograph directly above shows a pinch in xenon gas in a Perhapsatron. The photograph shows the pinch of the plasma going around a curve.

Methods of Confining Plasma

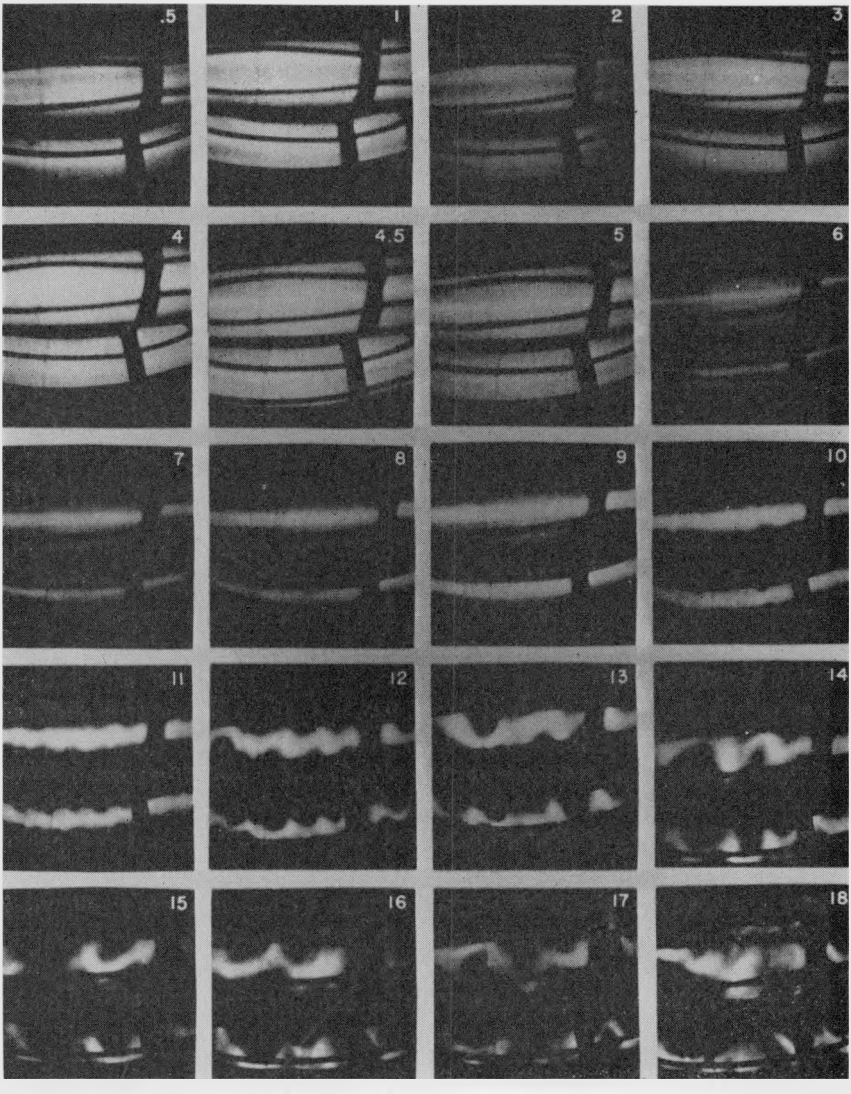
Providing adequate confinement at such temperatures for a sufficiently long period of time so that an appreciable fraction of the nuclei can undergo fusion is another problem. Clearly no materials can stand up to these enormous temperatures, hence some other means of confinement of the plasma must be found. It is known that the gravitational forces of the sun prevent the plasma from escaping from the hot region of the sun. Gravitational forces are much too weak to be useful in developing controlled thermonuclear devices on earth.

It is possible, however, to use magnetic fields to confine the plasma and to prevent it from vaporizing the walls of the reaction chamber. If a group of charged particles of the plasma are in a region in which there is no magnetic field, the particles will move in straight lines until they strike one another or until they eventually strike the walls of the reaction chamber. If a magnetic field is applied, the paths of these same particles will no longer be straight, but will be bent into tight spirals. The particles then will move down the magnetic lines of force in a path similar to the spiral stripes on a barber's pole. The only way, then, in which a charged particle can move outward toward the container walls is through colliding with other particles.

The collision shifts the instantaneous center of curvature of the particles' path. A strong magnetic field greatly reduces the diffusion of particles across the field. Roughly, they act as if they were tied to a line of force of the magnetic field. However, motions of particles along the lines of magnetic force are not impeded, and special techniques must be invoked to prevent loss of particles from the hot region in this way. One method used to prevent this loss of particles is to produce an endless discharge in a circular tube shaped like a doughnut (see photograph of Perhapsatron).

Another problem is that when magnetic force lines are employed as barriers against the escape of the plasma, pressure is built up inside the magnetic lines and the force walls imprisoning the plasma may become unstable. The force lines behave much like rubber bands around a rubber balloon, that is, they tend to bend inward and let the plasma flow out around them. At the present time, this phenomenon is one of the big difficulties, and scientists in the program are searching for an adequate solution.

The magnetic field must be strong enough to confine the ionized gas at the very high temperature required and the confinement must last long enough for nuclear reaction to take place effectively.



Pinch-effects. The series of photographs, taken at Los Alamos Scientific Laboratory, shows the birth and death of a "pinch" in a Perhapsatron. The horizontal black lines are primary windings and tape holding the windings in place. Two views are shown in each photograph, one from the side, the lower one in each picture being a mirror reflection from beneath. The numbers in the upper right corners of the pictures are the time, in millionths of seconds, from the start of the plasma discharge. In 6 microseconds (extreme right of second row), pinch is established. In the second row from the bottom, the pinch is beginning to become unstable.

The "Pinch Effect"

Several groups of scientists in the controlled thermonuclear program are working with what is known as the "pinch effect." They are trying to regulate the strength of the magnetic field, and to obtain a direct interplay between the magnetic energy and the energy of the plasma in order to improve stability.

The pinch effect can be described as the self-constriction of a group of charged particles moving in such a way as to produce an unidirectional current. The effect is found in another case. A heavy current, such as a bolt of lightning, can collapse a copper drain pipe when it passes through it. The effect is based upon the familiar fact that parallel circuits carrying current in the same direction attract each other.

In applying this fact to controlled thermonuclear research, the scientists are seeking, through heavy discharges of electricity, to pinch the atoms of the plasma together and suspend them in a thin line away from the wall of the container. Interesting results have been obtained in this particular effort, but much more work will have to be done. Very high temperatures have been produced in pinched discharges, but the time during which these can be maintained, at present, is in the range of microseconds. As yet, the pinch is not fully stable.

The Los Alamos Scientific Laboratory began pinch experiments in 1952 using a toroidal (doughnut) tube with and without an iron core in its early form and called it the Perhapsatron. The purpose of the Perhapsatron was to study the pinch in a toroidal geometry, with electrical equipment able to maintain currents of 10,000 to 50,000 amperes for longer times—some thousandths of seconds—than had been possible before. For short time studies of the pinch effect, a duration less than five microseconds (millionths of seconds) straight tubes are used. Such an arrangement, known as the Columbus geometry, is much simpler electromagnetically and has a higher order of symmetry than the torus. (See photograph of Columbus apparatus).

The pinch effect is but one of a number of alternate approaches being pursued in the Commission's controlled thermonuclear program. Each approach involves different configurations and different mechanisms of plasma heating and confinement.

There have been a number of interesting developments at every site of Commission-sponsored research, but all the work is still very much in the research stage. All devices built thus far have been designed for research purposes. It is anticipated that many years of intensive work will be required to develop a prototype thermonuclear

device which would yield more energy than it would consume. After that, many more years would be required to develop a full-scale device which might have a chance of competing economically with other sources of power.

Chemistry

Radioisotope Facility Tested

In a demonstration of the proposed flow system of the Multicurie Fission Products Pilot Plant to be completed later this year for handling radioisotopes, which are manufactured at Oak Ridge National Laboratory, approximately 8,000 curies of cesium 137 in the form of cesium chloride powder were recovered and purified from fission product waste solutions.

New Heavy Ion Accelerator in Operation

A new linear accelerator to be used chiefly for chemical transmutation experiments went into operation at the University of California Radiation Laboratory in Berkeley on April 11. Designed especially to accelerate the nuclei or ions of very heavy atoms, the machine, called the HILAC or Heavy Ion Linear Accelerator, now is accelerating nuclei of neon 20 to energies of 200 Mev.

The machine represents, in part, a joint project between the University of California and Yale University. Berkeley and New Haven scientists jointly developed the design of the machine and a duplicate was nearing completion in New Haven, Conn. Both machines were authorized and supported by Commission funds. Though the two machines will be essentially the same, the research emphasis at the two institutions will be different. In contrast with the chemical goals of UCRL experiments, Yale will be chiefly interested in physics.

The UCRL machine may permit synthesis of elements heavier than mendelevium (element 101). Elements heavier than uranium (element 92) are all synthetic, and are obtained by transmuting uranium nuclei, step by step, into successively heavier atoms.

The UCRL instruments also will permit a new type of exploration of nuclear forces. It will open up a new field of study of the elements polonium, astatine, radon, francium, radium, actinium, and thorium. At the present time it is difficult to obtain some isotopes of these elements in pure form. The HILAC will enable scientists to bombard lead and bismuth with heavy nuclei and synthenize isotopes of elements 86 (radon) through 90 (thorium) free of heavier isotopes.

Recovery of Neptunium

Research on the nuclear, chemical, and physical properties of neptunium, and the utilization of neptunium as a tool in research and development projects have been extremely limited because of the limited availability of the long-lived isotope neptunium 237, which has a half-life of 2.2 million years as contrasted with some 2 days for Np 238 or 239.

Highly irradiated reactor fuel contains appreciable quantities of neptunium 237, however, it is not ordinarily isolated during processing designed to separate plutonium. A process was developed at Oak Ridge National Laboratory in which neptunium 237 can be made to concentrate in a particular waste stream by simple changes of chemical conditions in part of the uranium processing cycle. Using this method, 40 grams of neptunium 237 was isolated during regular fuel processing operations at the Oak Ridge Metal Recovery Plant.

Decomposition of Boiling Water

Operational experience with Argonne National Laboratory's Borax-III powerplant at the National Reactor Testing Station in Idaho demonstrated that the rate of decomposition of water into hydrogen and oxygen is appreciable under boiling water conditions. Low, but corrosive, levels of oxygen appear in the effluent steam, in marked contrast to the radiation stability of water in nonboiling water moderated reactors.

Laboratory experiments at Argonne carried out with cobalt 60 gamma rays confirmed the Borax-III tests. During boiling both hydrogen and oxygen were stripped from the irradiated water, hydrogen more readily than oxygen. The yields of hydrogen and oxygen observed in the laboratory were about equal to the Borax-III yields and equivalent to the primary gamma ray decomposition of water into hydrogen and hydrogen peroxide.

Recombination of these products by the nascent hydrogen atoms and free hydroxyl radicals, effective in preventing decomposition of water in conventional reactors, was not as significant in irradiated boiling water. Since two-to-three-fold greater primary water decomposition was found for recoil protons than for cobalt 60 gamma rays, and since the recoil proton energy liberated in Borax-III is about 50 percent of the total ionizing energy, an even greater water decomposition yield might be expected in the boiling water reactor. The lower experimental yield indicated that about half the liberated hydrogen and hydrogen peroxide recombined under operating conditions of Borax-III.

Precision Spectroscopy Investigations [30]

Uranium 237 is a beta-emitting isotope produced by slow or fast neutron reactions on other uranium isotopes. Intense sources of uranium 237 were prepared by slow neutron irradiation of uranium 236 in the Materials Testing Reactor in Idaho and the sources then were subjected to precision beta and gamma ray spectroscopic studies at the University of California Radiation Laboratory. These studies showed a complex decay pattern with seven different excited levels of the daughter nucleus. The energies of these levels were measured to greater than 0.1 percent accuracy. The energy levels and transition characteristics were correlated with the theoretical model of football-shaped nuclei, in contrast with the more popularly known spherical model. This study and other similar precision spectroscopic investigations of radioactive heavy element and rare earth isotopes are adding to our knowledge of nuclear structure in the region of the fissionable isotopes.

Liquid Metal Slurries

The investigation of suspensions (slurries) of fissionable materials in liquid sodium-potassium alloy was continued at Argonne National Laboratory [31] with the aim of developing a fluid reactor fuel which might find application in fast power breeder reactors as well as in moderated reactors.

It was demonstrated that the pure compound uranium dioxide is wetted by sodium-potassium alloy at room temperature (a desirable characteristic, pointing to mechanical stability of the suspension) and could be circulated in a loop at a concentration of 10 percent by volume of uranium dioxide. Two small loops have been operated up to 600 degrees centigrade and, within the limits of the chemical detection techniques, no erosion or corrosion of the stainless steel loops occurred.

In the first high temperature loop, the uranium dioxide dropped out of suspension when the temperature rose above 500 degrees centigrade but immediately resuspended when the temperature dropped below 500° C. This effect was eliminated in the second loop by adding powdered uranium (1.5 percent by weight of the uranium dioxide) with the uranium dioxide. The cause for the uranium dioxide

[30] See p. 76, Twenty-first Semiannual Report to Congress (July–December 1956), for a description of work on the spectrometry of vapor polymerization. This work was credited only to University of California Radiation Laboratory whereas such work also is being done at Oak Ridge National Laboratory, and portions of the ORNL work, specifically the investigation of the trimer, were included in the referenced section.

[31] See p. 65, Nineteenth Semiannual Report to Congress (July–December 1955).

dropping out of suspension and the reason for the effectiveness of the uranium metal in preventing this still are under investigation. It was also observed in these loop experiments that very little change in particle size occurred.

An in-pile loop experiment was planned to investigate the stability of the uranium dioxide slurry under irradiation. If fission products have no deleterious effect on the stability or rheology of the slurry then the composition investigated to date could probably be used as fuel in enriched thermal reactors.

Other compounds being studied as slurry fuel possibilities are the uranium silicides (U_3Si) and (USi_2).

Radioactive Tracer Research

With the increasing use of radioactive tracers in industry, agriculture, and medicine and in research, the Commission's laboratories continued their efforts to broaden basic knowledge in this field. The following items are examples of Commission-sponsored research:

Beta-emitting *tritium* has great potential value as a radioactive label of molecules since it permits the tracing of many specific compounds through a plant or animal, or through an industrial process. Utilization of this valuable tool has been restricted in many cases because introduction of tritium into a specific molecule by conventional synthetic methods was prohibitively difficult or even impossible.

Increased use of tritium in tracer studies can be expected to follow the discovery at Argonne National Laboratory that organic compounds can be labeled with this radioactive hydrogen merely by exposure to tritium gas. To a surprising extent, the tritium beta-radiation catalyzes the exchange of tritium with ordinary hydrogen atoms in the organic compound. Materials of complex, or even unknown, structure can be labeled readily in this way, and concentrations of tritium analyzable after million-fold dilution can be introduced. The technique makes accessible, for the first time, many labeled compounds of biological interest and should greatly facilitate studies of metabolic processes. The simplicity of the technique and the low price of tritium make its large scale use in industrial research economically feasible.

The application of radioactive tracers as a research tool in chemical experiments was demonstrated at Ames Laboratory by solubility studies involving the *mecurous ion*. The radioactive mercury tracer has been used to study the solubility of mercury in water, benzene, hexane, and carbon tetrachloride. Though mercury usually is considered completely insoluble in these solvents, it does exhibit a

slight solubility that the sensitivity of the tracer method measured directly. The solubility was found to be one ounce in 120,000 gallons.

Research has been carried out at Brookhaven for several years on the incorporation of *carbon 14* into organic compounds by recoil when the radioactive carbon is formed in the presence of the organic compounds by the capture of neutrons in nitrogen. By applying this technique to the studies of numerous organic compounds, basic information necessary for the application of this technique was obtained. The method has been used to label nicotinic acid, used to study the formation of nicotine in tobacco plants.

Another application of the carbon 14 technique was to label gasolines for technical studies. Gasolines are such complex mixtures that labeling each constituent by ordinary synthetic methods would be inordinately difficult; however, it is readily accomplished by the recoil method.

The preparation of randomly labeled morphine also was studied; such material may prove valuable in drug addiction studies.

Process Development for Rare Earth Separations

The Ames Laboratory has been successful in developing processes for separating pure rare earths and producing rare earth metals to the point where industry took over the processes and is producing them on a large scale. The separation processes were successfully scaled up to columns 30 inches in diameter at Ames Laboratory and considerably larger in industrial laboratories.

A process for utilizing the mineral, xenotime, as a source of heavy rare earths was developed. Besides having a greater rare earth content, xenotime is more readily available and cheaper than gadolinite. The Ames Laboratory also developed a new ion exchange separation process for separating lutetium, ytterbium, thulium, erbium and holmium from one another.

METALLURGY

Niobium

An interesting new material in the atomic energy program, now the subject of considerable research and development, is the metal niobium (columbium). The metal has a fairly low neutron-absorption cross section and has excellent strength and ductility at high temperatures. Several years ago niobium was on the list of critical materials, but its increased industrial importance has resulted in discovery of

430209—57——9

vast new deposits all over the world. Heretofore used as a small addition to stainless steels and high temperature alloys, niobium now may be considered a base metal.

In addition to its low cross section and high-temperature strength, niobium has the advantages of being easily fabricated and welded, and of having good resistance to corrosion.

The current disadvantages of niobium, subject of research and development are: (*a*) the metal oxidizes readily with air at high temperatures; (*b*) it is easily embrittled by interstitial impurities such as oxygen, hydrogen, nitrogen, and carbon; and (*c*) the metal is quite expensive, costing approximately $50 to $100 per pound to produce by current processes.

Attempts were made to improve niobium's oxidation resistance by suitable alloy additions and research indicates some promise of achieving this.

The question of embrittlement due to interstitial impurities was subject to intensive fundamental research designed to prevent or control contamination as well as quantitatively to describe the specific effects produced by each detrimental element.

The high cost was attacked in two studies aimed at new extractive processes for winning niobium from its ores. One of these is by reduction of the niobium oxide, the other is an electrolytic process of fused salts.

The research was conducted by Ames Laboratory, Horizons, Inc., Oak Ridge National Laboratory, Sylvania Electric Products, Inc., Battelle Memorial Institute, Armour Research Foundation, and others.

Liquid Metals

Since liquid metals play an important part in the atomic energy program as coolants or fuel-bearing media, the Commission has supported research on liquid metals for many years. Recently, a more basic program was developed to obtain a better understanding of the structure of metallic liquids and their fundamental nature. In contrast with the solid state, metallic liquids are more difficult for experimental and theoretical research because of the high temperatures and the irregular atomic arrangement involved. Consequently, fundamental knowledge of metallic liquids, and the state of the theory, are much less developed than are knowledge and theory dealing with the solid state.

The new research program includes structural studies by means of X-ray and neutron diffraction; measurements of diffusion in liquid metals and alloys; volume changes upon melting; calorimetric meas-

urements of thermodynamic properties; measurements of ultrasonic attenuation and galvanomagnetic properties; thermodynamic activities; and electrical resistivity.

The research was conducted at the University of Chicago, University of Arkansas, Carnegie Institute of Technology, Columbia University, Harvard University, Massachusetts Institute of Technology, New York University, Purdue University, Yale University, Argonne National Laboratory, and the Brookhaven National Laboratory.

Biology and Medicine

During the first half of 1957, biomedical, biophysical and biochemical studies of the effects of radiation on living systems, the treatment of these effects and protection against them, and the use of radioisotopes in studies of diseases and their alleviation, resulted in a number of important contributions to progress in these fields. The Commission summarizes here a selection of important research during the past 6 months on treatment of irradiated experimental animals with bone marrow and chemicals, studies of toxicity of certain products essential in the atomic energy program, as well as a number of applications of atomic energy products which have beneficial uses for mankind, including research in cancer.

The Commission also reports the status of the Rongelap residents who were evacuated from their home island in the Pacific in March 1954, following accidental exposure to fall-out from a test series at the Eniwetok Proving Ground, and repatriated in June.

Three additional projects in the Commission's long-term study of the effects of radiostrontium in fall-out material from nuclear weapons tests ("Project Sunshine") are described. The Commission offered testimony before the Joint Committee on Atomic Energy during May and June in hearings on fall-out problems.

Brookhaven Medical Research Center

Construction of the new Medical Research Center at Brookhaven National Laboratory was about 42 percent completed at the end of the reporting period.[32]

The laboratory and hospital sectors were completely closed in except for the windows and doors. Work on interior masonry, and heating, ventilating, air conditioning, electric power and plumbing systems was well under way.

[32] See pp. 77–80, Twenty-first Semiannual Report (July-December 1956).

The basement, first floor, connecting wing, and patient preparatory room floor slabs were poured. All reactor and reactor enclosure foundations were completed. The installation of the reactor shielding forms, structural steel, and reactor enclosure was well under way. All phases on fabrication of the reactor components were completed and delivery to the job site was in progress.

Studies of Fall-Out

Commissioner Willard F. Libby's views on the results of studies conducted over the past four years as part of Project *Sunshine*, dealing with accumulations of radioactive fall-out from weapons tests were summarized in his address before the American Physical Society in Washington on April 26. The text of this address appears as appendix 11 to this Report.

More extensive data gathered by Project *Sunshine* were placed before the hearings of the Special Subcommittee on Radiation of the Congressional Joint Committee on Atomic Energy in May and June and will be published in the record of those hearings. Major new activities and findings of the Project during this reporting period are noted below.

Soil Sampling and Comparison of Collection Methods

The program of monitoring the distribution of fall-out over the surface of the earth by gummed paper collection was continued. It was supplemented by increased sampling of radiostrontium in soil samples taken from about 30 geographical locations outside the United States. Comparative studies were undertaken of the radioactivity retained in collection pots located adjacent to gummed paper stations in some 20 locations chosen for a variety of climatic conditions in the United States and abroad. In connection with soil samples, studies were being carried out to establish the reliability of chemical methods for estimating total strontium 90 content and the available strontium 90 content as related to available calcium content.

Distribution of Radiostrontium in Foodstuffs

A new sampling program was under way to measure accumulation of radioactive materials in flora and fauna, with special attention directed to strontium 90 in foods or assimilated by people, and the possible importance of such factors as geographic location, calcium

content of soils, and local dietary habits. Information was being collected from foreign countries on the foods which provide populations with their major sources of calcium, the average per capita consumption, and the average calcium content of each foodstuff. Samples both of foods in the composite diet and of human urine were collected by survey teams of the Interdepartmental Committee on Nutrition for National Defense, in cooperation with the Commission, for analysis here. Countries covered by survey teams were the Philippines and Turkey.

Stratospheric Sampling

Techniques were being developed to make possible the monitoring of radioactive fission products in the stratosphere. Such measurements would provide important information on quantities of weapon debris reaching the stratosphere, the distribution and retention of such materials in the stratosphere, and their release to the lower atmosphere. In experiments now being conducted with the Department of Defense, balloons are being used to carry sampling equipment to altitudes of 50,000 to 90,000 feet, where radioactive particles were filtered from a defined volume of air. Balloons are being launched at Minneapolis, Minn., San Angelo, Tex., and at France Air Force Base in the Panama Canal Zone.

Radiochemical analyses of the samples were being made on a pilot scale by the Commission's Health and Safety Laboratory, New York, until arrangements could be made with commercial laboratories to perform this work. Results of these studies will be useful in planning a world-wide network for monitoring long-lived radioisotopes in the stratosphere.

Radiation Effects

Radiation Damage to Mouse Testes

The high sensivity of the testes to ionizing radiation has been known for more than half a century. Experiments have demonstrated repeatedly that radiation depleted the spermatozoa-producing tissues of the testes and that recovery depended on the presence of some undifferentiated germ cells, the spermatogonia, which lie in the lining of the seminal tubules. However, there are divergent opinions even at the present time about the basic mechanism of the testes' dramatic response to low dosages of radiation and, on the other hand, their occasional recovery even after exposure to 1000 *r* (roentgens) or more.

In order to explain this peculiar radiation response, it was necessary first to make a detailed study of normal spermatogenesis—the process by which mature sperm are formed. By utilizing recently developed techniques, scientists at the Oak Ridge National Laboratory identified in mice every cell in the seminiferous epithelium—the spermatozoa-producing tissues—and placed each cell in its correct position in the developmental sequence of spermatogenesis. Furthermore, an improved estimate of the time required for spermatogenesis made it possible to develop a timetable of each phase of cell development.

By relating these data to irradiated testes, experimenters clearly demonstrated that both for low and high doses of ionizing radiation, depletion of germ cells resulted primarily from destruction of spermatogonia, and not from prolonged inhibition of cell mitosis, or division. The severe initial damage to the testes and their eventual return to fertility are both readily explained by differences in sensitivity among spermatogonia. Early spermatogonial stages are most resistant: a few of these cells survive doses as high as 1500 *r* of X-rays, and in time repopulate the sperm-producing tissues. Certain late spermatogonial states are extremely sensitive, with 50 percent destroyed by 20 to 24 *r* of cobalt 60 gamma rays. A decrease in the number of these cells can be readily demonstrated after doses as low as 5 *r* of cobalt 60 gamma rays.

Early Radiation Mortality in the Chicken

Argonne National Laboratory experimenters investigated a well defined early reaction to radiation injury in chickens that generally results in death within 2 days after exposure. This reaction can be reversed by the chicken, and apparently this does not depend on the rate of exposure to radiation, or on the accumulated dose.

Investigations of the mechanisms showed that early mortality in the chicken is associated with circulatory insufficiency, manifested in chicks as a fall in blood pressure, and in the adult rooster as inadequate flow of blood to vital areas. In mammals, a vascular response to radiation has been noted soon after exposure, but it is not usually severe enough to cause death. Early radiation effects in the chicken may differ from those in the mammal in that the chain of effects leads to some event that is critical for survival in the chicken but not in the mammal. Comparisons between the radiation response in chickens which leads to early death and that which causes death after 1 or 2 weeks may yield information about the mechanisms of radiation injury.

Long-Term Effects

At the University of California Radiation Laboratory, the long-term effects of chronic irradiation in humans are being studied in relation to a series of several hundred patients who have, over a span of up to 20 years, received radioactive isotopes as therapy for leukemia, a disease of the blood cells. Although these patients have accumulated significant whole body doses, of from 25 *r* to 500 *r*, no clear-cut evidence for radiation-induced malignancy or other forms of permanent radiation damage has been observed.

Strontium Metabolism

The metabolism of strontium was studied with complete safety in 12 human beings at Argonne Cancer Research Hospital. These individuals were given strontium 85, which serves as a tracer of the fission-produced isotopes, strontium 89 and 90. Strontium 85 is a short-lived gamma-emitter in contrast with long-lived beta-emitting strontium 89 and 90.

The loss of strontium from the bodies of these subjects was found to follow about the same pattern as is the case with ingested radium.

In connection with their biologic studies on strontium, the group was instrumental in developing special scintillation counting equipment that permits determination of the total-body content of strontium 85 for 1 to 2 months after oral administration of only 10 microcuries of the radioelement.

Radiation Effects on Molecules

The effects of radiation on hematin, a derivative of the iron-containing fraction of the hemoglobin of the blood cells, were studied at the University of California at Los Angeles. In dilute alkaline aqueous solutions, hematin is changed by a few thousand roentgens of gamma radiation to an oxidized compound which still has an intact porphyrin ring structure. A similar oxidized compound can be produced by adding traces of hydrogen peroxide to the solution, or by allowing the solution to stand exposed to air for several weeks.

Larger radiation doses cause rupture of the ring structure. The products formed when the ring opens are capable of reacting further to radiation, and thus partially protect the remaining unoxidized hematin. Various additives such as potassium cyanide and certain organic compounds also protect hematin.

Regulation of Levels of Circulating Blood Cells

Another investigation at Argonne National Laboratory deals with the ultimate interpretation of the hematological response to radiation injury. Consideration is given to development, distribution, and population of granulocytes, one of the types of white blood cells, under different conditions of production and utilization. To provide a background for such studies, the numbers of blood-forming myeloid and erythroid cells in bone marrow, their turnover times, and their rates of production, were estimated in various species including man.

In another study, recovery patterns were investigated in dogs after a deficiency of granulocytes in the blood had been induced abruptly either by injecting a leucocyte (white blood cell) antiserum to remove the cells by agglutination, or by exchange transfusion with leucocyte-depleted blood. Recovery appeared to be accomplished in large part by an accelerated release of young cells from bone marrow; other sources made a negligible contribution after leucopenia induced in this way. The machanisms governing neutrophil release from bone marrow also have been studied by perfusing isolated extremities of dogs with blood containing varying numbers of leucocytes.

Observations on irradiated animals indicated that the bone marrow was at first capable of releasing cells on demand, but became progressively deficient with passage of time after irradiation, presumably because the formation of new cells was blocked. In irradiated dogs, leucocyte recovery and the chances for survival appeared to increase when leucopenia was induced by the methods described above, and maintained during the first day after exposure to a median lethal dose of radiation. It was suggested that an abrupt leucopenia induced in this way might stimulate to new cell production those marrow cells still capable of responding to this physiological stimulus.

Experiments of this sort provide some understanding of the number of cells available for immediate release from bone marrow. Thus there is reason to believe that the size of this reservoir is a function of the normal state of the blood, and an idea of the nature of the control system was obtained from the various experiments.

Radiation Effects on Seeds

In a number of its laboratories and through contracts, the Commission sponsors research on the effects of radiation upon seed and plant development. Studies at Brookhaven National Laboratory were directed toward modifying the damage caused by X-rays by various treatments of the irradiated material. Experimenters found that in biological material, the effect of radiation does not stop with

the cessation of radiation, but may increase subsequently for relatively long periods. Dormant seeds of barley were irradiated and then stored for varying periods of time; the seeds then were germinated and grown on moist blotters. Radiation damage was measured as the percent of reduction in seedling height at 7 days as compared with a normal control. It was found that, in many situations, damage was increased by as much as a factor of 3 by storage for 24 hours. There were two components in the curve of damage related to time of storage. The first component was rapid, and almost reached its maximum after approximately 24 hours at room temperature, while the second component was very slow and lasted for 5 weeks or longer.

The water and oxygen contents during and following irradiation were very important in determining the amount of damage and the magnitude of the delayed effect. Low moisture content and high oxygen tension (excess oxygen) increase the delayed effect. The temperature of the seed both before and after the irradiation was also very important. High temperatures before the irradiation protected the seed, whereas high temperatures afterward increased the damage. Pressing seeds in dry ice immediately after the irradiation retarded the appearance of delayed damage, but as soon as the seeds were warmed to room temperature the course of the damage continued. When the seeds were irradiated with fast or thermal neutrons there was virtually no delayed effect.

These experiments have many important implications as to the way in which radiation acts on cells. They indicate strongly that the action of X-ray is not by a direct hit on a sensitive target. It appears that the X-rays sensitize certain sites within the cell and oxygen subsequently completes the destruction at the site. If the site can be desensitized before oxygen can reach it, as by adding deoxygenated water, the cell will return to normal. Another possible interpretation of these experiments is that free chemical radicals are formed at the time of the irradiation in dry seeds. These can be stored for relatively long periods of time and then produce destructive effects only in the presence of oxygen.

Physics of Tissue Damage

Quantitative prediction of the radiation effects that a given radiation exposure will have on man and other living organisms is hampered by a lack of mathematical formulation of the basic ideas of the nature and extent of radiation effects. A great deal of progress in physical and engineering sciences is due to the fact that the results of experimental or operational situations can be predicted by calculations.

Recently, certain mathematical theories have been applied to the behavior of biological systems.

This application presupposes that all organisms contain in their structural components, the molecules, bits of information or "directions" which determine their further development, interruption or cessation of function and death. This development process is usually orderly as a result of a very large but finite number of bits of information in the molecular structure of the organism. A symposium was held in Gatlinburg, Tenn., under the sponsorship of Oak Ridge National Laboratory on the application of this theory, termed "information theory" to health physics and radiobiology, and was attended by leading scientists from the National Laboratories, universities and other institutions. One interesting hypothesis offered was that radiation damage is equivalent to aging which results from a loss of "information content" in the cell. The concept of "information content" can be dealt with mathematically in much the same way that "entropy" is used in the second law of thermodynamics. It may be possible to develop this concept into a mathematical theory so that it will be possible to calculate in advance the biological consequences of a planned radiation exposure schedule. Thus, radiation hazards could be treated in the same quantitative way as an engineering problem in reactor technology.

Genetics Research

Experiments have indicated that certain treatments, if applied after irradiation, may modify the amount of genetic damage caused by radiation.

Decrease in Lethal Mutations by Treatment After Irradiation

An important type of radiation damage to chromosomes is an increase in the frequency of recessive lethal mutations, a change in the germ plasm that may cause death of the offspring if the recessive change is inherited from both parents. The nuclei of all living cells contain chromosomes which are strings of chemical entities called genes that govern the heredity of the cells and consequently of the whole organism. Ionizing radiation affects genes and chromosomes, and the altered, or mutated, gene or chromosome will continue in all future generations. The recessive lethal mutation was studied at Oak Ridge National Laboratory in the one-celled animal, *Paramecium aurelia.*

Work with this organism showed that the number of lethal mutations resulting from a dose of radiation could be decreased after irradiation by starvation, or exposure to streptomycin or 2,4 dinitrophenol, which slow the growth and division of the cell. To be successful, treatment must be started within an hour after irradiation.

The experiments showed that, for an appreciable time after irradiation, at least part of the mutation process is not irrevocable, and that during this time, the radiation damage that leads to mutation can be reversed. A possible interpretation of the mechanism of the successful treatments is that they delay the irrevocable formation of the mutations, and thus allow more time for recovery from the initial radiation damage.

Reduction in the amount of mutation was found following irradiation with alpha-particles as well as with X-rays. Previously, other procedures that modified X-ray damage failed to give protection against damage from heavy particles such as alpha-radiation.

Post-Irradiation Modification of Chromosome Aberrations

One form of radiation-induced genetic damage that has lent itself readily to quantitative studies is chromosome aberration. When ionizing radiation breaks chromosomes, the fragments may remain separate or rejoin. If they remain separate the cell usually dies because the piece broken off and its necessary genes are ultimately lost. If the breaks rejoin, they may reform the original chromosome—which would not be detectable as an aberration—or may join with another fragment different from its original part. The latter combination, known as a chromosome exchange, is in many cases also lethal to the cell. Since almost all genetic changes brought about by radiation are deleterious, fundamental studies were carried out on breakage and rejoining of chromosomes in the hope that, after better delineating these two processes, scientists could devise methods of modifying the amount of genetic damage.

Work performed at Oak Ridge National Laboratory, partially characterized the chemical nature of the induced breaks and indicated that certain post-irradiation treatments can modify the number of aberrations induced. In the seed of *Vicia faba* chromosome segments remained separated for as much as 2 hours; rejoining depended upon cellular metabolism and the production of adenosinetriphosphate (ATP). ATP is a high-energy phosphate compound utilized as a source of energy in the living organism to drive most anabolic reactions. Since the chromosome breaks stay open for long periods of time, and also require a source of energy for their closing, it was postulated that the breaks involved are breaks of covalent chemical bonds in which

two atoms are linked by sharing the same electron or electrons. Another type of break which closes very rapidly also is induced. This break might involve a different type of chemical bond.

By inhibiting the metabolic processes of cells after irradiation, it was possible to decrease the amount of ATP available. This prevented rejoining and kept chromosome segments separate. If the chromosome breaks are kept open until additional breaks are produced by more radiation at a later time, the earlier breaks then can rejoin with the later ones and yield an increased number of exchange linkages. The converse experiment, in which ATP was added, caused breaks to close faster, and thus segments from a first dose of radiation were not capable of rejoining those caused by a second dose. Less damage then resulted.

Protection Against Radiation

Long-term Protection of Irradiated Mice

When AET (2-aminoethylisothiouronium.Br.HBr) administered to mice before irradiation was combined with bone marrow injections after irradiation, the mice were found to tolerate 2 to 3 times the amount of radiation which would have killed 50 percent of the untreated control animals in 30 days.[33] The survivors of these high levels of radiation—1,400 to 2,600 *r* of whole body X-ray or gamma radiation—were observed at Oak Ridge National Laboratory throughout their lives, for periods up to and exceeding 2 years after irradiation, to determine the extent to which the protective agents would prevent delayed effects of radiation.

Preliminary data indicate that, in general, protection was afforded against the life-shortening action of radiation that was similar to the protection given against death within 30 days. Since most animals observed to date received both AET and bone marrow, comparison between benefits from the two agents must await the results of current experiments.

The protection observed in these experiments confirmed the results of earlier studies with spleen-shielding, reducing the oxygen tension or administering cysteine, and demonstrated that protective and recovery-promoting measures are effective not only against acute effects of irradiation, but also have an effect on delayed injury.

[33] See p. 85, Eighteenth Semiannual Report (January–June 1955).

Mechanism of Delayed Reaction to Foreign Bone Marrow

Many mice protected against acute irradiation death by injection of a foreign bone marrow, such as from a normal rat or a normal mouse of a different strain, subsequently died of a delayed reaction.

The serum proteins in the treated animals' blood was identified as its own, not that of the donor; electrophoretic analysis of these serum proteins showed increased gamma globulin and decreased albumin concentrations during this delayed reaction. Immune response studies revealed that treated mice were capable of responding to sheep antigen but not to mouse or rat antigens. From these findings, it was deduced that the delayed foreign bone marrow syndrome was due to an antigen-antibody reaction of the host's immune mechanism against transplanted, proliferating foreign tissue.

Recognition Factor of Antibody-producing Cell

The ability of irradiated mice to produce antibodies to cells of another species injected into their bodies was tested using as antigens the red cells of the rat, a closely related animal, and of the sheep which is more distantly related. It was found that although normal mice produce antibodies to these two antigens equally well, irradiated mice responded to sheep antigen more strongly than to rat antigen. This was interpreted to mean that irradiated mice's systems were able to recognize foreign antigens in proportion to the degree that its species was remote from the recipient.

This ability of the immune mechanism to recognize and react variably helps explain why the transplantation of bone marrow between closely related species (mouse to mouse, or rat to mouse) is more successful than between distantly related species (rabbit, dog and monkey to mouse). Some preliminary irradiation of the host seems to produce a sort of paralysis of the immunity mechanism. The antibody reaction against foreign cells is depressed still further with the result that the frequency of successful transplants is still greater in the irradiated host. Unfortunately, the host must be heavily irradiated to accomplish the necessary depression of the immune mechanisms.

The recovery of the immune antibody-antigen mechanism of mice pre-treated with MEG (2-mercaptoethylguanidine hydrobromide) and then exposed to 950 *r* was shown to be comparable with that of mice exposed to 950 *r* and then post-treated with bone marrow from the same strain of mice. It was deduced that there existed either different types of antibody-producing cells, or an antibody-producing cell with the ability to recognize varying degrees of antigenicity, i. e., (*a*) homologous (antigen from another strain of the same species) (*b*)

closely related heterologous (rat, guinea pig in relation to mouse), and (*c*) distantly related heterologous antigens (man, rabbit, and sheep in relation to mouse). In terms of these hypothetical properties, the degree of destruction of antibody-producing cells by X-rays would be in the order mentioned. This hypothesis was experimentally substantiated in part. Mice treated with MEG and exposed to 950 *r* accepted transplants of homologous bone marrow but would not tolerate transplants of closely related heterologous bone marrow.

Mechanism of Red Blood Cell Production

The mechanism of the action of erythropoietin, a hormone that controls the production of red blood cells, was traced at Argonne Cancer Research Hospital. Researchers established that it is the relationship of the oxygen supply in the tissue to the tissue demand for oxygen, rather than either of these factors acting independently, that controlled red blood-cell production through the action of the hormone. Cell production was profoundly decreased in rats in which the tissue supply of oxygen remained normal while demand was reduced by acute starvation or removal of the pituitary gland, and also decreased in rats in which the supply of oxygen was increased by transfusion-induced oversupply of red cells or hyperventilation but the demand remained normal. Rats so treated responded in an exaggerated manner to injection of a plasma rich in erythropoietin.

Red blood-cell production increased in rats in which the demand for oxygen was increased by injecting the chemical compounds, dinitrophenol or triiodothyronine while the supply remained normal, and in rats in which the oxygen supply was decreased by repeated hemorrhage or induced anemia while the demand remained normal. Evidence now points to the kidney as the site of production of erythropoietin, although it is possible that the hormone may be formed elsewhere as a precursor activated by the kidney.

Extension of this investigation to human beings revealed that erythropoietin was present in very small amounts in the plasma of normal healthy male subjects.[34] However, its concentration was markedly elevated in two-thirds of the anemic patients studied. The hormone appeared in the urine of some anemic patients but not in the urine from normal persons. The feasibility of using erythropoietin in clinical trials was considered since it might prove valuable in anemias resulting from chronic infection, chronic systemic diseases, and kidney diseases, as well as for supportive treatment in radiation sickness.

[34] See p. 83, Twenty-first Semiannual Report (July–December 1956).

The role of the pituitary also was investigated in relation to its action in hemoglobin formation. Animals whose red blood cell production has been inhibited incorporate very little iron into hemoglobin. This incorporation, however, can be greatly increased by minute amounts of pituitary material or by a fraction isolated from circulating plasma. The chemical isolation of the pituitary principle and its relation to the plasma erythropoietic hormone in both animals and man has been under investigation at the University of California Radiation Laboratory.

Toxicity Studies

Tests for Uranium Body Burdens

A problem of long-standing importance in maintaining safe working conditions in uranium-processing plants is that of defining the quantitative relationship between uranium excretion from the body—measured routinely among uranium processors—and its long-term storage in tissues and organs.

Investigations started several years ago at Oak Ridge National Laboratory determined the pattern of excretion of uranium and its deposition in organs and tissues for man so that it was possible to estimate the burden of uranium in the body within a factor of three from the measured urinary excretion. Attempts will be made to secure a more precise estimate.

Through studies with dogs, it was found that:

a) Ingested or inhaled uranium is eliminated predominantly via the gastro-intestinal tract.

b) About 10 percent of an inhaled dose of uranium is absorbed into the blood stream, whereas only about one-tenth of one percent of ingested uranium is absorbed.

c) The levels of uranium in the feces decrease as much as 500-fold within one week after ingestion; but in the case of inhalation, the decrease is more gradual and shows a 20-fold reduction in one week.

d) Urinary excretion levels follow a course similar to the levels in feces; at most a 20-fold reduction is evidenced when uranium is inhaled, while a reduction of the order of 100-fold occurs when the uranium is ingested.

In the studies with mice, a pathological effect on the gastro-intestinal tract was not found after 120 days of continuous oral administration of uranium 233 in the drinking water at about 100 times the maximum permissible concentration. These studies are being continued.

Uranium mines. In cooperation with the Public Health Service and the Veterans Administration (Veterans Administration Hospital, Grand Junction, Colo.) investigations were being conducted by the University of Rochester to define better any hazard in uranium mines that may exist due to the radioactive gas, radon, that occurs in association with uranium.[35]

Dogs exposed for 110 days in one mine will be returned to Rochester for long-term measurement of radioactivity in the urine, and eventually of total body stores of radioactivity. Dogs and other animals were exposed to experimentally produced radon atmospheres at Rochester. From these measurements, and from studies on uranium miners themselves, it is expected that occasional measurement of urinary samples will make it possible to warn if cumulative exposure approaches a potential danger line. This may reduce the need for day-by-day monitoring of all working areas in the uranium mines themselves.

In other experiments, animals inhaling atmospheres containing large amounts of radon, specifically half the lethal dose, showed no definable decrease in life-span. In studies on mice highly susceptible to lung cancers, the incidence of lung cancer was not increased following radon exposures.

Beneficial Applications of Atomic Energy

Thyroid-Uptake Calibration and Seminar Program

Three years ago the Oak Ridge Institute of Nuclear Studies undertook a program to "standardize" the iodine 131 thyroid-uptake techniques so that results would be comparable regardless of the particular type of apparatus employed in the different laboratories. Life-size half-body mannequins containing simulated thyroid glands with suitable amounts of "mock-iodine" giving off a gamma-emission spectrum closely approximating that of iodine 131 were sent for testing to some 300 scientists in the United States and England. Using these test results, and data from basic studies at ORINS, a seminar in September 1956 helped establish methods for inter-laboratory calibration and during the last 6 months five additional seminars were held on methods likely to give the most reliable results. Two seminars, January 14–15 and February 11–12, were primarily for invited groups of physicians and physicists; two, March 18–19 and April 15–16, were open to all qualified physicians and physicists; and one was held May 17 for representatives of manufacturers of uptake-calibration equipment. One will be scheduled later for qualified technicians.

[35] See pp 223-225, Twenty-first Semiannual Report (July-December 1956).

Tracer Studies

Hormone research. Control of carbohydrate metabolism by means of hormones was studied at Brookhaven National Laboratory in a collaborative research project with the New York University Medical School. Glucose labeled with radioactive carbon 14 was used to study the pattern of glucose uptake and production after insulin injection.

A small dose of insulin was administered intravenously to experimental animals in the post-absorptive state, that is, several hours after a meal. The resulting decrease of the blood sugar level was traced almost exclusively to an increase in the rate at which tissues took up glucose from the blood. There was also a transient, early, minor decrease in the rate at which the liver contributed glucose to the blood stream. The maximum uptake of glucose by the tissues occurred 10 to 15 minutes after insulin was injected; subsequently, the rate of uptake fell off sharply, but it did not drop below the pre-insulin level.

The blood glucose concentration then returned to its previous, normal level as a result of an abrupt increase in the liver's output of glucose. This increased rate of output first appeared about 15 to 20 minutes after insulin was given, and just after the period of maximum uptake of glucose by the tissues. The output rate reached its maximum 20 to 30 minutes after insulin injection. As the blood glucose concentration approached normal, the rate of glucose production by the liver returned nearly to the pre-insulin level.

A regimen of growth hormone injections was found to restore to normal the impaired ability of the liver to put glucose into the blood of a hypophysectomized dog—one with its pituitary gland removed. This was observed both in the resting post-absorptive state, in which the blood glucose turnover rate is raised to normal, and also in response to the extra demand for glucose brought about by insulin-induced shortage of blood sugar. A regimen of cortisone injections was found to produce the same effects as the growth hormones in the hypophysectomized dog.

The liver of the adrenalectomized dog—one with its adrenal glands removed—was found to be considerably less deficient in glucose-producing ability. This is understandable, since the dog's intact pituitary gland was secreting a growth hormone which partially compensates for the missing adrenal cortex secretion. The hypophysectomized dog lacked growth hormone and also lacked a sufficient secretion of the cortisone-like adrenal hormones, since the ACTH secretion from the pituitary was not present to stimulate adrenal

430209—57——10

secretion. Thus, the hypophysectomized dog's liver is most inadequate in glucose output, but it can be restored to normal either by growth hormone or cortisone.

The action of growth hormone or cortisone in bringing about a diabetic state when administered in large amounts is ascribed to the resulting overproduction of glucose from the liver. At first, the pancreas responds to the extra glucose by secreting extra insulin. This was shown in experiments by the finding that glucose uptake by the tissues is increased in the whole animal early in a regimen of growth-hormone administration, in spite of the fact that growth hormone inhibits uptake of glucose by the tissues. When the pancreas no longer can secrete enough insulin to handle the over-production of glucose, the diabetic state is produced.

Radioactive manganese in liver tumors. The goal of a series of studies at Brookhaven National Laboratory is to place an element or a compound upon a specific physiological target, so as to permit effective therapy with a radioactive isotope and safe diagnostic procedure with radioactive isotopes. Besides these objectives, the studies open the possibility of other research on specific target distribution of drugs already in use. Success in such studies could reduce the hazard of many drugs now employed and at the same time increase their effectiveness.

One series of studies was carried out with the beta-gamma emitter, manganese 56.[36] It was observed that, following intravenous injection into test animals, by far the largest fraction of the isotope could be found in the liver within 3 minutes, and it persisted there at least 30 minutes after injection. It was observed also that the radioactive isotope was removed very rapidly from the blood, and no significant fraction accumulated in bone marrow.

Subsequent observations suggested that the biological half-time in the liver was about 4 hours. Since the radiological half-life of manganese 56 is 2.6 hours, about two-thirds of the radiation which the isotope could deliver would be emitted during the time it was in hepatic structures.

Therefore, this isotope was considered as promising for possible therapy in hepatoma (tumor of the liver), since the hazard to the blood appeared small and the strong emission of short-range beta particles would provide effective local radiation. Cautious trial of manganese 56, in cancer of the liver which had been metastasized (transported elsewhere in the body) indicated that it did have a palliative effect, but that the depressive effects of radiation on the blood-cell producing system were significant and much greater than ex-

[36] See p. 102, Twentieth Semiannual Report (January–June 1956).

pected from a consideration of the curves of manganese disappearance from the blood.

Laboratory investigations indicated that manganese distributed itself intracellularly, and that this distribution within cells was not uniform.

Manganese localized largely in the mitochondria structures of cells, with only about half as much manganese in the nucleus. Secondary distribution, after leaving the liver, led manganese to the central nervous system among other organs. Because of the short half-life of the isotope, however, its secondary distribution may be ignored if it can be localized initially in the liver.

Two subsequent studies were made to determine (*a*) the effects of the procedures of administration, and (*b*) the effects of using various simple salts of the isotope, upon the isotope's primary distribution. Both showed a profound effect on the primary localization of manganese. Hence, by choice of a suitable salt and also by choice of the route of administration, approximately 90 percent of the administered isotope could be promptly localized in the liver, thereby possibly reducing its hematologic effect to tolerable limits.

With this new information, additional clinical trials may be undertaken to determine the useful palliative effects of manganese.

Tritium studies. Radioactive hydrogen, or tritium, an isotope with a half-life of 12 years and a pure beta emitter of very low energy has special values in experimental work. The radiation's effective range in tissue is very short, significantly less than half the diameter of a cell. With tritium, uniform tissue distribution is easily accomplished by administration of tritium oxide (water composed of oxygen and radiohydrogen). However, more precise data of a different type can be obtained by specific incorporation of tritium within a cell structure. The compound thymidine, fed to an organism, becomes incorporated into a thymidine molecule to provide lethal radiation to a cell. The amount was found to be somewhat less than expected and to be within the range of accomplishment. If one-tenth of one percent of thymidine molecules each contained one tritium atom, the resultant radiation would be of the order of an LD 50 dose—that necessary to destroy half the cells—using tritiated water studies for dosimetric comparison.

Thus, by incorporation of tritium into thymidine it is possible to achieve specific non-uniform distribution of a radioactive substance within a cell and by virtue of proper isotope selection prove the location of the tag within the cell. This is difficult to accomplish with a carbon 14 label because the greater energy of the beta particle prevents good resolution by radioautography. With carbon the radioautograph shows cell location but not chromosome localization. With

tritium, chromosome localization within the cell can be demonstrated by radioautographs. Advantage is taken of the weakness of the tritium beta emission also to confine effects to a small region within the cell. With this use of tritium it is possible to observe primarily the nuclear effects in cells as contrasted to cytoplasmic effects in the case of manganese 56. It is now possible not only to study effects of localized radiation upon the genetic material of the cell itself, but also to develop a therapeutic procedure in the future.

Cancer Therapy and Research

At Argonne Cancer Research Hospital, Chicago during this reporting period new therapeutic techniques using additional radioisotopes were tested and the teletherapy machines were employed in treating large numbers of patients. Treatments with the proton beam of the University of California 184-inch synchrocyclotron continued.

A new cobalt 60 teletherapy machine, designed for greater efficiency and economy of operation, was soon to be installed at Oak Ridge Institute of Nuclear Studies Hospital.

Experimental Work at Argonne Hospital

At Argonne Cancer Research Hospital, Chicago, tumors of the eye were successfully treated with iodine 131. The technique involves enclosing the iostope in a polyethylene envelope that is then placed next to the eye.

Important technical advances were made in effecting total destruction of the pituitary gland in patients suffering from inoperable malignancies. This was accomplished by surgical implantation of yttrium 90 sources of radiation.

A process was developed that permits the use of palladium 103 as a therapeutic agent for cancer of the female reproductive system. Radiopalladium may prove to have certain advantages over radiogold for this purpose because it emits only soft X-rays with relatively low penetration whereas gold 198 emits highly penetrating hard gammas.

Lutecium 177 and dysprosium 165 were studied in tumor-bearing and normal rats to learn the effect of their radiations in tissue. Both isotopes are more inert biologically and less toxic than some other radioelements now used clinically.

Both the Van de Graaff generator of 2 Mev X-rays and the cobalt 60 therapy unit were used during the last 6 months to treat a large number of patients with various types of malignancies. Carcinomas of the urinary bladder were treated by means of conical rotation with

the Van de Graaff, and the results were highly encouraging. A rather complete set of isodose curves was calculated to assist the radiotherapist in treating patients with deep pelvic malignancies.

The beam application device for treating patients with the linear electron accelerator was almost completed.

Radium patients. Four patients who have excessive body burdens of radium and are being followed clinically at the Argonne Cancer Research Hospital have developed carcinoma of the mastoid. This is a rare site for cancer and its occurrence in radium cases was investigated to obtain more information on its origin and growth under these particular circumstances.

Proton Brain Work at Radiation Laboratory

The beam from the 184-inch synchrocyclotron at the University of California Radiation Laboratory has been used for a number of years as a tool in biological studies. Recently, both basic endrocrinological studies and experimental cancer therapy have been under investigation.

The pituitary glands of a number of patients with advanced mammary carcinoma were irradiated by the collimated proton beam from the cyclotron and effective destruction was obtained in a number of cases. In some patients, marked regression of the tumor, as well as objective improvement, was observed. The results with this series of patients were of sufficient promise to warrant a follow-up and this is planned. A new head-rotating device, which will allow highly localized internal radiation doses, has been under construction and will be used with a second series of patients.

The cyclotron beam also was used to destroy specific parts of the hypothalamus of experimental animals. This has allowed the study of some fundamental endocrinological processes. A locus in the hypothalamus was found which apparently controls the cells in the pituitary responsible for producing growth hormone.

X-ray Beam from Synchrotron at San Francisco

The 70 Mev X-ray beam produced by the electron synchrotron of the Radiological Laboratory of the Medical School of the University of California at San Francisco now is being used for the treatment of selected cancer patients. These very high energy X-rays probably represent the upper limit of X-ray energy that may find application in cancer therapy. At least 5 years will be needed to evaluate satisfactorily the effectiveness of this extremely penetrating radiation.

Oak Ridge Institute Teletherapy Unit Design

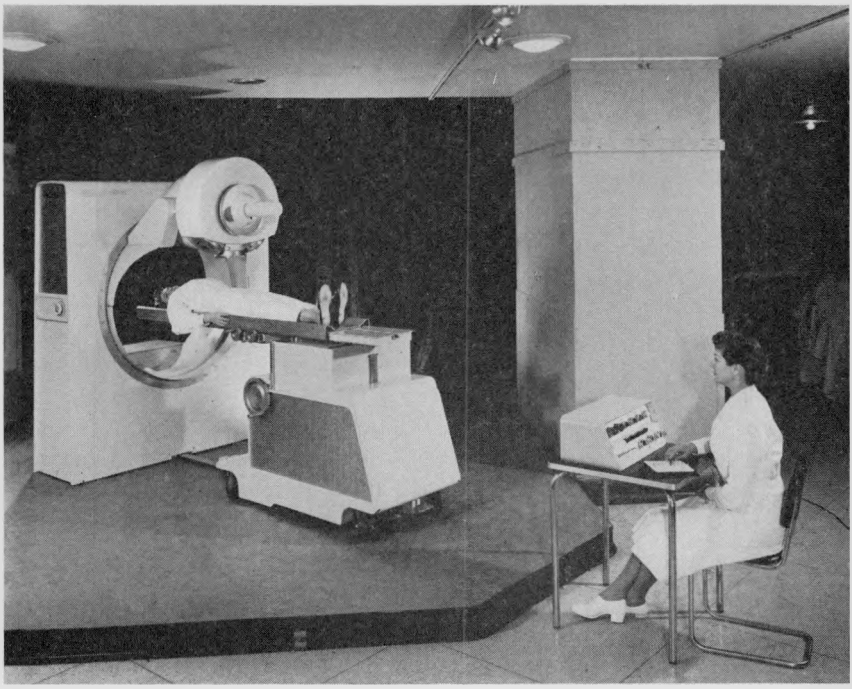
In 1955, the Oak Ridge Institute of Nuclear Studies negotiated a contract with the X-ray Division of the Westinghouse Electric Corp. to develop and manufacture a new cobalt 60 teletherapy unit—one that could solve many economic problems associated with the manufacture and installation of such machines. One important goal was a machine that would allow a large selection of portals for the gamma-ray beam without the impracticality and expense of interchangeable cones or variable-field diaphragms. After much study and research, designers agreed upon a compromise pattern involving a revolving turret with seven fixed portals. A floor-mounting mechanism was devised to permit placing the machine in a corner, so that a minimum weight of room shielding was required. Horizontal suspension over the patient also allowed an easy rotational adaptation.

Another purpose of the Westinghouse contract was to develop a machine that projects two opposing beams of radiation and can use "worn-out" sources from other machines that have lost some effectiveness through radioactive decay. An opposed-field, double-head, rotating floor stand was designed to mount the mechanism. There are probably some theoretical disadvantages to such an opposed-beam technique in all except 360-degree rotating therapy. The machine is designed to measure these disadvantages. It will also be adaptable to pendulum-arc types of treatment.

A special treatment table for the machine also was designed as part of the mechanism of the rotating machine to provide an increased degree of flexibility in positioning patients. Studies with previous devices showed that the cost of positioning patients was one of the largest economic problems using rotational machines. The newly designed table may solve this problem.

Construction of a test unit was essentially complete by December 1956 when the machine and table were shown for criticism at meetings of the Radiological Society of North America, Chicago. The machine and table then were returned to the Westinghouse shops in Baltimore for minor changes, and the improved device was expected to be installed at Oak Ridge late in 1957.

Since the radiation characteristics of the beam are fairly well known, the teletherapy program for 1957 will involve chiefly investigation of the mechanical parameters of variations in the machine itself, as a prerequisite to efficient use of the device.



Teletherapy. A new teletherapy unit using cobalt 60 permits easier control of the emitted gamma-ray beam. The drum-like portion of the unit directly above the woman posing as a patient contains seven fixed portals for the cobalt 60 rays—the cobalt itself would be within the drum—and these provide a large selection of portals without the need for interchangeable cones or variable-field diaphragms. Three of the ports are visible on the lowest are of the drum.

Radiation Detection Instrumentation

Personnel monitoring. Recent experiments by the monitoring group at Oak Ridge National Laboratory have extended down to eight effective kilovolts (kev) the previous data on photon energy response and filtration of an emulsion used in film packets for monitoring radiation levels. Previously, data extended down to approximately 21 kev. Information within the 8 to 21 kev range should prove useful for measuring exposures near low energy X-ray machines and certain radioisotopes.

A film badge designed at Hanford was put into extensive service during the first quarter of 1957. This personnel meter is about one-third the weight of the previous badge and contains three times as many radiation absorbers, thus allowing for more sensitive energy discrimination and improved dose evaluation. Automatic techniques

for processing the daily and cumulative radiation exposure history of employees were applied. Data processing, in conjunction with improved dosimetric techniques, resulted in a more sensitive control for personnel exposures.

A dual-filter device for continuous detection of airborne alpha particle emitters was developed at Hanford. Portable instrumentation developed included a scintillation fast neutron meter, and a scintillation gamma meter.

Measurement of cerebral blood flow. A method of estimating cerebral blood flow by injecting a gamma-emitting radioisotope into the carotid artery of the neck and measuring the activity with a scintillation counter placed over the *torcula Herophili*—a venous sinus through which 85 percent of the cerebral blood flow normally passes—was developed cooperatively by the Atomic Energy Project of the University of California at Los Angeles, and the University of California at Los Angeles School of Medicine, Neurosurgery Department.

Repatriation of the Rongelapese

After the Commission determined that the degree of contamination from fallout after a weapons test had declined on Rongelap Atoll to an acceptable level, the Rongelapese were returned to their home island on June 29. The Rongelapese, last evacuated Marshall Islanders to be returned to their home island, were removed from the atoll after a fall-out of radioactive fission products following the March 1, 1954, detonation in the Eniwetok Proving Ground.

Medical Re-examination of Rongelapese

A medical resurvey of the Marshallese exposed to fall-out in March, 1954 was performed at the end of a three-year period. Preliminary data indicated that there were no illnesses or clinical conditions encountered which could be related to radiation effects. Those who received significant exposure appeared to be recovering satisfactorily. Although statistical analyses have not yet been carried out on the blood examinations, it appears that the blood cell counts are about equal to those in the unirradiated people examined. Numerous other blood examinations were run during this period and the results will be published.

The beta-radiation burns of the skin showed continued improvement and there was further evidence of repigmentation in those areas in which pigment aberrations were evident. There was no evidence of

any malignancy in any of the scars resulting from radiation burns. Numerous urine samples were taken for radiochemical analyses to determine the amount of radioactivity remaining in the exposed people. Since urinalyses made last year showed very little remaining activity, it was decided that a more sensitive measure of residual activity was desirable. Accordingly, 4 Rongelap people, 2 Utirik people and 1 Marshallese control from Majuro, were taken to Argonne National Laboratory and total body activity was counted in the Human Radiation Detector for body radioactivity there. This examination showed that detectable amounts of activity still were present, but the levels of activity were only a few times higher than those found in other people throughout the world; all were well below acceptable tolerance levels.

Anthropometric measurements of the Marshallese children indicate some preliminary evidence of slight impairment of their growth. None of the effects is major and there is no deformity.

No deaths have occurred among the Rongelap people except for one still-birth, one infant who died 8 hours after birth of an umbilical cord infection, and a 46-year-old man whose death was attributed to hypertension. These deaths were not believed to be related to any radiation effects.

Some 130 persons of the 157 originally exposed on the island of Utirik who had been exposed to much smaller amounts of fall-out were examined and found to be generally in good health with no illnesses or clinical conditions which could be related to radiation effects. There had been 6 deaths among the Utirik people during the last 3 years but no relation to radiation effects could be established as a cause of these deaths. The death rate was about that to be expected.

External Gamma Dose Rates

The radiation survey of Rongelap Island in July 1956 showed gamma values ranging from 0.2 to 0.5 milliroentgen per hour, with an average of 0.4 milliroentgen per hour. Estimates of decay indicated that dose rates at the time of repatriation would be less than 30 milliroentgens per week or slightly less than 0.12 milliroentgen per hour. It was also estimated that the gamma dose on Rongelap will total about 0.5 roentgen for the first year of reoccupation and gradually decline thereafter. The Rongelapese who go on fishing expeditions to some other islands in the Rongelap Atoll could be exposed to levels of radioactivity higher than those on Rongelap itself; however, much of their time is spent on fishing boats over waters with gamma activity near background values. Thus the initial external gamma radiation

received by the Rongelapese as a whole can be expected to be 0.5 roentgen or less per year.

There are no radiation standards which apply directly to the Rongelap situation. However, standards established for normal atomic energy activities involving much larger numbers of people may be of some significance in evaluating the Rongelap data. For occupational conditions, the National Committee on Radiation Protection and Measurement recommends that adult workers not be exposed to more than 0.3 rem or 300 millirems (roentgen equivalent for man) of whole body radiation per week, or a 13-week dose of 3 rems when the weekly limit is exceeded. This standard is further restricted by an age qualification, which provides that the maximum permissible accumulated dose in rems, at any age, is equal to five times the number of years beyond age 18, provided no annual increment exceeds 15 rems. Thus, for persons over 18 years of age the accumulated maximum permissible dosage is 5(N–18) rems, where N is the age. This standard applies to all critical organs except the skin, for which the value is double. For a large population, in contrast with a small group such as the Rongelapese, the maximum permissible exposure is an average of 14 million rems per million persons during the period from conception up to the age of 30, and one-third of that amount in each decade thereafter.

Food Supply and Body Content of Strontium 90

Strontium 90 is the radioactive isotope of principal concern in the food chain of the Marshallese. Analysis of the results from all Pacific Islands surveyed in late 1956 showed a decline of strontium 90 with the passage of time, except in the land crabs. Additional collections of land crabs will be made on Rongelap to establish the reason for their increase in strontium 90 activity.

Maximum permissible exposure to strontium 90 for the general population, in terms of maintained level in the body, is 100 Sunshine Units (100 micromicrocuries of strontium 90 per gram of calcium). Exposure of the Rongelapese can be reduced by eliminating land crabs from the diet and by the use of imported rice. Because only a part of the strontium 90 will go from food to bone, it is expected that these measures may limit the ultimate body burden for the Rongelapese to substantially less than 100 Sunshine Units.

Swine, chickens, ducks, and rats have continued to live on Rongelap during the period of highest strontium 90 contamination of the soil-plant-animal cycle. Examinations of rats collected and sacrificed 2 years after the initial fall-out show no gross or pathological changes that could definitely be ascribed to radiation.

Medical Surveillance

When the Rongelap people are returned to their home island, they will be given regular monthly medical examinations by local health personnel and an annual examination by a physician from the United States. A dispensary will be maintained for regular health services. They will be observed for any unusual body accumulation of strontium 90.

Biological Surveys

A summary report of the several biological surveys made of the Marshall Islands is being prepared by the Commission. The studies were made by the University of Washington, the Naval Radiological Defense Laboratory, and the New York Health and Safety Laboratory.

Ecological Studies

Plans have been made for a long-term study of the effects of environmental conditions and processes on plant and animal life on Rongelap Atoll and in adjacent waters. An effort will be made also to determine the relationship between biological systems of the land and the sea. Climatic data will be collected on temperature, rainfall, light intensities, wind, and relative humidity. Indigenous soil factors will be analyzed by mapping of soil and radiation patterns, and aquatic features will be studied in both fresh and salt water. An inventory of plant and animal life will include the determination of species association; mapping of vegetation patterns; plant and animal population studies; study of the production, utilization, exchange, and transfer of mineral and organic materials between the land and sea; sampling of the lagoon bottom; and sampling for radioactivity in selected plants and animals. This study is expected to begin about the time the Rongelap people are returned to their home island.

Nuclear Materials Management

Standards

The proposed program for developing, preparing, and distributing certified standard samples of materials peculiar to the atomic energy industry was initiated. Development and preparation will be by the Commission, principally at the New Brunswick Laboratory, N. J., with certification and distribution by the National Bureau of Standards.

Peaceful Uses of Nuclear Materials

Domestic. A symposium on "Modern Approaches to Isotopic Analysis of Uranium" was held at Chicago, February 5–7. The 23 papers covered such approaches as mass spectrometry, emission spectrography, neutron activating, gamma counting, pulse analysis and nuclear magnetic resonance spectrometry. About 200 persons attended the meeting, including about 50 from private industry. The papers will be distributed on a classified basis.

A symposium attended by 104 representatives of private industry was held in New York March 5–7, on handling and accounting for source and special nuclear materials. The 20 papers covered application of accounting, chemical and physical measurements, and mathematical statistics in the areas of fuel fabrication, reactor operation, chemical processing, and scrap recovery. The papers will be distributed on an unclassified basis.

The annual meeting of Commission and contractor personnel, concerned with materials management, was held in Washington during the week of June 17. Approximately 150 attended.

Inspection

Programs of inspection specifically designed to result in annual appraisals of contractor performance were instituted by Commission Operations Offices.

Inspection policies appropriate to a program for carrying out the safeguard provisions of the United States agreements for cooperation with other countries were being developed.

License Compliance

Inspection units have been established in nine Commission operations offices. Initial staffs of professional personnel are conducting inspections of byproduct and source material licensees gathering information to show whether or not the licensees are conducting their operations in accordance with regulations. Cooperation with the various States continued.

Inspections were conducted of licensed reactors in operation as well as those undergoing preoperational testing and start-up.

Construction and Supply

Construction

As of June 30, 1957, the Nation's investment in atomic energy facilities stood at about $7.0 billion, representing a two-fold increase within 5 years.

Costs incurred by the Commission for new plant and equipment averaged about $25 million a month during the 6-month reporting period, and fiscal year 1957 costs were estimated to approximate the $300 million annual rate of the previous fiscal year. Construction activity was expected to continue at about present levels during the next 6 months.

Small Business

A substantial portion of the Commission's subcontract dollars continued to go to small business. In the fiscal year 1956, small business received 45.7 percent of Commission subcontract dollars. During the first three quarters of fiscal year 1957, subcontracts in the amount of $160.7 million or 38.6 percent went to small business out of a total of $415.7 million. The change in the small business share is attributed to the decrease in plant construction and the expansion of reactor development programs. The requirements for equipment and materials used in reactor work are extremely exacting. At present, the number of small businesses which can meet these exacting requirements is growing but still is relatively small. The Commission continues to examine the reactor development program to be sure that the maximum opportunities are available to small business concerns.

From July 1, 1951, to March 31, 1957, subcontract awards to small business by Commission cost reimbursable contractors amounted to $1.355 billion or 40 percent of a total of $3.409 billion. During the same period, direct contract awards to small business amounted to $280 million or 3.3 percent of $8.50 billion.

Saving on Postage Accounting

A new procedure was worked out between the Post Office Department and the Commission to save manpower and record-keeping on postage charges paid by the Commission. Arrangements were made to pay all postage costs quarterly, with payments based on a formula developed from postage-payment records of past experience and current mail sampling. This procedure eliminated the need for postal metering machines, postage stamps, and stamp-accountability records.

Mobilization Planning

The Commission participated with the Office of Defense Mobilization (ODM) and other Government Departments and agencies in various mobilization readiness plans. Exercises during the first months of 1957 demonstrated that the Commission was ready to carry out its responsibilities during an emergency, both at headquarters and in its operations offices throughout the country.

Community Operations

Sale of Property, Oak Ridge and Richland

Public response to the program for the sale of community property at *Oak Ridge*, Tenn., was enthusiastic during the reporting period. The progress of the sales program, by Housing and Home Finance Agency, which began with the offering of residential lots on July 31, 1956, has been very successful. The sale of 119 residential lots under lease had been offered by the Commission on December 20, 1955. To date, all the single and duplex houses and a major portion of the vacant residential lots and improved commercial properties have been offered for sale.

Sale of housing at *Richland*, Wash., was delayed by objections of residents to the appraised values of certain types of units, particularly the duplex houses. A consultant employed by the Federal Housing Administration to review the appraisals recommended substantial reductions on duplexes and lesser reductions on several other types of residential units. The revised appraised values were published on January 29, and on February 11 the Housing and Home Finance Agency issued a finding of feasibility of sale as required under the Atomic Energy Community Act of 1955. The sales program got under way at Richland March 21 with an offering of 228 vacant residential lots. The first group of 203 single-family houses was offered for sale to occupants on June 12, and by the end of the month, some 70 individuals had indicated a wish to purchase.

The status of the disposal of residential and commercial property at Oak Ridge and Richland is summarized as follows:

STATUS OF COMMUNITY PROPERTY DISPOSAL AS OF JUNE 30, 1957

Type of property	*Oak Ridge*		*Richland*	
	Number offered	*Percent sold*	*Number offered*	*Percent sold*
Single and duplex residences	4,360	87	203	0
Residential lots	812	15	228	11
Improved commercial properties	37	0	0	0

Self-government, Oak Ridge and Richland.

Oak Ridge residents have indicated an increasing amount of interest in local self-government and several preliminary steps were taken toward its establishment.

During March, the Tennessee Legislature enacted a general law providing an additional method under which Oak Ridge could incorporate. The Town Council was considering retaining a consulting firm to undertake an organizational and fiscal study relating to the establishment of a new city. The Oak Ridge Regional Planning Commission, established as legal entity under state law, adopted subdivision regulations. A zoning ordinance was enacted and a county building inspector and a board of appeals appointed.

The *Richland* Community Advisory Council has shown active interest in the problems of incorporation. Last December the Council drew up a schedule for incorporation under state law. The schedule contemplated that initial steps toward incorporation would begin 16 months after the HHFA finding of feasibility on an assumption that one-half of the residential units would have been sold by that time.

On May 21, a memorandum of agreement with the General Telephone Co. of the Northwest was executed providing for sale of the properties and transfer of operating responsibility for the Richland community telephone system, effective July 1.

A new contract was being negotiated with the Kadlec Methodist Hospital, deeded to the Methodist Board last September, to provide for a diminishing annual hospital subsidy which will terminate as soon as the hospital becomes self-supporting.

Los Alamos Activities

Access controls to the community of Los Alamos, N. Mex., were removed in February after determination that security of Los Alamos Scientific Laboratory could be continued without controlling access to the community. Control of air space above Los Alamos, and of the Los Alamos airstrip, was continued. Removal of community access controls will result in direct savings of approximately $100,000 per year.

A general plan was being prepared to cover anticipated community development at Los Alamos for the next 10 years. Major items under consideration included building codes, covenants, zoning requirements, and estimates of the projected community needs and commercial services. This will facilitate consideration of sale of lots for private home construction, as authorized by the Congress, and the sale or long-term lease of lots for commercial enterprises.

Additional school facilities, costing approximately $965,000 were planned for Fiscal Year 1958 to accommodate the expected large increase in enrollment.

The program for eliminating substandard housing at Los Alamos continued during the reporting period with completion of 125 replacement units. It was expected the remaining 101 units would be complete by October.

New Commission Headquarters

The Commission expected to move its headquarters in November to its new 400,000-square-foot office building being erected at Germantown, Md., some 23 miles northwest of Washington, D. C. As of the close of the reporting period, construction of the brick-faced, four-story, air-conditioned building was 72 percent complete and approximately on schedule.[37] The move out of the District of Columbia was planned to comply with the dispersal policy established by the President.

Under Public Law 31, 84th Congress, approved May 6, 1955, which authorized the new headquarters,[38] the Commission is required also to maintain an office within the District of Columbia for service of process and legal papers. In addition, the Commission planned to maintain there a few other offices including a room to provide public access to documents relating to its licensing program and other information, and an employment interview office.

Before selecting the 109-acre Germantown site, the Commission considered approximately 50 potential locations for its headquarters, and surveyed the pattern of employee residence distribution in Washington and its environs. After selection of the site, the survey was brought up to date, and employees who lived beyond reasonable commuting distance were encouraged to move to more convenient locations. A manual of information on local government, planning, neighborhood evaluation, community facilities, taxes, etc., was issued. Supplements included surveys of available apartments and rentals, development housing, and lists of real estate dealers. The Commission also proposed legislation to reimburse employees for some costs of moving, and to permit subsidization of a part of employees' costs of commuting to new headquarters. Simultaneously, a recruitment campaign to replace persons who leave the Commission was carried out in areas convenient to the new site.

[37] For description, see p. 94, Twenty-first Semiannual Report (July–December 1956).

[38] See p. 103, Nineteenth Semiannual Report to Congress (July–December 1955).

As a result of these complementary activities, employee distribution, between October 1954 and January 1957, altered and the number of employees living within 30 minutes' drive of the new site increased from 12 to 22 percent. Employees living 30 minutes to an hour away decreased from 48 to 43 percent of all employees, and those more than an hour's drive away decreased from 40 to 35 percent.

The Commission expected to lose personnel as a result of the move and engaged the research firm, Harbridge House, Inc., Boston, Mass., to conduct a survey in January 1957. The survey indicated that, under conditions and circumstances prevailing at that time, the Commission could expect to lose between one-fourth and one-third of all employees, with the greatest loss in lower grades. Through its employee relations program, the Commission hoped to reduce the estimated loss.

Organization and Personnel

Personnel Activities

Principal Personnel Changes

On June 17, the President sent to the Senate his nominations to fill two vacancies on the Commission.

John F. Floberg was nominated for a 5-year term ending June 30, 1962, replacing Commissioner Thomas E. Murray whose term expired June 30 of this year.

John S. Graham was nominated for the unexpired term of Commissioner John von Neumann, ending June 30, 1959.

Commissioner von Neumann died on February 8 (see Foreword).

William Mitchell resigned June 15 as General Counsel of the Commission to reenter the private practice of law. He had served as General Counsel since March 16, 1953. Edward Diamond, Deputy General Counsel, is Acting General Counsel.

Eger V. Murphree was appointed by the President April 17, 1957, to the General Advisory Committee to serve the unexpired term of Dr. Eugene P. Wigner ending August 1, 1958. Dr. Wigner's resignation was accepted by the President January 24, 1957.

430209—57——11

Awards to Employees

Interest and participation in the program of awards for suggestions and superior performance increased during fiscal year 1957, as compared with the years ended June 30, 1955, and June 30, 1956, as the following tables show:

	Suggestions made	*Suggestions adopted*	*Superior performance awards*	*Special act or service awards*
1955 (7 months)	85	4	15	0
1956	342	45	77	2
1957 (9 months)	390	72	101	1

Cash Awards

	1955	*1956*	*1957 (9 mo.)*
Suggestions	$665	$2,305	$2,425
Superior Performance	1,825	23,260	21,730
Special Act or Service	-------	900	400
	2,490	26,465	24,555

Net first-year dollar benefits from suggestions were $49,824 for 1955; $234,703 for 1956; and $60,415 for the first nine months of 1957.

Award to Dr. Fidler. Dr. Harold A. Fidler, Manager of the San Francisco Operations Office was selected as one of 10 career employees of the Federal Government to receive this year's National Civil Service League Career Service Awards.

Dr. Fidler was recognized for his role in the negotiation of major Commission contracts for research and development of nuclear weapons and reactor technology, and for basic and applied research in physical and life sciences.

Dr. Fidler's association with atomic energy activities began in 1942 when he was made responsible for the initial phases of research and development on the atomic bomb being conducted at the University of California for the Manhattan Engineer District, for which he was awarded the Legion of Merit.

The Career Service Award, consisting of a scroll and a personal memento, is presented each year by the National Civil Service League, a non-partisan citizen's organization for good government.

Davis receives Flemming award. W. Kenneth Davis, Director, Division of Reactor Development, was one of 10 Federal employees who were presented with the Arthur S. Flemming Award on February 14.

Davis was selected in recognition of his leadership, guidance and administration of the reactor development program through a difficult

and complex period of expansion resulting from increasingly heavy military requirements and new civilian demands since the passage of the Atomic Energy Act of 1954. In meeting this challenge, Davis' scientific competence, foresight, managerial ability and devotion to duty were cited as having been directly responsible for the successful execution of the reactor development program.

The awards are presented annually under the auspices of the Junior Chamber of Commerce, Washington, to outstanding young men in the Federal Government.

Safety and Fire Protection

1956 Accident Record

The occupational injury rate for all Commission activities during the calendar year of 1956 increased 13.7 percent over the previous year, from 2.11 injuries per million man-hours worked in 1955 to 2.40 in 1956. The 10-year average including 1956 was 3.30. Most of the increase occurred in construction work. Total man-hours on construction work were less than in the previous year, but instead of being predominately on comparatively few major projects, where safety programs were well maintained, construction work in 1956 was among a number of small projects where safety precautions are more difficult to enforce. The accident rate in Commission operating activities also increased slightly; among Government employees, there was a slight decrease.

The number of disabling injuries—those that required at least one day's absence from the job—was 527 in 1956 as compared with 476 in 1955, but the days absent for all injuries were fewer—only 359 days were lost per million man-hours worked in 1956 as compared with 410 days the year before. Sixty-eight percent of disabling injuries in 1956 occurred in Commission operating activities, 28 percent in construction, and 5 percent among Government employees. Eight fatal on-the-job accidents occurred during 1956. One resulted from a fall, one from electric shock, two from motor vehicle accidents, and four from explosions.

1956 Industrial Property Damage Record

After years of operating far below comparable national averages for losses to industrial property, the Commission's 1956 losses of $3,147,423, its highest, about equalled national averages. Most of the loss, as in previous years, was due to fires, and particularly to the fire which severely damaged a $14 million gaseous diffusion plant at

Paducah, Ky., and caused $2.1 million of the year's $2.2 million fire total.[39] The Commission's 10-year average fire loss, including 1956, is 60 percent below average loss experience of the best class of industrial risks carried by private industrial insurance companies on an amount of property evaluation equivalent to that maintained by the Commission.

The Commission budgeted during this reporting period $14 million to improve further the fire protection facilities in gaseous diffusion plants. Since 1952, in terms of costs per million dollars of the replacement value of its property, the Commission has saved $25 million over the years by reducing the recurring costs of operating fire departments at its installations. Relative costs have been pushed down steadily over recent years and, for the last 2 years, the rate per million ($616 in 1956) has stood at about one-third the 1952 rate. Absolute costs also have declined despite large increases in property values as plant was expanded. In 1952, the Commission paid out about $5.5 million in recurring costs of operating fire departments; in 1956, for property valued at more than twice the 1952 total, the costs were only $4.2 million. If the 1952 rate of costs had prevailed for 1956 valuations, the costs would have been considerably more than $12 million.

Some savings in 1956 resulted from the reduction in volume of construction actually in progress. Increase in built-in protection in installations, and greater efficiency and economy in the use of manpower have assisted the accomplishment. These savings were accomplished at the same time that general quality of protection was improved.

The principal problems which require solution for improved fire protection involve research and evaluation already under way on fire and explosion risks peculiar to atomic energy operations, such as those involving explosions of thorium, zirconium, and similar metals, which resulted in three of the eight on-the-job fatalities in 1956.

Safety Training

Under a program established during 1956 for training fire and police department instructors in the hazards of the atomic energy industry,[40] eight 3-day courses were given to assist instructors in teaching municipal fire and police officers to cope with emergencies involving radiation. Sixteen additional courses were scheduled.

Presentation of the courses was scheduled in response to requests on the basis of need, with priority given to densely populated in-

[39] See p. 100, Twenty-first Semiannual Report to Congress (July–December 1956).
[40] See p. 101, Twenty-first Semiannual Report to Congress (July–December 1956).

dustrial areas, or to areas where Commission contractors operate plants.

MANPOWER, EARNINGS, LABOR-MANAGEMENT

Manpower Branch Established

A Manpower Branch was established in the Division of Organization and Personnel to improve the analysis and coordination of manpower supply, demand, and utilization with emphases on problems associated with supplies of scientific and engineering manpower.

Of four surveys undertaken by the Commission [41] to determine present and future national requirements for scientists and engineers in atomic energy activities, two studies were completed, those of (*a*) the needs of private industry, and (*b*) the requirements of the Commission and its contractors. Continuing are (*c*) a study of the needs of colleges and universities being conducted by the American Society for Engineering Education, Urbana, Ill., under contract to the Commission, and (*d*) a study of the needs of other Federal agencies by Commission staff.

The results of these separate surveys will be combined in an attempt to summarize national needs. It will provide a basis for planning education and training programs for the expanding atomic energy industry (see Education and Training).

A functional inventory of all Commission Federal employees was completed, to assist in identifying problems of manpower utilization. Functional and activity data will be used in analysis of potential workloads to develop staffing standards and improved controls. A program of functional surveys is planned to assure continuing scrutiny of these problems, with special attention to utilization of scientific and engineering personnel.

Employment

Federal employment of the Commission, totaling 6,647 in May, has remained steady since June 1956. Contractor employment totaled 111,999 in May and comprised 97,089 operating contractor employees and 14,910 construction and design contractor employees.

Employment among operating contractors engaged in research and development activities continued upward and reached 39,873 in May a 17 percent increase since June 1956 chiefly attributable to nuclear propulsion development. Employment in production and service activities was stable at 57,216. Employment of construction and

[41] See pp. 55–56, Twenty-first Semiannual Report to Congress (July–December 1956).

design contractors remained at late 1956 levels. The greatest activity was at Savannah River, Oak Ridge, Hanford, Pittsburgh, Idaho, and Las Vegas facilities.

Earnings and Hours of Atomic Energy Workers

Production and other manual workers of the Commission's operating contractors averaged $2.52 per hour in gross earnings during March. This compared with $2.58 per hour for manual workers in industries handling products of petroleum and coal and $2.39 per hour in inorganic chemical industries, two groups whose processes and equipment are similar to those of the Commission. During the 12-month period preceding March 1957, the rate of increase in earnings for atomic energy employees was 4.1 percent. For the other two industries, percentage increases were 2.4 and 4.8, respectively. During the year, employees of Commission contractors worked an average of 40.8 hours per week, whereas workers averaged 41.1 hours in the petroleum industry and 41.0 in chemicals.

Labor-Management Relations

Production and maintenance employees of Goodyear Atomic Corp., operator of the Commission's Portsmouth, Ohio, plant, were on strike from May 10 to May 16 as a result of a dispute over renewal of a labor agreement between the contractor and Oil, Chemical, and Atomic Workers International Union, AFL–CIO, representing the employees. Although the agreement had expired on April 29, it had been extended from day to day thereafter, subject to cancellation upon 48-hours' notice. Such notice was given on May 8 by the union after its local membership repudiated a tentative settlement negotiated on May 6.

The union declined an offer of assistance made by the Atomic Energy Labor-Management Relations Panel and, thereupon, the President on May 13 appointed a board of inquiry pursuant to the provisions of the national emergency section of the Taft-HartleyAct. The board held hearings in Washington on May 14 and filed its report with the President on May 15, whereupon the President instructed the Attorney General to petition the Federal District Court to enjoin continuation of the strike. This order was issued late in the evening on May 15 and later consented to by stipulation of the parties filed May 23. The union members returned to work on May 16 under the terms of the 80-day injunction called for by the Act. As of the date of this report, the Federal Mediation and Conciliation Service was attempting to bring about a settlement of the dispute between the parties, but no agreement had been reached.

On May 26, the Atomic Energy Labor-Management Relations Panel was requested by Goodyear Atomic Corp. and United Plant Guard Workers of America to intervene in another dispute at the Portsmouth plant. This dispute also arose out of contract renewal negotiations. The single issue involved had to do with the proper classification for guards in the Goodyear wage schedule. The Panel held hearings in Portsmouth on this dispute and issued a recommendation on June 24, which served as a basis for settlement of this dispute.

At Buffalo, N. Y., employees of ACF Industries, Inc., walked out on May 10 as a result of a dispute over a company-sponsored survey of production flow-time. The action of the workers was not authorized and was disavowed by the representative of the employees, United Steelworkers of America, AFL–CIO. The company has declined to discuss the issue until employees return to work. This work stoppage was continuing at the time of this report.

The effect of the strikes at Portsmouth and Buffalo has been to increase the percentage of time lost as a result of work stoppages among Commission operating contractors during the first 5 months of 1957 to 0.2 from 0.1 for a comparable period last year. Time lost as a result of strikes by employees of Commission construction contractors, however, decreased during 1957. During the period from January through May, the percentage of idle to scheduled time in the Commission construction program was 0.3, compared with a 5.3 percent loss in the same period in 1956.

Coverage of Davis-Bacon Act

The Commission is experiencing difficulty in carrying out its responsibilities under the Davis-Bacon Act. This Act requires the payment of minimum wage rates, as predetermined by the Secretary of Labor to be prevailing in an area, on contracts for the construction, alteration or repair of public buildings and public works. It is in the attempt to apply the provisions of the Act to operating plants, principally production operations, that the difficulties are being encountered. The specific problem is distinguishing plant maintenance work, which is not covered by the Act, from construction, alteration or repair work. The Commission has found it necessary to formulate criteria of its own for making such distinctions. In addition, at the larger production installations, special committees have been established to review work to decide whether it is covered.

In practice, a determination that work is subject to the Davis-Bacon Act means that construction wage rates will probably be applied and construction workers who did not previously perform the work may expect to be hired to replace the regular plant maintenance employees

of the contractor who usually are paid at wage rates established in collective bargaining between the contractor and a certified union, as distinguished from Davis-Bacon wage rates determined by the Secretary of Labor. The contractor's regular employees expect to perform required work in the plant at the wage rates they have established in collective bargaining. The decision as to Davis-Bacon coverage obviously takes on the character of a jurisdictional award under these circumstances.

It is apparent from the number of complaints being made by both construction unions and plant unions that the present system is inadequate despite a rather broad recent revision of the criteria used. The Commission is, therefore, conducting an intensive study at all principal operating contractor locations to determine if the Commission can do anything more to improve the situation.

APPENDIX 1

Organization and Principal Staff of U. S. Atomic Energy Commission

Atomic Energy Commission	Lewis L. Strauss, *Chairman.* Willard F. Libby. Thomas E. Murray. Harold S. Vance. (Vacancy.)
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.	David F. Shaw.
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 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 Civilian Application	Harold L. Price.
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 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	T. H. JOHNSON.
Director, Division of Security	JOHN A. WATERS, Jr.

MANAGERS OF OPERATIONS OFFICES AND AREAS:

Albuquerque (N. Mex.) Operations Office.	KENNER F. HERTFORD.
Buffalo (N. Y.) Area	HENRY A. NOWAK.
Burlington (Iowa) Area	E. W. GILES.
Dayton (Miamisburg, Ohio) Area.	JOHN H. ROBERSON.
Kansas City (Mo.) Area	SETH R. WOODRUFF, Jr., *Acting*.
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	J. J. FLAHERTY.
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.
Denver (Colo.) Area	ERNEST E. THURLOW.
Salt Lake (Salt Lake City, Utah) Area.	ARTHUR E. GRANGER.
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	KENNETH A. DUNBAR.
St. Louis (Mo.) Area	FRED H. BELCHER.
San Francisco (Calif.) Operations Office.	HAROLD A. FIDLER.
Southern California (Canoga Park) Area.	A. P. POLLMAN.
Savannah River (Aiken, S. C.) Operations Office.	ROBERT C. BLAIR.
Dana (Terre Haute, Ind.) Area	CHARLES W. REILLY.
Schenectady (N. Y.) Operations Office.	JON D. ANDERSON.

APPENDIX 2

MEMBERSHIP OF COMMITTEES

STATUTORY COMMITTEES

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 nine members of the Senate and nine 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 W. STERLING COLE (New York).
Representative JAMES E. VAN ZANDT (Pennsylvania).
Representative JAMES T. PATTERSON (Connecticut).
Representative THOMAS A. JENKINS (Ohio).
JAMES T. RAMEY, *Executive Director*

Military Liaison Committee

Under Sec. 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. DAVID L. MCDONALD, United States Navy.
Capt. 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 Sec. 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 and 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.
ISAAC HARTER, of Babcock & Wilcox Tube Co., Beaver Falls, Pa.
JOHN V. L. HOGAN, consulting engineer, Hogan Laboratories, Inc., New York, N. Y.
LAWRENCE E. KINGSLAND, Kingsland, Rogers & Ezell, St. Louis, Mo.

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. GIOACCHINO FAILLA, chairman; director, radiological research laboratory, College of Physicians and Surgeons, Columbia University, New York, N. Y.
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. SIMEON T. CANTRIL, director, Tumor Institute of Swedish Hospital, Seattle, Wash.

Dr. EDWIN B. FRED, president, University of Wisconsin, Madison, Wis.

Dr. H. BENTLEY Glass, professor of biology, the Johns Hopkins University, Baltimore, Md.

Dr. HANSON BLATZ, scientific secretary; chief, radiation branch, health and safety laboratory, Atomic Energy Commission, New York, N. Y.

Advisory Board of Contract Appeals

This board was established in February 1950. One or more of its members hears contract appeals arising under the "disputes articles" of 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 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.

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.

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. PAUL C. AEBERSOLD, secretary; assistant director for isotopes and radiations, division of civilian application, Atomic Energy Commission, Washington, D. C.

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.

Advisory Committee on Reactor Safeguards

This committee was formed in 1953 from the former Reactor Safeguard Committee and the Industrial Committee on Reactor Location Problems. The committee reviews safety studies referred to it by the Commission staff and advises the Commission with regard to the hazards of proposed or existing reactor facilities and the adequacy of proposed reactor safety standards.

Dr. C. ROGERS MCCULLOUGH, chairman; deputy director for hazards evaluation, division of civilian application, Atomic Energy Commission, Washington, D. C.

Dr. MANSON BENEDICT, professor of chemical engineering, Massachusetts Institute of Technology, 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. HYMER FRIEDELL, atomic energy research project, Western Reserve University, Cleveland, Ohio.

J. Z. HOLLAND, secretary; office of general manager, Atomic Energy Commission, Washington, D. C.

Dr. I. B. JOHNS, Monsanto Chemical Co., Everett, Mass.

Dr. MARK M. MILLS, radiation laboratory, University of California, Livermore, Calif.

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

D. A. ROGERS, manager, central engineering, Allied Chemical and Dye Corp., Morristown, N. J.

REUEL C. STRATTON, assistant director, department of research, the Travelers Insurance Cos. of Hartford, Conn.

Dr. HARRY WEXLER, director of meteorological research, U. S. Weather Bureau, Department of Commerce, Washington, D. C.

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

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.

CURTISS 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.

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.

Dr. ARTHUR B. WELSH, medical coordinator for civil defense, Department of Health of Pennsylvania, Harrisburg, Pa.

Committee on Raw Materials

This committee was appointed in October 1947 to review the Atomic Energy Commission's raw materials program and to advise on questions of exploration development, and procurement.

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

FRANCIS C. FRARY, technical advisor, 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.

430209—57——12

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. THOMAS B. DREW, head, department of chemical engineering, Columbia University, New York, N. Y.
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.

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. 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, supervisor, analytical work, Knolls Atomic Power Laboratory, Schenectady, N. Y.
CHARLES D. W. THORNTON, assistant to president, Farnsworth Electronics Co., Ft. Wayne, Ind.
Dr. EDWARD WICHERS, chief of chemistry, National Bureau of Standards, Department of Commerce, Washington, D. C.

Metallurgy and Materials Advisory Panel

The 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. EDWARD EPREMIAN, division of research, Atomic Energy Commission, Washington, D. C.

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.

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 1956 to July 1957.

Dr. RICHARD F. TASCHEK, chairman; physics division, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. ERWIN F. SHRADER, vice chairman; division of research, Atomic Energy Commission, Washington, D. C.

Dr. JACOB BENVENISTE, University of California Radiation Laboratory, Livermore, Calif.

Prof. TOM W. BONNER, department of physics, Rice Institute, Houston, Tex.

Dr. JOHN E. EVANS, Phillips Petroleum Co., Idaho Falls, Idaho.

Dr. ERWIN R. GAERTTNER, General Electric Co., Schenectady, N. Y.

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.

Prof. WILLIAM W. HAVENS, Jr. department of physics, Columbia University, New York, N. Y.

Dr. ALEXANDER S. LANGSDORF, physics division, Argonne National Laboratory, Lemont, Ill.

Prof. HENRY W. NEWSON, department of physics, Duke University, Durham, N. C.

Dr. VANCE SAILOR, reactor division, Brookhaven National Laboratory, Upton, Long Island, N. Y.

Dr. IRA F. ZARTMAN, division of reactor development, Atomic Energy Commission, Washington, D. C.

Dr. CARROLL W. ZABEL, secretary; physics division, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

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.

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

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.

Reactor Physics Planning Group

This group is appointed for one year terms to consider the status of development of reactor physics data in relation to the development of reactor concepts. The committee's recommendations have been extremely valuable in charting the future of work in the field of reactor physics.

Dr. ROBERT A. CHARPIE, assistant director, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. E. RICHARD COHEN, group leader, theoretical physics, North American Aviation, Inc., Downey, Calif.

Dr. KARL COHEN, consultant, atomic power equipment dept., General Electric Co., Schenectady, N. Y.

Dr. GERHARD G. DESSAUER, director, physics section, E. I. duPont de Nemours & Co., Inc., Savannah River Plant, Augusta, Ga.

Dr. W. K. ERGEN, physicist, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. PAUL GAST, consulting physicist, engineering department, General Electric Co., Hanford Works, Richland, Wash.

Dr. GERALD GOERTZEL, assistant technical director, Nuclear Development Corp. of America, White Plains, N. Y.

Dr. A. F. HENRY, central physics and mathematics department, Westinghouse Electric Corp., Pittsburgh, Pa.

Dr. HENRY HURWITZ, consulting physicist, Knolls Atomic Power Laboratory, Schenectady, N. Y.

Dr. IRVING KAPLAN, head, reactor physics division, Brookhaven National Laboratory, Upton, Long Island, N. Y.

Dr. SIDNEY KRASIK, manager, central physics and mathematics department, Westinghouse Electric Corp., Pittsburgh, Pa.

JOHN W. MORFITT, manager of nuclear development laboratory, General Electric Co., Cincinnati, Ohio.

Dr. WARREN E. NYER, atomic energy division, Phillips Petroleum Co., Idaho Falls, Idaho.

Dr. HUGH PAXTON, physicist, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. THOMA M. SNYDER, manager, nuclear physics section, Knolls Atomic Power Laboratory, Schenectady, N. Y.

Dr. BERNARD I. SPINRAD, physics section, Argonne National Laboratory, Lemont, Ill.

F. W. THALGOTT, reactor engineering division, Argonne National Laboratory, Lemont, Ill.

Dr. IRA F. ZARTMAN, division of reactor development, Atomic Energy Commission, 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. THOMAS H. JOHNSON, chairman; director, division of research, Atomic Energy Commission, Washington, D. C.

Dr. WILLIAM M. BROBECK, assistant director, University of California Radiation Laboratory, Berkeley, Calif.

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 Agricultural & Mechanic Arts
- Kansas State College
- Loyola University (Chicago, Ill.)
- Marquette University
- Mayo Foundation
- Michigan College of Mining and Technology
- Michigan State University of Agriculture and Applied Science
- Northwestern University
- Ohio State University
- Oklahoma Agricultural and 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

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	Adm. EDWARD L. COCHRANE
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

The participating institutions are:

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

Knolls Atomic Power Laboratory (General Electric Co., contractor), Schenectady, N. Y.

General Manager	F. E. CREVER
Manager, SIR Project	K. A. KASSELRING
Manager, SAR Project	B. H. CALDWELL, Jr.
Manager, Technical Department	F. E. CREVER, Acting
Manager, Auxiliary Operations Department	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

Mound Laboratory (Monsanto Chemical Co., contractor), Miamisburg, Ohio

Project Director	HOWARD K. NASON
Plant Manager	EDWARD C. McCARTHY

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. H. M. PHILLIPS

The sponsoring universities of the Institute are:

Agricultural and Mechanical College of Texas	Vanderbilt University
Alabama Polytechnic Institute	Virginia Polytechnic Institute
Catholic University of America	University of Alabama
Clemson Agricultural College	University of Arkansas
Duke University	University of Florida
Emory University	University of Georgia
Florida State University	University of Kentucky
Georgia Institute of Technology	University of Louisville
Louisiana State University	University of Maryland
Meharry Medical College	University of Miami
Mississippi State College	University of Mississippi
North Carolina State College	University of North Carolina
North Texas State College	University of Oklahoma
Rice Institute	University of Puerto Rico
Southern Methodist University	University of South Carolina
Tulane University of Louisiana	University of Tennessee
Tuskegee Institute	University of Texas
	University of 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	JOHN BREITENSTEIN

Sandia Laboratory (Sandia Corp., contractor), Sandia Base, Albuquerque, N. Mex.

President	JAMES W. MCRAE

University of California at Los Angeles, Atomic Energy Project (University of California, contractor), Los Angeles, Calif.

Director	Dr. STAFFORD WARREN
Project Manager	ROBERT J. BUETTNER

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. SEABO G
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. M. JARVIS

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–Dec. 31, 1956		Jan. 1, 1957–May 31, 1957		Total to May 31, 1957	
	Activity (Curies)	Shipments	Activity (Curies)	Shipments	Activity (Curies)	Shipments
Iodine 131	3,975	33,320	345	1,852	4,320	35,172
Phosphorus 32	1,083	19,410	73	1,079	1,156	20,489
Carbon 14	50	2,658	4	113	54	2,771
Tritium	6,948	451	2,185	59	9,133	510
Strontium 89, 90	416	1,084	12	49	428	1,133
Cobalt 60	190,007	1,429	50,627	136	240,634	1,565
Cesium 137	5,272	763	1,943	61	7,215	824
Iridium 192	10,481	318	2,283	46	12,764	364
Others	965	17,649	427	1,918	1,392	19,597
Irradiated Units[2]		13,316		676		13,992
Total	219,197	90,398	57,899	6,019	277,096	96,417
Shipments to AEC Installations		10,623		589		11,212

[1] Domestic shipments from Oak Ridge National Laboratory.
[2] Includes irradiated units of Iodine 131 and Phosphorus 32.

LOCATION AND TYPE OF NEW USERS

(Jan. 1, 1957–May 31, 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			2
Alabama	3	1	1				5
Arizona							
Arkansas			2				2
California	19	1	15	2			37
Colorado	2		5				7
Connecticut	1		6		1		8
Delaware			2				2
District of Columbia	1			3			4
Florida	8	1	1				10
Georgia	1		1				2
Hawaii							
Idaho	1						1
Illinois	9	2	9	6		1	27
Indiana	7	1	3	1			12
Iowa	3						3
Kansas							
Kentucky	2		1			1	4
Louisiana	2		1				3
Maine			1	1			2
Maryland	2		3				5
Massachusetts	2		6	1		1	10
Michigan	8		1	1	1		11
Minnesota	5		4			1	10
Mississippi							
Missouri	3	1	4	6			14
Montana		1					1
Nebraska	1						1
Nevada	1			1			2
New Hampshire			1				1
New Jersey	4		6				10
New Mexico	1		1				2
New York	29	1	9	3	1		43
North Carolina	4	1	2	1			8
North Dakota	1						1
Ohio	11		3	1			15
Oklahoma	3	1	4				8
Oregon	3						3
Panama							
Pennsylvania	7	2	6	10	1		26

LOCATION AND TYPE OF NEW USERS—Continued

(Jan. 1, 1957–May 31, 1957)

States and Territories	Medical Institutes and Physicians	Colleges and Universities	Industrial Firms	Federal and State Laboratories	Foundations and Institutes	Other	Total
Puerto Rico		1					1
Rhode Island			3	2			5
South Carolina	1			1		1	3
South Dakota	3						3
Tennessee	3		1			3	7
Texas	8		10				18
Utah	2	1	2				5
Vermont							
Virginia	2		2	1		2	7
Washington	2		2	1			5
West Virginia	3						3
Wisconsin	14				2		16
Wyoming	1						1
Total	184	15	118	43	6	10	376

LOCATION AND TYPE OF ALL USERS

(Aug. 2, 1946–May 31, 1957)

Alaska	2	1		2			5
Alabama	15	4	20	4	2		45
Arizona	10	1	3	2			16
Arkansas	14	1	10	1			26
California	202	18	166	48	11	7	452
Colorado	34	3	17	4	2	3	63
Connecticut	18	5	58	4	2		87
Delaware	2	1	12	2	1		18
District of Columbia	16	3	6	20			46
Florida	39	7	9	5		2	62
Georgia	18	5	13	9			45
Hawaii	6	1	1	3	2		13
Idaho	6	1	5				12
Illinois	103	16	110	21	5	3	258
Indiana	36	5	36	1		1	79
Iowa	24	5	9				38
Kansas	24	4	7				35
Kentucky	13	3	14	3	1	3	37
Louisiana	23	5	19	3		1	51
Maine	5	3	18	2		1	29
Maryland	23	5	28	17		2	75
Massachusetts	47	17	106	13	3	4	190
Michigan	60	8	44	4	2	1	119
Minnesota	27	9	16	1		1	54
Mississippi	6	3	8	3			20
Missouri	57	6	18	9		1	91
Montana	9	2		1			13
Nebraska	15	3	1	3			22
Nevada	6		3	2			11
New Hampshire	3	2	4	2			11
New Jersey	51	4	122	7	6	1	191
New Mexico	11	3	5	3			22
New York	247	30	188	31	11	7	514
North Carolina	25	7	16	8		1	57
North Dakota	9	2		1			12
Ohio	93	9	111	11	3	2	229
Oklahoma	28	2	31	1	3		65
Oregon	17	3	5	5		1	31
Panama	1			1			2
Pennsylvania	81	14	137	22	5	1	260
Puerto Rico	7	2		2			11
Rhode Island	6	2	16	3			27
South Carolina	6	3	5	3		1	18
South Dakota	11	2					13
Tennessee	32	5	15	6		5	63
Texas	103	7	101	8	4	1	224
Utah	10	4	7	2			23
Vermont	4	1	2				7
Virginia	20	4	24	9		2	59
Washington	22	6	15	8			51
West Virginia	22	2	8	2			34
Wisconsin	44	3	41	4	4		96
Wyoming	4	1	1	1	1	1	9
Total	1,717	263	1,611	327	69	54	4,041

SHIPMENTS OF RADIOACTIVE ISOTOPES TO FOREIGN COUNTRIES

Country	Jan. 1, 1957–May 31, 1957	Total Jan. 1947 to May 31, 1957	Country	Jan. 1, 1957–May 31, 1957	Total Jan. 1947 to May 31, 1957
Argentina	0	126	Israel	17	32
Australia	2	114	Italy	17	68
Austria	2	4	Japan	56	573
Belgian Congo	0	3	Korea	1	1
Belgium	16	193	Lebanon	0	7
Bermuda	0	16	Mexico	44	253
Bolivia [1]	0	0	Netherlands	16	98
Brazil	46	543	New Zealand	2	15
British West Africa	3	4	Nicaragua [1]	0	0
Canada	181	1,554	Norway	7	73
Chile	4	160	Pakistan	0	10
Colombia	9	47	Paraguay [1]	0	0
Costa Rica	0	2	Peru	16	85
Cuba	38	500	Philippines	17	27
Denmark	7	246	Portugal	0	12
Dominican Republic	0	1	Republic of China	1	3
Egypt	1	3	Russia	1	1
El Salvador	0	1	Spain	2	17
England	14	194	Sweden	15	263
Federal Republic of Germany	23	74	Switzerland	4	89
Finland	4	25	Syria	0	2
France	34	187	Thailand	7	9
Gold Coast	0	1	Trieste	0	4
Greece	6	7	Turkey	0	5
Guatemala	1	37	Union of South Africa	1	38
Honduras	1	2	Uruguay	1	12
Iceland	0	5	Venezuela	63	144
India	11	52	Yugoslavia	2	4
Indonesia	2	5			
Iran	5	6	Total	705	5,963
Ireland [1]	0	0			

[1] Authorized to receive isotopes; no shipments made.

Kind of Isotope	Jan. 1, 1957–May 31, 1957	Total Jan. 1947 to May 31, 1957	Kind of Isotope	Jan. 1, 1957–May 31, 1957	Total Jan. 1947 to May 31, 1957
Phosphorus 32	40	1,073	Strontium 89, 90	18	169
Iodine 131	257	2,124	Calcium 45	14	151
Carbon 14	59	457	Other	181	1,184
Sulfur 35	9	151			
Iron 55, 59	44	268	Total	705	5,963
Cobalt 60	83	386			

APPENDIX 5

COMMISSION-OWNED PATENTS

PATENTS ISSUED TO THE COMMISSION WHICH ARE AVAILABLE FOR LICENSING[1]

The following 118 U. S. Letters Patents owned by the United States Government as represented by the Atomic Energy Commission are in addition to the 111 patents listed in the 21st Semiannual report. The patents listed have been made available for licensing at periodic intervals. Licenses are granted on a non-exclusive, royalty-free basis.

PATENT NO.	TITLE	PATENTEE
2,552,032	The Separation of Phosphorous	A. H. Booth, Ontario, Canada.
2,610,303	Coincidence Circuit	R. E. Bell, Ontario, Canada.
2,617,526	Apparatus for Sorting Radioactive Ore	C. M. LaPointe, Port Radium, Northwest Territories, Canada.
2,621,110	Recovery of Radioactive Phosphorous from Neutron Irradiated Sulfur.	J. G. MacHutchin and L. C. Watson, Ontario, Canada.
2,639,974	Method of Separating Uranium from Its Ores	A. H. A. Ross, R. H. Farmer, and A. G. W. Lamont, Ontario, Canada.
2,665,970	Precipitation of Vanadium Oxides	J. Halpern and F. A. Forward, British Columbia, Canada.
2,673,294	Discriminator Circuit	W. J. Battell, Ontario, Canada, N. F. Moody London, England.
2,677,773	Electroscope	H. Carmichael and P. G. Salmon, Ontario, Canada.
2,683,806	Discriminator Circuit	N. F. Moody, London, England.
2,691,100	Electronic Counter	N. F. Moody, London, England, and W. D. Howell, Ontario, Canada.
2,698,383	Electronic Counter	N. F. Moody, London, England
2,727,806	Precipitation of Uranium from Alkali Metal Carbonate Solutions.	F. A. Forward and J. Halpern, British Columbia, Canada.
2,738,253	Uranium Separation Process	A. Thunaes, E. A. Brown, H. W. Smith and J. Brannen, Ontario, Canada.
2,774,730	Neutronic Reactor Having a Flattened Activity Curve.	G. J. Young, Chicago, Ill.
2,774,937	Method of Measuring Q	M. H. Dazey, Palos Verdes Estates, Calif.
2,775,399	Mercury Bellows Pump	E. S. Robinson, A. C. Briesmeister, and B. B. McInteer Los Alamos, New Mex.
2,775,552	Continuous Electrolytic Process for Reducing Uranium in Solution.	R. Q. Boyer, Berkeley, Calif.
2,775,696	Millivolt Gating Circuit	R. E. Thomas, Walnut Creek, Calif.
2,775,697	Crystal Diode Coincidence Circuit	R. Madey, Berkeley, Calif.
2,775,698	Multichannel Pulse Analyzer	P. R. Bell and G. G. Kelley, Oak Ridge Tenn., and C. G. Goss, Glenview, Ill.
2,775,741	Phase Shifting Device	P. I. Corbell, Palo Alto, Calif.
2,776,184	Processes for Recovering and Purifying Uranium.	M. D. Kamen, Berkeley, Calif.
2,776,185	Method of Concentrating Fissionable Material.	L. B. Werner and B. A. Fries, Richland, Wash., and G. T. Seaborg, Chicago, Ill.
2,776,189	Nitric Acid Recovery and Purification	F. W. Winn, San Gabriel, Calif.
2,776,263	Corrosion Inhibitors for Deuterium Exchange Process.	C. F. Hiskey, Brooklyn, N. Y., and D. T. Vier, Santa Fe, N. Mex.
2,776,368	Coaxial Tube Coupling	H. M. Owren & V. L. Smith, Livermore and D. R. Branum, Alameda, Calif.
2,776,377	In Vivo Radiation Scanner	H. O. Anger, Berkeley, Calif.
2,777,809	Preparation of Uranium	M. Kolodney, New York, N. Y.
2,777,812	Leak Detection System	R. W. Powell, Sayville, N. Y., and P. H. Lee, Belle Haven, Va.
2,778,730	Plutonium Alloy and Method of Separating It from Plutonium.	F. H. Spedding and T. A. Butler, Ames, Iowa.
2,778,792	Method for Unloading Reactors	L. Szilard, Chicago, Ill.
2,778,843	Uranium Chelates of Di (Salicylal) Alkylenediimine and Process for Their Preparation.	H. D. Brown, Plainfield, N. J., and F. J. Wolter, Cleveland, Ohio.
2,778,937	Cyclotron Square Wave RF System	G. B. Rossi, Berkeley, Calif.
2,778,949	Electrostatic Pulse Analyzer System	C. J. Borkowski and F. M. Porter, Oak Ridge, Tenn.
2,779,657	Recovery of Uranium from Wash Liquids	A. E. Ballard, Oak Ridge, Tenn.
2,779,728	Control Device for a Neutronic Reactor	W. H. Zinn and T. Brill, Chicago, Ill.

[1] Patents listed as of May 28, 1956. 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.

PATENTS ISSUED TO THE COMMISSION WHICH ARE AVAILABLE FOR LICENSING—Continued

PATENT No.	TITLE	PATENTEE
2,779,875	Galvanometer Pulse Analyzer System	C. J. Borkowski and F. M. Porter, Oak Ridge, Tenn.
2,779,876	Radioactivity-Distribution Detector	C. A. Tobias, Walnut Creek, and H. O. Anger, Berkeley, Calif.
2,780,099	Vacuum Gauge	G. A. Kuipers, Oak Ridge, Tenn.
2,780,112	Two Roller Anti-Friction Latch	J. N. Young, Chicago, Ill.
2,780,455	Combination of Acceleration Sensing and Integrating Means.	H. F. Devaney, Albuquerque, N. Mex.
2,780,514	Method of Recovering Uranium from Aqueous Solutions.	G. A. Lutz, Columbus, Ohio.
2,780,515	Method for Improved Precipitation of Uranium Peroxide.	A. J. Miller, Oak Ridge, Tenn.; B. M. Pitt, Evanston, and F. Grieger, Urbana, Ill.
2,780,516	Chemical Purification of Uranium Compounds.	J. C. Nevenzel, Pasadena, Calif.
2,780,517	Separation of Uranium from Foreign Substances.	B. J. Fontana, Berkeley, Calif.
2,780,518	Process for Recovery of Uranium from Aqueous Solutions.	J. W. Gates, Jr., Rochester, N. Y., and L. J. Andrews, Davis, Calif.
2,780,519	Recovery of Uranium from Ores	D. Kaufman, Cambridge, and S. E. Bailey, Brookline, Mass.
2,780,532	Uranium Separation Process	R. M. Hainer, Revere, Mass., and E. C. Evers, Philadelphia, Pa.
2,780,589	Still Column with Concentric Condenser	A. K. Brewer, Washington, D. C., and T. I. Taylor, New York, N. Y.
2,780,595	Test Exponential Pile	E. Fermi, Chicago, Ill. (deceased).
2,780,596	Neutronic Reactor	G. A. Anderson, Chicago Heights, Ill.
2,781,303	Process of Recovering Uranium from Solution.	R. Q. Boyer, Berkeley, Calif., and S. B. Kilner, Knoxville, Tenn.
2,781,304	Electrodeposition of Uranium	H. A. Wilhelm and D. H. Ahmann, Ames, Iowa.
2,781,307	Apparatus for the Measurement of Neutron Absorption.	E. P. Wigner, Oak Ridge, Tenn.
2,781,308	Neutronic Reactor Control	E. C. Creutz, Santa Fe, N. Mex., and W. H. Zinn, Chicago, Ill.
2,781,309	Radiation System	J. S. Levinger, Berwyn, Pa., M. B. Sampson, Santa Fe, N. Mex., A. H. Snell, Oak Ridge, Tenn., and R. G. Wilkinson, Santa Fe, N. Mex.
2,781,448	Gating Circuit	W. C. Struven, Berkeley, Calif.
2,781,452	Ion Beam Receiver	E. J. Lofgren, Berkeley, Calif., and F. Fairbrother, Jr., Livermore, Calif.
2,782,081	Pump Cylinder Assembly	J. Entwistle, Long Island City, N. Y.
2,782,091	Uranium Recovery Process	J. J. Brunner, Weston, Mass.
2,782,092	Recovery of Metal Salts from Mixtures	D. X. Klein, Wilmington, Del., and W. V. Wirth, Woodstown, N. J.
2,782,116	Method of Preparing Metals	F. H. Spedding and H. A. Wilhelm, Ames, Iowa, and W. H. Keller, St. Louis, Mo.
2,782,117	Method of Reclaiming Uranium	H. A. Wilhelm, Ames, Iowa, and C. F. Gray, Baton Rouge, La.
2,782,158	Neutronic Reactor	J. A. Wheeler, Richland, Wash.
2,782,475	Apparatus for Vacuum	H. W. Wilhelm and C. F. Gray, Ames, Iowa.
2,782,941	Follow-Up Mechanism	H. V. Lichtenberger, Idaho Falls, Idaho, and L. J. Koch, Clarendon Hills, Ill.
2,782,993	Automatic Control System with Remote Adjustment.	W. H. Appleton and G. M. Farly, Berkeley, Calif.
2,783,320	Pressure Switch	A. F. Fink, Albuquerque, N. Mex.
2,783,376	High Speed Positive Pulse Generator	W. A. Hane, Seattle, Wash.
2,783,433	Regulated Power Supply	W. R. Baker, Berkeley, Calif.
2,784,054	Separation of Uranium from Other Metals by Hydriding and Extraction with Oxidizing.	J. H. Carter, Harrisonburg, Va., and T. A. Butler, Ames, Iowa.
2,784,084	Zirconium Ternary Alloys	L. L. Marsh, Jr., and W. Chubb, Columbus, Ohio.
2,784,799	Gas Recovery System	J. Ise, Jr., and G. P. Millburn, Concord, Calif.
2,784,910	Pulse Height Analyzer	A. Ghiorso, A. E. Larsh, Jr., Berkeley, Calif.
2,785,046	Separation of Uranium from Other Metals by Hydriding.	T. A. Butler, Ames, Iowa.
2,785,047	Method of Separating Plutonium from Contaminants.	H. S. Brown, Chicago, Ill., and O. F. Hill, Richland, Wash.
2,785,064	Method of Forming Crucibles and Reaction Chambers for Production of Uranium of High Purity.	H. A. Wilhelm, Ames, Iowa.
2,785,065	Method of Producing Metals from Their Halides.	F. H. Spedding, H. A. Wilhelm, and W. H. Keller, Ames, Iowa.
2,785,311	Low Voltage Ion Source	E. O. Lawrence, Berkeley, Calif.

PATENTS ISSUED TO THE COMMISSION WHICH ARE AVAILABLE FOR LICENSING—Continued

PATENT NO.	TITLE	PATENTEE
2,785,951	Bismuth Phosphate Process for the Separation of Plutonium from Aqueous Solutions.	S. G. Thompson and G. T. Seaborg, Chicago, Ill.
2,785,972	Preparation of Uranium Metal	C. H. Prescott, Jr. (deceased) and J. A. Holmes, Berkeley, Calif.
2,786,143	Source Unit for Producing Ionized Gas	L. Ruby, Berkeley, R. B. Crawford, Walnut Creek, and W. G. Pon, Oakland, Calif.
2,786,832	Preparation of Flavonoid Glucosides	S. H. Wender, Norman, Okla., and D. W. Fox, Schenectady, N. Y.
2,787,526	Method of Isotope Concentration	J. S. Spevack, New York, N. Y.
2,787,527	Method for Recovering Boron Values	M. Kilpatrick, Philadelphia, Pa.
2,787,529	Method for Determining Boron Fluoride Ether Complex in a Composition.	W. A. Winsten, Forest Hills, and I. Kirshenbaum, New York, N. Y.
2,787,536	Process for Melting and Refining Uranium	F. H. Spedding and H. A. Wilhelm, Ames, Iowa.
2,787,537	Method of Producing Metal	H. A. Wilhelm, Ames, Iowa.
2,787,538	Production of Uranium	F. H. Spedding, H. A. Wilhelm and W. H. Keller, Ames, Iowa.
2,787,587	Isotope Exchange Process	R. W. Woodward, Oak Ridge, Tenn.
2,787,593	Method and Means of Producing Steam in Neutronic Reactors.	H. E. Metcalf, Los Angeles County, Calif.
2,787,737	Electromagnet Regulator	K. G. Macleish, Rochester, N. Y.
2,788,656	Means for Investigating Gases	H. H. Sander, Albuquerque, N. Mex.
2,789,072	Heat Treated Uranium Alloy and Method of Preparing Same.	D. W. White, Jr., Burnt Hills, N. Y.
2,789,221	Method and Apparatus for Nuclear Particle Acceleration.	C. A. Tobias, Walnut Creek, Calif.
2,789,222	Frequency Modulation System	M. D. Martin and W. W. Salsig, Berkeley, and K. R. MacKenzie, Pacific Palisades, Calif.
2,789,229	Ion Producing Mechanism	E. O. Lawrence, Berkeley, Calif.
2,789,688	Sample Holder	W. J. Stinson, Ballston Spa, N. Y.
2,789,878	Protactinium Extraction Process	D. F. Peppard, Oak Park, Ill.
2,789,879	Recovery of Uranium from Phosphoric Acid	D. Kaufman, Cambridge, Mass.
2,789,884	Method of Preparing Pure Boric Oxide	C. J. Rodden, New Brunswick, and A. R. Eberle, S. Plainfield, N. J.
2,789,897	Magnesium Reduction Process for Production of Uranium.	C. B. Sawyer and B. R. F. Kjellgren, Cleveland, Ohio.
2,790,086	Radiation Detecting and Measuring System	H. G. Beyer, Forest Hills, and W. J. Stinson, Skaneateles Falls, N. Y.
2,790,701	Process of Recovering Uranium	M. D. Kamen, Berkeley, Calif.
2,790,760	Neutronic Reactor	R. W. Powell, Sayville, N. Y.
2,790,761	Neutronic Reactor	L. A. Ohlinger, Los Angeles, Calif.
2,790,902	Ion Accelerator Beam Extractor	B. T. Wright, Los Angeles, Calif.
2,790,919	Ionization Chamber for Fission Counting	J. H. Lykins, M. J. Bartkus, and H. A. Kermicle, Oak Ridge, Tenn.
2,790,931	Electrostatic Memory System	R. W. Schumann, St. Paul, Minn.
2,790,949	Thermionic Ionization Vacuum Gauge	O. H. Ottinger and R. R. Feezell, Oak Ridge, Tenn.
2,791,119	Liquid Level Indicator	W. H. Zinn, Chicago, and J. M. Harrer, Elmhurst, Ill.
2,791,371	Radio Frequency Ion Pump	J. S. Foster, Jr., and F. Fairbrother, Jr., Livermore, Calif.
2,791,372	Pump	A. A. Abbatiello, Teaneck, N. J.
2,792,412	Recovery of Ruthenium from Aqueous Solutions.	H. R. Schmidt and R. L. Moore, Richland, Wash.
2,792,535	Timing Circuit	W. C. Struven, Berkeley, Calif.
2,792,634	Tolerance Inspection Gage	J. T. Howe, Oak Ridge, Tenn., F. Kerze, Jr., Washington, D. C.
2,793,309	Neutron Proportional Counter	J. A. Simpson, Jr., Chicago, Ill.
2,793,753	Removal of Material from Processing Tanks	D. S. Webster, Richland, Wash.

APPENDIX 6

Publications of the U. S. Atomic Energy Commission

Listed here are a number of special publications sponsored by the Atomic Energy Commission. In addition, the Commission encourages project scientists to submit nonclassified articles for publication in the established scientific and technical journals. Hundreds of reports, not published elsewhere, may be obtained from the Office of Technical Services, Department of Commerce, Washington 25, D. C. Lists of titles and prices of these reports are available from the Office of Technical Services. Essentially complete collections of the Commission's nonclassified reports are available in a number of libraries (see pages 183–185). Guides to the published and report literature may be found in Nuclear Science Abstracts (see page 180).

SEMIANNUAL REPORTS TO CONGRESS

The Commission's semiannual reports to Congress on the progress of the Commission's program are published and made available to the public by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. An alternate title, indicating the principal subject of the report, has been given to each of the later reports. Indexes to the semiannual reports are also available from the Superintendent of Documents.

First Semiannual Report, January 1947.

Second Semiannual Report, July 1947.

Third Semiannual Report, January 1948.

Fourth Semiannual Report, *Recent Scientific and Technical Developments in the Atomic Energy Program of the United States,* July 1948. 35 cents.

Fifth Semiannual Report, *Atomic Energy Development, 1947–1948,* January 1949. 45 cents.

Sixth Semiannual Report, *Atomic Energy and the Life Sciences,* July 1949. 45 cents.

Seventh Semiannual Report, *Atomic Energy and the Physical Sciences,* January 1950. 50 cents.

Eighth Semiannual Report, *Control of Radiation Hazards in the Atomic Energy Program,* July 1950. 50 cents.

Ninth Semiannual Report, *AEC Contract Policy and Operations,* January 1951. 40 cents.

Tenth Semiannual Report, *Major Activities in the Atomic Energy Programs, January–June 1951,* July 1951. 35 cents.

Eleventh Semiannual Report, *Some Applications of Atomic Energy in Plant Science,* January 1952. 50 cents.

Twelfth Semiannual Report, *Major Activities in the Atomic Energy Programs, January–June 1952,* July 1952. 35 cents.

Thirteenth Semiannual Report, *Assuring Public Safety in Continental Weapons Tests,* January 1953. 50 cents.

Fourteenth Semiannual Report, *Major Activities in the Atomic Energy Programs, January–June 1953,* July 1953. 30 cents.

Fifteenth Semiannual Report, *Major Activities in the Atomic Energy Programs, July–December 1953*, January 1954. 45 cents.

Sixteenth Semiannual Report, *Major Activities in the Atomic Energy Programs, January–June 1954*, July 1954. 45 cents.

Seventeenth Semiannual Report, *Major Activities in the Atomic Energy Programs, July–December 1954*, January 1955. 45 cents.

Eighteenth Semiannual Report, *Major Activities in the Atomic Energy Programs, January–June, 1955*, July 1955. 50 cents.

Nineteenth Semiannual Report, *Major Activities in the Atomic Energy Programs, July–December, 1955*, January 1956. 60 cents.

Twentieth Semiannual Report, *Major Activities in the Atomic Energy Programs, January–June 1956*, July 1956. $1.25.

Twenty-first Semiannual Report, *Radiation Safety and Major Activities in the Atomic Energy Programs, July–December 1956*, January 1957. $1.25.

Cumulative Index to the First Fifteen Semiannual Reports to Congress, January 1947–December 1953. 35 cents.

Cumulative Index to the Sixteenth Through the Twentieth Semiannual Reports to Congress, January 1954–June 1956. 30 cents.

Index to the Twenty-first Semiannual Report to Congress, July–December 1956. 15 cents.

GENERAL PUBLICATIONS

The following is a list of semitechnical and nontechnical publications of interest to the general reader.

Selected Readings on Atomic Energy. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, November 1955. 53 pages. 25 cents. A bibliography of official publications, books, magazines, pamphlets and teaching units for educators, and indexes and bibliographies on atomic energy.

Prospecting for Uranium. U. S. Atomic Energy Commission and U. S. Geological Survey. Revised October 1951. Washington, U. S. Government Printing Office, 1951. 128 pages. 55 cents. A nontechnical booklet describing the uranium-bearing minerals, where to look for them, and instruments to use in prospecting and in laboratory testing and analysis of ores. It contains six color plates of principal minerals. Laws, regulations, and price schedules for uranium-bearing ores are included.

Prospecting With a Counter. Robert J. Wright. U. S. Atomic Energy Commission. Revised July 1954. Washington, U. S. Government Printing Office, 1954. 68 pages. 30 cents. A summary of information on field counters, their operation, use, abuse, and their application to prospecting, mining and geologic problems.

Selling to AEC. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1955. 27 pages. This publication provides certain basic information helpful to those who want to do business with the Commission or its contractors. It indicates who does the buying, what is bought, where procurement offices are located, and other general information.

A Guide for Contracting of Construction and Related Engineering Services. U. S. Atomic Energy Commission. Revised January 1955. Washington, U. S. Government Printing Office, 1955. 16 pages. 15 cents. This booklet gives the Commission's policy on awarding contracts for construction and architect-

engineering services, procedures followed when requests for bids are formally advertised and when contracts are negotiated. Operations offices and officials responsible for letting such contracts are listed.

Atoms for the World. Laura Fermi. Chicago, University of Chicago Press, 1957. 227 pages. $3.75. An intimate and informative account, by the historian for the United States delegation, of United States participation in the International Conference on the Peaceful Uses of Atomic Energy, which was held in 1955 at Geneva, Switzerland.

TECHNICAL PUBLICATIONS

The items listed below, together with the National Nuclear Energy Series described in the next section, are publications of scientific and technical interest.

Books

Principles of Nuclear Reactor Engineering. Samuel Glasstone. New York, D. Van Nostrand Co., 1955. 861 pages. $7.95. A text written for the student and the practicing engineer. An overall review of the fundamental scientific principles upon which reactor engineering is based.

The Elements of Nuclear Reactor Theory. Samuel Glasstone and Milton C. Edlund. New York, D. Van Nostrand Co., 1952. 416 pages. $4.80. This is an introduction to nuclear reactor theory intended for the use of scientists, engineers, and advanced students interested in the field of nuclear reactors. It explains the physical concepts and processes involved in a nuclear chain reaction and the methods for calculating critical conditions for chain reacting systems.

Sourcebook on Atomic Energy. Samuel Glasstone. New York, D. Van Nostrand Co., 1950. 546 pages. $3.75. This presents a comprehensive, technical description of the theory, history, development, and uses of atomic energy. Chapters are included on the structure of the atom, radioactivity, isotopes, neutron research, acceleration of charged particles, and other phases of nuclear science. (2d Edition in Press.)

Energy in the Future. Palmer Cosslett Putnam. New York, D. Van Nostrand Co., 1953. 556 pages. $12.75. This book presents a study of the problem of where we can find sources of low-cost energy in an abundance equal to the maximum plausible demands by the expanding and industralizing populations of the future, and what is the maximum plausible role that nuclear fuels may be called on to play in the next 50 to 100 years.

The Metal Beryllium. Edited by D. W. White and J. E. Burke. Cleveland, American Society for Metals, 1955. 703 pages. $8.00. Presents basic information on the element beryllium, and covers all aspects of beryllium technology for the use of workers in the field, with emphasis on the possible uses of beryllium in atomic energy work.

Manuals, Handbooks and Reports

Isotopes—an 8-Year Summary of Distribution. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1955. 357 pages. $2.00. A detailed account of isotope utilization during the first 8 years of the Commission's distribution program. It is also a supplement of the 3-year and 5-year

reports of similar title issued by the Commission in 1949 and 1951. This report is a useful reference to the uses of isotopes and a bibliography of published articles on isotope work.

Introduction to the Theory of Neutron Diffusion. Vol. 1. K. M. Case, F. de Hoffmann, and G. Placzek. Numerical work by B. Carlson and M. Goldstein. Washington, U. S. Government Printing Office, 1954. 174 pages. $1.25. A monograph intended for purposes of research in physics and mathematics as well as teaching on the graduate level. This monograph, presenting work sponsored by the Los Alamos Scientific Laboratory, gives a detailed discussion of the general equations of one-velocity neutron diffusion theory and of their solution for the special case of a homogeneous infinite medium with isotropic scattering. Emphasis is placed on fairly complete tables and graphs.

Nuclear Power Reactor Technology. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1953. 88 pages. 25 cents. This publication contains reports to the U. S. Atomic Energy Commission by four separate teams of industrial representatives appraising the prospect for possible nuclear power development. Studies were made to determine the engineering feasibility for designing, constructing and operating dual-purpose reactors to produce fissionable material and power, and to recommend industry's role in designing, building, and operating such reactors.

Nuclear Power Reactors. Vol. 2. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, March 1955 (submitted October 1953). 30 pages. 15 cents. This publication contains reports to the U. S. Atomic Energy Commission of two teams of industrial representatives. Appraises the practicability of building a nuclear reactor for the generation of central-station power. The study group undertook to determine whether any of the known reactor systems can be shown to be technically and economically feasible, and competitive for central-station power. Studies were made on the projected possibilities of different reactor systems.

Handbook on Aerosols. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1950. 147 pages. 70 cents. Contains chapters from the National Defense Research Committee Summary Technical Report, Division 10, declassified by the Army at the request of the Commission, on the properties and behavior of aerosols, principles and instruments used in meteorology studies, and information useful in studies of the disposal of gaseous radioactive wastes, the dispersal of insecticides, the disposal of industrial gases, etc.

Handbook on Air Cleaning—Particulate Removal. Sheldon K. Friedlander, Leslie Silverman, Philip Drinker, and Melvin W. First. Harvard University and U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, September 1952. 89 pages. 45 cents. A compilation of data resulting from the study of air cleaning equipment and procedures. Such studies applied principally to the removal of radioactive dust and contamination from exhaust gases, etc.

Liquid Metals Handbook (NAVEXOS-P-733, Rev.). Richard N. Lyon, Editor-in-Chief. Sponsored by the Committee on Basic Properties of Liquid Metals, Officer of Naval Research, Department of the Navy, in cooperation with the Atomic Energy Commission and the Bureau of Ships, Department of the Navy. Second edition (Revised). Washington, Government Printing Office, 1954. 269 pages. $1.25. This volume summarizes current information on the physical

and chemical properties of liquid metals, their present industrial uses, and their use and potentialities as heat-transfer media.

Liquid Metals Handbook; Sodium (NaK) Supplement (TID–5277). Carey B. Jackson, Editor-in-Chief. Sponsored by the Atomic Energy Commission and the Bureau of Ships, Department of the Navy. Washington, U. S. Government Printing Office, 1955. 445 pages. $2.00. This volume, which supplements the *Liquid Metals Handbook* above, presents a significant amount of experimental data and analysis of thermal shock and thermal stresses, convective flow and mass transfer, mainly applicable to Sodium and NaK.

Meteorology and Atomic Energy (AECU–3066). Prepared by U. S. Department of Commerce, Weather Bureau, for U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1955. 169 pages. $1.00. This volume summarizes some of the meteorological techniques that are available and describe their application to problems of atmospheric pollution that might arise in connection with the operation of atomic energy installations.

Handling Radioactive Wastes in the Atomic Energy Program. U. S. Atomic Energy Commission. Revised August 1951. Washington, U. S. Government Printing Office, 1951. 30 pages. 15 cents. Discusses the sources and types of radioactive wastes in atomic energy operations, methods developed for their safe handling and disposal, and methods specified for the safe handling of radioisotopes by private users.

Neutron Cross Sections (BNL–325). Donald J. Hughes, John A. Harvey, et al. Brookhaven National Laboratory. Washington, U. S. Government Printing Office, 1955. 328 pages. $3.50. This is a second edition of a compilation of data in tabular and graphic form prepared by the Atomic Energy Commission Neutron Cross Section Advisory Group originally issued as report AECU–2040. Cross section values for nuclides, elements, and compounds are given for neutrons ranging in energy from 0.0001 electron volts to 100 Mev.

Neutron Cross Sections, Supplement 1. Brookhaven National Laboratory. Washington, U. S. Government Printing Office, 1957. 129 pages. $1.75. This brings *Neutron Cross Sections* (BNL–325) up to date. All data available up to October 1, 1956, have been considered, as well as fission data available up to November 15, 1956. In addition, all of the material presented in the addendum to BNL–325 has been included.

Reactor Handbook: Vol. I (AECD–3645)—Physics; Vol. II (AECD–3646)—Engineering; Vol. III (AECD–3647)—Materials. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1955. Vol. I, 304 pages. $4.25; Vol. II, 1,088 pages. $5.50; Vol. III, 614 pages. $3.50. These volumes provide a condensed and reliable source of nuclear reactor data. Contents: Vol. I—Reactor physics and radiation shielding; Vol. 2—Light- and heavy-water cooled systems, liquid-metal cooled systems, gas-cooled systems, aqueous fuel systems, liquid-metal fuel systems, fused salt systems, handling and control, and reactor designs; Vol. 3—General properties of materials.

High Voltage Problems (TID–5211). J. D. Trimmer and Harry Pearlman. U. S. Atomic Energy Commission, 1951. 226 pages. $1.85. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) This report presents an account of work done in connection with the high voltage systems used in the electromagnetic separation process. Sparking and insulator breakdowns are treated in detail.

Vacuum Problems and Techniques (TID–5210). C. E. Normand, Frank A. Knox, G. W. Monk, et al. U. S. Atomic Energy Commission, 1950. 265 pages. $1.75. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) This report describes and evaluates the original vacuum equipment required in the operation of the electromagnetic separation process. It presents significant improvements in efficiency resulting from changes in operating techniques, and brings together information widely spread throughout the literature.

Research Reactors; Selected Reference Material (TID–5275). U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1955. 442 pages. $2.00. This volume presents detailed descriptions of six types of research reactors developed in the national atomic energy program; selected design drawings of reactors, components, and supporting facilities are included. The document was prepared to present the details of the U. S. program to delegates attending the International Conference on the Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1955.

Chemical Processing and Equipment; Selected Reference Material (AECD–5276). U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1955. 302 pages. $2.00. Describes the chemical and engineering aspects of processing materials associated with nuclear reactors. It includes descriptions of radio-chemical laboratories, remote control handling equipment. Like *Research Reactors* described above, this volume was prepared for the benefit of delegates to the International Conference.

Radioisotopes in Medicine (ORO–125). Edited by Gould A. Andrews, Marshall Brucer, and Elizabeth B. Anderson. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1953. 817 pages. $5.50. This is the published proceedings of the second advanced training course given by the Oak Ridge Institute of Nuclear Studies. The course was concerned with specialized medical application emphasizing more direct clinical uses of radioisotopes. Chapters include tumor localization, diagnostic and therapeutic uses of radioiodine, therapy with radioactive colloids and other phases of medical utilization of radioisotopes.

Reactor Shielding Design Manual (TID–7004). Edited by Theodore Rockwell III. U. S. Atomic Energy Commission, 1956. 466 pages. $2.10. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Describes the procedures and data which are used in the design, construction and testing of shielding for the reactor plants of the naval reactors program and for the Shippingport pressurized water reactor.

Nuclear Level Schemes (TID–5300). K. Way, R. W. King, C. L. McGinnis, R. van Lieshout. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1955. 240 pages. $1.75. A ready reference source of nuclear information consisting of a collection of diagrams showing positions and properties of nuclear energy levels, characteristics of radioactive decay and nuclear reactions, together with a tabular compilation of the experimental data and bibliographic references to the original paper.

The Chemistry and Metallurgy of Miscellaneous Materials (TID–5212). Edited by Laurence L. Quill. U. S. Atomic Energy Commission, 1955. 172 pages. $1.00. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Consists of individual papers dealing with miscellaneous chemical, metallurgical and structural subjects.

Determination of the Isotopic Composition of Uranium (TID–5213). Edited by A. E. Cameron. U. S. Atomic Energy Commission, 1950. 166 pages. $1.52. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Presents some of the solutions to problems encountered in the adaptation of known methods and principals to the routine determination of the isotopic composition of uranium.

Electrical Equipment for Tanks and Magnets (TID–5214). Edited by C. R. Baldock and E. D. Hudson. U. S. Atomic Energy Commission, 1947. 401 pages. $2.65. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Presents an account of the electrical engineering phases of the electromagnetic separation process as they related to electrical equipment used in the separation of isotopes.

Magnets and Magnetic Measuring Techniques (TID–5215). Edited by R. K. Wakerling and A. Guthrie. U. S. Atomic Energy Commission, 1949. 213 pages. $1.45. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) A report of the successful adaptation of the mass spectrographic method of separating uranium isotopes to an electromagnetic separation plant, with emphasis upon magnets and associated measuring techniques.

Electrical Circuits for Calutrons (TID–5216). Edited by R. K. Wakerling and A. Guthrie. U. S. Atomic Energy Commission, 1949. 280 pages. $1.85. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) A report of the successful adaptation of the mass spectrographic method of separating uranium isotopes to an electromagnetic separation plant, with emphasis upon electrical circuiting.

Electromagnetic Separation of Isotopes in Commercial Quantities (TID–5217). Edited by R. K. Wakerling and A. Guthrie. U. S. Atomic Energy Commission, 1949. 434 pages. $2.65. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) A report of the successful adaptation of the mass spectrographic method of separating uranium isotopes to an electromagnetic separation plant, and describes the production of isotopes by the electromagnetic separation process in commercial quantities.

Sources and Collectors for Use in Calutrons (TID–5217). Edited by R. K. Wakerling and A. Guthrie. U. S. Atomic Energy Commission, 1949. 273 pages. $1.85. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) A report of the successful adaptation of the mass spectrographic method of separating uranium isotopes to an electromagnetic separation plant, and describes the sources and collectors for use in calutrons.

Problems of Physics in the Ion Source (TID–5219). Edited by Arthur H. Barnes, S. M. MacNeille, and Chauncey Starr. U. S. Atomic Energy Commission, 1951. 294 pages. $1.50. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Presents the fundamental processes involved in the operation of calutron source units, and describes the experiments that enabled the investigators to determine these processes.

Reactor Shielding Design Manual (TID–7004). Edited by Theodore Rockwell, III. U. S. Atomic Energy Commission, 1956. 466 pages. $2.10. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Describes the procedures and data which are used in the design,

construction and testing of shielding for the reactor plants of the naval reactors program and for the Shippingport pressurized water reactor.

Some Effects of Ionizing Radiation on Human Beings; A Report on the Marshallese and Americans Accidentally Exposed to Radiation from Fallout and a Discussion of Radiation Injury in the Human Being (TID–5358). Edited by Drs. E. P. Cronkite, V. P. Bond, and C. L. Dunham. U. S. Atomic Energy Commission, 1956. 106 pages. $1.25. (Available from Office of Technical services, U. S. Department of Commerce, Washington 25, D. C.) Presents an authoritative treatise on the observed effects of the accidental deposition of radioactive materials on inhabited islands and Task Force ships following the detonation of a thermonuclear devise at the Pacific Proving Ground on March 1, 1954.

A Conference on Radioactive Isotopes in Agriculture (TID–7512). U. S. Atomic Energy Commission, 1957. 416 pages. $3.00. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Comprises a collection of papers presented at the January 1956 Conference on Radioactive Isotopes in Agriculture held at the Michigan State University and treats such major topics as waste disposal in agricultural research installations, radiobiological studies, new techniques in tracer use, ionizing radiation in food preservation and lactation.

Trilinear Chart of Nuclides, Second Edition (completely revised and updated). W. H. Sullivan. U. S. Atomic Energy Commission, January 1957. $2.00. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Especially designed for convenient classroom and desk reference use. It presents systematics and physical constants data for all experimentally identified nuclides known from information available as of July 1956.

The Effects of Nuclear Weapons. Edited by Dr. Samuel Glasstone. Washington, U. S. Government Printing Office, $2.00. A publication prepared by the Armed Forces Special Weapons Project of the Department of Defense at the request of the Atomic Energy Commission. It updates information appearing in *The Effects of Atomic Weapons*, 1950, and provides the latest knowledge of weapons effects obtained by observation and experiment in laboratory work and nuclear test detonations since 1950. It also includes data on radiological, blast and heat effects of nuclear detonations. Requirements of the Federal Civil Defense Administration for information necessary for civil defense planning are taken into account. The publication was issued July 12, 1957.

Atomic Energy Facts (TID–7010). Washington, U. S. Government Printing Office, 1957. A handbook of the Commission's and atomic energy activities. Chapters include production of uranium and thorium, power reactors, fuel cycles, reactor materials, research reactors and radioisotopes. The organization and functions of the Atomic Energy Commission are described. A chapter, Government and Atomic Energy, covers technical information services; the access permit program; materials, services, and facilities and licenses available from the Commission; Government atomic energy patents available for licensing; and doing business abroad. Illustrated with photographs, flow diagrams, etc.

The Experimental Boiling Water Reactor (TID–7012). Washington, U. S. Government Printing Office, 1957. A detailed engineering description of this

experimental atomic power plant written by the designers at the Argonne National Laboratory.

Neutron and Gamma Irradiation Facilities (TID–7009). Compiled by John H. Martens and F. G. Minuth. Washington, U. S. Government Printing Office, 1957. A compact reference on high level nuclear irradiation facilities in the United States. Forty facilities, currently operative or scheduled to become operative soon, are described, along with information on the services provided and how to obtain them.

Hot Laboratory Equipment. Compiled by Brookhaven National Laboratory. Washington, U. S. Government Printing Office, 1957. A descriptive, illustrated catalog of enclosures for radioactive operations, manipulators, viewing and optical equipment, chemical equipment, physical-measurement equipment, materials-handling equipment, decontamination and monitoring instruments, shielding devices, and machine tools.

Periodicals and Catalogs

Nuclear Science Abstracts, issued twice a month by the Commission's Technical Information Service, contains abstracts of all-current Commission declassified and unclassified reports, of non-Commission reports related to atomic energy, and of articles appearing in both of foreign and domestic periodical literature. $7.50 per year. ($9.50 per year foreign.) [1]

Isotopes—Catalog and Price List, Oak Ridge National Laboratory, Oak Ridge, Tenn., July 1952, lists and describes radioactive and stable isotopes available from ORNL and includes prices and instructions for ordering the isotopes. $1 per copy.

THE NATIONAL NUCLEAR ENERGY SERIES

These volumes were written by the scientists who performed the research and development on the atomic energy enterprise under the Manhattan Engineer District and later under the Atomic Energy Commission. The following volumes have been published for the Commission project by the McGraw-Hill Book Co., New York, N. Y.

Division I: The Electromagnetic Separation Process

Vacuum Equipment and Techniques, vol. 1, edited by A. Guthrie and R. K. Wakerling, 1949. Describes the development and study of high vacuum equipment and high vacuum systems for the large-scale separation of isotopes by the electromagnetic process. 264 pages. $3.75.

The Characteristics of Electrical Discharges in Magnetic Fields, vol. 5, edited by A. Guthrie and R. K. Wakerling, 1949. Covers most of the significant studies by the University of California Radiation Laboratory on electrical discharges with emphasis on studies of electrical discharges in vapors of uranium compounds. 376 pages. $5.00.

Division II: Gaseous Diffusion Project

Engineering Developments in the Gaseous Diffusion Process, vol. 16, edited by M. Benedict and C. Williams, 1949. Describes a number of mechanical, electrical, and chemical engineering developments related to the operation and handling of materials used in the gaseous diffusion process—principally special plant instruments, vacuum engineering, development of heat-transfer equipment, and absorption of uranium hexafluoride and fluorine. 129 pages. $2.00.

[1] Available from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Division III: Special Separations Project

The Theory of Isotope Separation, vol. 1B. Karl Cohen, 1951. Presents the theory of cascades as generally applicable to the problems of isotope separation. Different types of centrifuges and other methods of separation are also discussed. 165 pages. $2.50.

Spectroscopic Properties of Uranium Compounds, vol. 2, edited by G. H. Dieke and A. B. F. Duncan, 1949. Presents data compiled from a comprehensive study of the absorption and fluorescence spectra of uranium compounds and describes the experimental techniques used in the studies. 290 pages. $4.25.

Physical Properties and Analysis of Heavy Water, vol. 4A. I. Kirschenbaum, 1951. Describes the physical properties of heavy water, chemical equilibria or exchange reactions and methods of isotopic analysis. 438 pages. $6.00.

Bibliography of Research on Heavy Hydrogen Compounds, vol. 4C, compiled by A. H. Kimball, edited by H. C. Urey, and I. Kirschenbaum, 1949. Contains about 2,000 references to published literature on research with heavy hydrogen. References are arranged by subject with an index of the hydrogen compounds and authors. 350 pages. $4.75.

Production of Heavy Water, vol. 4F, edited by G. M. Murphy. Is being compiled from works of other authors. It will present laboratory pilot-plant studies for various separation processes investigated and engineering surveys of actual production plants with descriptions of their operations. 394 pages. $5.25.

Division IV: Plutonium Project

Optical Instrumentation, vol. 8, edited by G. S. Monk and W. H. McCorkle, 1954. Contains useful and practical techniques and methods of optical instrumentations in nuclear research. It is a summary of the optics work carried out as part of the plutonium project. 262 pages. $3.75.

Radiochemical Studies: The Fission Products, vol. 9, edited by C. D. Coryell and N. Sugarman, 1951. Presents 336 original research papers on the techniques and results of radiochemical studies of uranium and plutonium fission products. 2,086 pages (in 3 parts). $27.75.

The Actinide Elements, vol. 14A, edited by G. T. Seaborg and J. J. Katz, 1954. Is a companion volume to vol. 14B, Division IV, NNES, *The Transuranium Elements*, published in 1949, and summarizes available information on the elements in the actinide series. Also included is an Index for the *Transuranium Elements*. 870 pages. $11.75.

The Transuranium Elements, Research Papers, vol. 14B, edited by G. T. Seaborg, J. J. Katz, and W. M. Manning, 1949. Includes 163 research papers on neptunium, plutonium, americium, curium, and several of the heavy elements related to them, and historical summaries of transuranium element research. 1,733 pages (in 2 parts). $23.75.

The Chemistry and Metallurgy of Miscellaneous Materials; Thermodynamics, vol. 19B, edited by L. L. Quill, 1949. Contains 10 research papers on the thermodynamic properties of the elements and several of their compounds. 329-pages. $4.50.

Industrial Medicine on the Plutonium Project, vol. 20, edited by R. S. Stone, 1951. Describes the medical program established for the care and protection of workers on the plutonium project. 511 pages. $7.

Biological Effects of External X- and Gamma Radiation, part I, vol. 22B, edited by R. E. Zirkle, 1954. Deals with radiological research and investigations performed at the National Cancer Institute of the effects of continuous X- and gamma irradiation on life span, weight, blood picture, and breeding behavior of small laboratory mammals. 530 pages, $7.25.

Biological Effects of External Beta Radiation, vol. 22E, edited by R. E. Zirkle. Offers a collection of original reports on the effects of beta rays applied to the surface of the mammalian body. 242 pages. $3.50.

Histopathology of Irradiation from External and Internal Sources, vol. 22I, edited by W. Bloom, 1948. Is an advanced treatise on the histopathological and cytological effects of total-body irradiation. 808 pages. $10.75.

Toxicology of Uranium, vol. 23, edited by A. Tannenbaum, 1950. Describes the studies made on the distribution, accumulation, excretion, and chemical and physiological effects of uranium and uranium compounds in the animal body. 323 pages. $4.75.

Division V: Los Alamos Project

Electronics: Experimental Techniques, vol. 1, edited by W. C. Elmore and M. L. Sands, 1948. Describes a number of complete circuits and circuit elements developed at Los Alamos for making nuclear and other physical measurements. 417 pages. $5.50.

Ionization Chambers and Counters: Experimental Techniques, vol. 2, edited by B. Rossi and H. Staub, 1949. Describes the physical principles of ionization chambers and counters, and includes previously unpublished project developments by scientists at the Los Alamos Laboratory. 243 pages. $3.25.

Miscellaneous Physical and Chemical Techniques of the Los Alamos Project, vol. 3, edited by A. C. Graves and D. K. Froman. Describes a variety of laboratory techniques used at Los Alamos in early studies. Drawings and diagrams of the laboratory and apparatus are given. 323 pages. $4.25.

Division VI: University of Rochester Project

Pharmacology and Toxicology of Uranium Compounds, vol. 1, edited by C. Voegtlin and H. C. Hodge. Parts I and II, published in 1949, summarize the results of 3 years research on the toxicity of various uranium compounds and the mechanism of uranium poisoning. 1,084 pages (in 2 parts). $14.25.
Parts III and IV, published in 1953, continue from Parts I and II, with results of long-term studies, mainly on the chronic inhalation toxicity of uranium compounds. Major problems considered are bone deposition of uranium and carbohydrate metabolism. Bibliography, index. 1,381 additional pages (in 2 parts). $18.00.

Biological Effects of External Radiation, vol. 2, edited by Henry A. Blair, 1954. Reports the studies made during the war period at the University of Rochester on the biological effects of X-radiation along with a collaborative study of the chronic effects of neutron irradiation made with the Biochemical Foundation, Newark, Del. Included in the volume are the effects of single doses of whole-body X-radiation, chronic X-radiation, and fractionated doses of fast neutrons. 508 pages. $7.00.

Biological Studies with Polonium, Radium, and Plutonium, vol. 3, edited by R. M. Fink, 1949. Describes the studies made of the biological effects of these alpha-emitting elements in the animal body, air monitoring precautions, and equip-

ment used in atomic energy laboratories where work with these elements is carried on. 411 pages. $5.50.

Division VII: Materials Procurement Project

Preparation, Properties, and Technology of Fluorine and Organic Fluoro Compounds, vol. 1, edited by C. Slesser and S. R. Schram. Describes development in the large-scale manufacture of fluorine, and purifying and handling fluorine. It describes the preparation and the chemical and physical properties of various fluorocarbon compounds. 868 pages. $11.50.

The Metallurgy of Zirconium, vol. 4, edited by B. Lustman and F. Kerze, 1955. Comprises contributions by participants in the Navy-AEC program on the development of zirconium for reactor applications. 780 pages. $10.00.

Division VIII: Manhattan Project Chemistry

Analytical Chemistry of the Manhattan Project, vol. 1, edited by C. J. Rodden, 1950. Describes methods of analyzing the many different materials used in the atomic energy project—with emphasis on analytical methods for the determination of uranium and thorium. 748 pages. $10.00.

Chemistry of Uranium. Part I. The Element, Its Binary and Related Compounds, vol. 5, by J. J. Katz and E. Rabinowitch, 1951. Is a detailed discussion of the physical and chemical properties of uranium, its occurrence in nature and extraction from ores, and preparation and physical properties of its binary compounds, 609 pages, $8.25.

Medical Effects of the Atomic Bomb in Japan, edited by Ashley W. Oughterson and Shields Warren. Is based upon the 6-volume report of the *Joint Commission for the Investigation of the Effects of the Atomic Bomb in Japan*. It presents a great mass of unique and authoritative information of importance to national defense, and is a valuable contribution to fundamental medical knowledge.

DEPOSITORY LIBRARIES

In order to make the nonclassified results of Commission research and development available to the public, the following libraries serve as depositories for essentially all the Commission's nonclassified reports. A number of other university and public libraries also receive copies of the reports that are sold by the Office of Technical Services.

ALABAMA
- Auburn, Alabama Polytechnic Institute.
- Birmingham, Birmingham Public Library.

ARKANSAS
- Fayetteville, University of Arkansas.

CALIFORNIA
- Berkeley, University of California General Library.
- Los Angeles, University of California Library.
- Menlo Park, Stanford Research Institute.
- San Diego, San Diego Public Library.

COLORADO
- Denver, Denver Public Library.

CONNECTICUT
- New Haven, Yale University Library.

DISTRICT OF COLUMBIA
- Washington, Library of Congress.

FLORIDA
- Coral Gables, University of Miami Library.
- Gainesville, University of Florida Library.

GEORGIA
- Atlanta, Georgia Institute of Technology Library.

ILLINOIS
- Chicago, John Crerar Library.
- Chicago, University of Chicago Library.
- Evanston, Northwestern University Library.
- Urbana, University of Illinois Library.

INDIANA
- Lafayette, Purdue University Library.
- Indianapolis, Indianapolis Public Library.

IOWA
- Ames, Iowa State College Library.

KANSAS
- Manhattan, Kansas State College Library.

KENTUCKY
- Lexington, University of Kentucky Library.
- Louisville, University of Louisville Library.

LOUISIANA
- Baton Rouge, Louisiana State University Library.
- New Orleans, Tulane University Library.

MARYLAND
- Baltimore, The Johns Hopkins University Library.
- College Park, University of Maryland Library.

MASSACHUSETTS
- Cambridge, Harvard University Library.
- Cambridge, Massachusetts Institute of Technology Library.

MICHIGAN
- Ann Arbor, University of Michigan Library.
- Detroit, Detroit Public Library.

MINNESOTA
- Minneapolis, University of Minnesota Library.

MISSOURI
- Kansas City, Linda Hall Library.
- Rolla, University of Missouri School of Mines and Metallurgy Library.
- St. Louis, Washington University Library.

NEW JERSEY
- Princeton, Princeton University Library.

NEW MEXICO
- Albuquerque, University of New Mexico Library.

NEW YORK
- Buffalo, University of Buffalo, Lockwood Memorial Library.
- Ithaca, Cornell University Library.
- New York, Atomic Industrial Forum.
- New York, Columbia University Library.
- New York, New York Public Library.
- Troy, Rensselaer Polytechnic Institute Library.
- Rochester, University of Rochester Library.
- Schenectady, Union College Library.

NORTH CAROLINA
- Charlotte, Charlotte and Mecklenburg County Public Library.
- Durham, Duke University Library.
- Raleigh, North Carolina State College Library.

OHIO
- Cincinnati, University of Cincinnati Library.
- Cleveland, Cleveland Public Library.
- Columbus, Ohio State University Library.
- Toledo, University of Toledo Library.
- Youngstown, Youngstown Public Library.

OKLAHOMA
- Stillwater, Oklahoma Agricultural and Mechanical College Library.

OREGON
- Corvallis, Oregon State College Library.
- Portland, Portland Public Library.

PENNSYLVANIA
- Philadelphia, University of Pennsylvania Library.
- Pittsburgh, Carnegie Library of Pittsburgh.
- University Park, Pennsylvania State University, Pattee Library.

PUERTO RICO
- Rio Piedras, University of Puerto Rico Main Library.

RHODE ISLAND
- Providence, Brown University.

SOUTH CAROLINA
- Columbia, University of South Carolina, McKissick Memorial Library.

TENNESSEE
- Knoxville, University of Tennessee Library.
- Memphis, Cossett Memorial Library.
- Nashville, Joint University Libraries.

TEXAS
- Austin, University of Texas Library.
- College Station, Agricultural and Mechanical College of Texas Library.
- Dallas, Southern Methodist University.
- Houston, Rice Institute.
- San Antonio, San Antonio Public Library.

UTAH
- Salt Lake City, University of Utah Library.

VIRGINIA
- Blacksburg, Virginia Polytechnic Institute.
- Charlottesville, University of Virginia, Alderman Library.

WASHINGTON
- Pullman, State College of Washington Library.
- Seattle, University of Washington Library.

WISCONSIN
- Madison, University of Wisconsin Library.
- Milwaukee, Milwaukee Public Library.

INDUSTRIAL DEPOSITORIES

To provide industry with specialized industrial information materials and to facilitate inspection of such materials, the Commission has set up special depositories at the Atomic Industrial Forum, Inc., in New York City, at the John Crerar Library in Chicago, in the Stanford Research Institute, Stanford, Calif., and at the Georgia Institute of Technology Library, Atlanta, Ga. Industrial depository collections are comprised of a complete collection of unclassified "basic science" reports which have been found to contain technological developments of special value to American industry not directly connected with the U. S. Atomic Energy Program. Abstracts of these reports were published in a series of special bibliographies entitled, "Selected AEC Reports of Interest to Industry," which is also available at the depositories. A modest program for making unclassified engineering drawings available for inspection at industrial depositories has also been initiated.

CLASSIFIED DEPOSITORIES

The Commission established a series of depository libraries where the access permit holders participating in the Civilian Applications Program can consult classified reports made available to them. These depositories have been located at the Massachusetts Institute of Technology for the Boston area; at the Argonne National Laboratory for the Chicago area; at the National Reactor Testing Station, Idaho Falls, Idaho; at the New York Operations Office, New York City; at the Reference Center, Technical Information Service, Oak Ridge, Tenn.; at the Stanford Research Institute, Palo Alto, Calif.; and at the Atomic Energy Commission Headquarters, Washington, D. C.

APPENDIX 7

Regulations of the U. S. Atomic Energy Commission [1]

Part 20—Standards for Protection Against Radiation

In July 1955 the Commission issued for public comment a proposed regulation to establish general standards for protection of licensees, their employees, and the public against radiation hazards arising out of the possession or use of special nuclear, source, or byproduct material under license issued by AEC. In preparing the effective regulation published below, the Commission has had the benefit of numerous comments and suggestions received since publication of the proposed rules. A number of changes suggested by those comments have been incorporated in the following regulation.

The regulation establishes standards which must be followed in handling radioactive materials which are subject to the licensing authority of the Commission and provides procedures whereby deviations from such standards may be authorized on a case-to-case basis. The regulation prescribes limits which govern exposure of personnel to radiation and concentrations of radioactive material, concentrations of radioactive material which may be discharged into air and water, and disposal of radioactive wastes. It also establishes certain precautionary procedures and administrative controls.

The standards established by this regulation will be found to agree substantially with those published by the National Committee on Radiation Protection in N. B. S. Handbook 52 "Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water," and N. B. S. Handbook 59 "Permissible Dose from External Sources of Ionizing Radiation." The National Committee on Radiation Protection has under review recommendations to limit cumulative exposures over periods of years. The Commission is giving consideration to appropriate amendments to its regulations to deal with this cumulative exposure problem.

Limitations upon levels of radiation and concentrations of radioactive material in areas affected by but not controlled by the licensee are contained principally in § 20.102 ("Permissible Levels of Radiation in Unrestricted Areas"), § 20.103 ("Concentrations in Effluents to Unrestricted Areas"), and the sections on waste disposal. The sections are designed to assure that individuals in "unrestricted areas" do not receive exposure in excess of 10 percent of the limits established for persons exposed in restricted areas. For this purpose, the sections limit levels of radiation and concentrations of radioactive material which may be created in unrestricted areas by licensees, without special authorization from the AEC, to extremely low levels. These levels are believed to be sufficiently low to assure that there is no reasonable probability of individuals in unrestricted areas receiving exposures in excess of 10 percent of the permissible levels for restricted areas. Procedures are incorporated in those sections, however, under which the Commission may authorize licensees in specific cases to create higher levels in unrestricted areas where the circumstances of the particular case are such as to provide reasonable assurance that

[1] Policies and regulations of the U. S. Atomic Energy Commission announced prior to July 1957 can be found in the Federal Register and in the following semiannual reports: Fifth, Sixth, Ninth through the Seventeenth, Nineteenth, Twentieth and Twenty-first.

individuals in the unrestricted areas will not receive exposures in excess of 10 percent of the limitation established for restricted areas.

It is believed that the standards incorporated in these regulations provide, in accordance with present knowledge, a very substantial margin of safety for exposed individuals. It is believed also that the standards are practical from the standpoint of licensees. It should be emphasized that the standards are subject to change with the development of new knowledge, with significant increase in the average exposure of the whole population to radiation, and with further experience in the administration of the Commission's regulatory program.

Pursuant to the Administrative Procedures Act, Public Law 404, 79th Congress, 2d Session, the following rules are published as a document subject to codification to be effective 30 days after publication in the FEDERAL REGISTER.

GENERAL PROVISIONS

PERMISSIBLE DOSES, LEVELS, AND CONCENTRATIONS

PRECAUTIONARY PROCEDURES

WASTE DISPOSAL

RECORDS, REPORTS, AND NOTIFICATION

EXCEPTIONS AND ADDITIONAL REQUIREMENTS

ENFORCEMENT

AUTHORITY: §§ 20.1 to 20.601 issued under sec. 161 (b), 68 Stat. 948, 42 U. S. C. 2201.

GENERAL PROVISIONS

§ 20.1 *Purpose.* (a) The regulations in this part establish standards for protection against radiation hazards arising out of activities under licenses issued by the Atomic Energy Commission and are issued pursuant to the Atomic Energy Act of 1954 (68 Stat. 919).

(b) The use of radioactive material or other sources of radiation not licensed by the Commission is not subject to the regulations in this part. However, it is the purpose of the regulations in this part to control the possession, use, and transfer of licensed material by any licensee in such a manner that exposure to such material and to radiation from such material, when added to exposures to unlicensed radioactive material and to other unlicensed sources of radiation in the possession of the licensee, and to radiation therefrom, does not exceed the standards of radiation protection prescribed in the regulations in this part.

§ 20.2 *Scope.* The regulations in this part apply to all persons who receive, possess, use or transfer byproduct material, source material, or special nuclear material under a general or specific license issued by the Commission pursuant to the regulations in Part 30, 40, or 70 of this chapter.

§ 20.3 *Definitions.* (a) As used in this part:

(1) "Act" means the Atomic Energy Act of 1954 (68 Stat. 919) including any amendments thereto;

(2) "Airborne radioactive material" means any radioactive material dispersed in the air in the form of dusts, fumes, mists, vapors, or gases;

(3) "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;

(4) "Commission" means the Atomic Energy Commission or its duly authorized representatives;

(5) "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;

(6) "Individual" means any human being;

(7) "Licensed material" means source material, special nuclear material, or byproduct material received, possessed, used, or transferred under a general or specific license issued by the Commission pursuant to the regulations in this chapter;

(8) "License" means a license issued under the regulations in Part 30, 40, or 70 of this chapter. "Licensee" means the holder of such license;

(9) "Person" means (i) any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, Government agency other than the Commission, any State, any foreign government or nation or any political subdivision of any such government or nations, or other entity; and (ii) any legal successor, representative, agent, or agency of the foregoing;

(10) "Radiation" means any or all of the following: alpha rays, beta rays, gamma rays, X-rays, neutrons, high-speed electrons, high-speed protons, and other atomic particles; but not sound or radio waves, or visible, infrared, or ultraviolet light;

(11) "Radioactive material" includes any such material whether or not subject to licensing control by the Commission;

(12) "Restricted area" means any area access to which is controlled by the licensee. "Restricted area" shall not include any areas used as residential quarters, although a separate room or rooms in a residential building may be set apart as a restricted area;

(13) "Source material" means any material except special nuclear material, which contains by weight one-twentieth of one percent (0.05 percent or more of (i) uranium, (ii) thorium, or (iii) any combination thereof;

(14) "Special nuclear material" means (i) plutonium, uranium 233, uranium enriched in the isotope 233 or in the isotope 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 (ii) any material artificially enriched by any of the foregoing but does not include source material;

(15) "Unrestricted area" means any area entry into which is not controlled by the licensee, and any area used for residential quarters.

(b) Definitions of certain other words and phrases as used in this part are set forth in other sections, including:

(1) "Airborne radioactivity area" defined in § 20.203;

(2) "Radiation area" and "high radiation area" defined in § 20.202;

(3) "Personnel monitoring equipment" defined in § 20.202;

(4) "Survey" defined in § 20.201;

(5) Units of measurement of dose (rad, rem) defined in § 20.4;

(6) Units of measurement of radioactivity defined in § 20.5.

§ 20.4 *Units of radiation dose.* (a) "Dose," as used in this part, is the quantity of radiation absorbed, per unit of

mass, by the body or by any portion of the body. When the regulations in this part specify a dose during a period of time, the dose means the total quantity of radiation absorbed, per unit of mass, by the body or by any portion of the body during such period of time. Several different units of dose are in current use. Definitions of units as used in this part are set forth in paragraphs (b) and (c) of this section.

(b) The rad, as used in this part, is a measure of the dose of any ionizing radiation to body tissues in terms of the energy absorbed per unit mass of the tissue. One rad is the dose corresponding to the absorption of 100 ergs per gram of tissue. (One millirad (mrad) = 0.001 rad.)

(c) The rem, as used in this part, is a measure of the dose of any ionizing radiation to body tissue in terms of its estimated biological effect relative to a dose of one roentgen (r) of X-rays. (One millirem (mrem) = 0.001 rem.) The relation of the rem to other dose units depends upon the biological effect under consideration and upon the conditions of irradiation. For the purpose of the regulations in this part, any of the following is considered to be equivalent to a dose of one rem:

(1) A dose of 1 r due to X— or gamma radiation;

(2) A dose of 1 rad due to X—, gamma, or beta radiation;

(3) A dose of 0.1 rad due to neutrons or high energy protons;

(4) A dose of 0.05 rad due to particles heavier than protons and with sufficient energy to reach the lens of the eye;

If it is more convenient to measure the neutron flux, or equivalent, than to determine the neutron dose in rads, as provided in subparagraph (3) of this paragraph, one rem of neutron radiation may, for purposes of the regulations in this part, be assumed to be equivalent to 14 million neutrons per square centimeter incident upon the body; or, if there exists sufficient information to estimate with reasonable accuracy the approximate distribution in energy of the neutrons, the incident number of neutrons per square centimeter equivalent to one rem may be estimated from the following table:

430209—57——14

§ 20.5 *Units of radioactivity.* (a) Radioactivity is commonly, and for purposes of the regulations in this part shall be, measured in terms of disintegrations per unit time or in curies. One curie (c) = 3.7×10^{10} disintegrations per second (dps) = 2.2×10^{12} disintegrations per minute (dpm). A commonly used submultiple of the curie is the microcurie (μc). One $\mu c = 0.000001$ $c = 3.7\times10^{4}$ dps $= 2.2\times10^{6}$ dpm.

Neutron energy	Number of neutrons per square centimeter equivalent to a dose of 1 rem
Thermal	960×10^{6}
0.0001 mev	480×10^{6}
0.01 mev	480×10^{6}
0.1 mev	96×10^{6}
0.5 mev	38×10^{6}
1 mev	29×10^{6}
2 mev	19×10^{6}
3 mev. and higher	14×10^{6}

NOTE: Many radioisotopes disintegrate into isotopes which are also radioactive. In expressing maximum permissible concentrations in air and water of these materials as in Appendix B of this part, the activity stated is that of the parent isotope. In some cases, the fact that daughter products may contribute to the total dose has been taken into account in the determination of the maximum permissible concentration of the parent isotopes. In the tables of Appendix B of this part this is indicated by writing $Ba^{140}+La^{140}$, $Sr^{90}+Y^{90}$, Rn^{222}+dr, Ra^{226}+½ dr, etc.

EXAMPLE. In Column 1, Table I, Appendix B the maximum permissible concentration of Ba^{140} in air for occupational use is $2+10^{-7}\mu c$/ml. This is the maximum permissible concentration regardless of whether or not any of the La^{140} which may have resulted from the decay of the Ba^{140} is present or not. However, the value given for Ba^{140} is less than it would be if La^{140} were a stable isotope, not only because of the possibility of La^{140} in the air but principally because, if the Ba^{140} is inhaled, its radioactive decay in the body will result in the production of La^{140} in the body.

(b) *Radon.* Airborne radioactivity of radon and its decay products may be de-

termined by measurement of the activity of one or more decay products on dust filtered from the air. For purposes of the regulations in this part, the limit prescribed here will be considered to be met if the measured radioactivity of one or more decay products (for example, RaC′) does not exceed that which would result from the occurrence, at the time of sampling, of 1×10^{-7} microcuries, per milliliter of air, of Rn^{222} and each of its short-lived decay products, RaA, RaB, RaC, and RaC′. For this purpose, due allowance shall be made for changes in the radioactivity of the measured decay products from time of sampling through the period of measurement.

(c) *Natural uranium and natural thorium.* Natural uranium and natural thorium occur as mixtures of isotopes of the respective elements. In the case of uranium or of thorium, the number of microcuries shall be determined by dividing the total rate, in dpm, of alpha emissions from the mixture by 2.2×10^{6} dpm per μ c.

§ 20.6 *Interpretations.* Except as specifically authorized by the Commission in writing, no interpretation 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.

§ 20.7 *Communications.* All communications and reports concerning the regulations in this part, and applications filed under them, should be addressed to the Atomic Energy Commission, 1901 Constitution Avenue, NW., Washington 25, D. C., Attention: Division of Civilian Application.

PERMISSIBLE DOSES, LEVELS, AND CONCENTRATIONS

§ 20.101 *Exposure of individuals in restricted areas*—(a) *Exposure to radiation.* (1) Except as provided in subparagraph (2) of this paragraph, no licensee shall possess, use, or transfer licensed material in such a manner as to cause any individual in a restricted area to receive in any period of seven consecutive days from radioactive material and other sources of radiation in the licensee's possession a dose in excess of the limits specified in Appendix A of this part.

(2) A licensee may permit an individual in a restricted area to receive a dose in excess of the limits established in subparagraph (1) of this paragraph: *Provided,* (i) That the dose during any period of 7 consecutive days does not exceed three times the limits specified in Appendix A of this part, and (ii) that the dose during any period of 13 consecutive weeks does not exceed 10 times the limits specified in Appendix A of this part.

(b) No licensee shall possess, use or transfer licensed material in such a manner as to cause any individual in a restricted area to be exposed to airborne radioactive material possessed by the licensee in an average concentration in excess of the limits specified in Appendix B, Table I, of this part.

The limits given in Appendix B, Table I of this part, are based upon exposure to the concentrations specified for forty hours in any period of seven consecutive days. In any such period where the number of hours of exposure is less than forty, the limits specified in the table may be increased proportionately. In any such period, where the number of hours of exposure is greater than forty, the limits specified in the table shall be decreased proportionately.

(c) *Exposure of minors.* No licensee shall possess, use, or transfer licensed material in such a manner as to cause any individual under 18 years of age within a restricted area to receive in any period of seven consecutive days from radioactive material and other sources of radiation in the licensee's possession a dose in excess of 10 percent of the limits specified in Appendix A of this part, or to be exposed to airborne radioactive material possessed by the licensee in a concentration in excess of the limits specified in Appendix B, Table II, of this part. For purposes of this paragraph, concentrations may be

averaged over periods not greater than a week.

§ 20.102 *Permissible levels of radiation in unrestricted areas.* (a) There may be included in any application for a license or for amendment of a license proposed limits upon levels of radiation in unrestricted areas resulting from the applicant's possession or use of radioactive material and other sources of radiation. Such applications should include information as to anticipated average radiation levels and anticipated occupancy times for each unrestricted area involved. The Commission will approve the proposed limits if the applicant demonstrates that the proposed limits are not likely to cause any individual to receive a dose in any period of seven consecutive days in excess of 10 percent of the limits specified in Appendix A of this part.

(b) Except as authorized by the Commission pursuant to paragraph (a) of this section, no licensee shall possess, use, or transfer licensed material in such a manner as to create in any unrestricted area from radioactive material and other sources of radiation in his possession:

(1) Radiation levels which, if an individual were continuously present in the area, could result in his receiving a dose in excess of two millirems in any one hour, or

(2) Radiation levels which, if an individual were continuously present in the area, could result in his receiving a dose in excess of 100 millirems in any seven consecutive days.

§ 20.103 *Concentrations in effluents to unrestricted areas.* (a) There may be included in any application for a license or for amendment of a license proposed limits upon concentrations of licensed and other radioactive material released into air or water in unrestricted areas as a result of the applicant's proposed activities. Such applications should include information as to anticipated average concentrations and anticipated occupancy times for each unrestricted area involved. The Commission will approve the proposed limits if the applicant demonstrates that it is not likely that any individual will be exposed to concentrations in excess of the limits specified in Appendix B, Table II, of this part. For purposes of this paragraph, concentrations may be averaged over periods not greater than one year.

(b) Except as authorized by the Commission pursuant to § 20.302 or paragraph (a) of this section, no licensee shall possess, use, or transfer licensed material in such a manner as to release into air or water in any unrestricted area any concentration of radioactive material in excess of the limits specified in Appendix B, Table II of this part. For purposes of this paragraph, concentrations may be averaged over periods not greater than one year.

(c) For purposes of this section, determinations as to the concentration of radioactive material shall be made with respect to the point where such material leaves the restricted area. Where the radioactive material leaves the restricted area in a stack, tube, pipe, or similar conduit, the determination may be made with respect to the point where the material leaves such conduit.

(d) The provisions of this section do not apply to disposal of radioactive material into sanitary sewerage systems (see § 20.303).

§ 20.104 *Medical diagnosis, therapy, and research.* Nothing in the regulations in this part shall be interpreted as limiting the intentional exposure of patients to radiation for the purpose of medical diagnosis or medical therapy.

§ 20.105 *Measures to be taken after excessive exposures.* In the event that any individual in a restricted area receives a dose or is exposed to concentrations of radioactive material in excess of the permissible limits established in § 20.101, the licensee shall limit the weekly dose or exposure of the individual to 10 percent of such permissible limit until such time as the average weekly dose or exposure to the individual for the period beginning with the week in which the excessive dose or

exposure occurred is less than the permissible limit established in § 20.101.

PRECAUTIONARY PROCEDURES

§ 20.201 *Surveys.* (a) As used in the regulations in this part, "survey" means an evaluation of the radiation hazards incident to the production, use, release, disposal, or presence of radioactive materials or other sources of radiation under a specific set of conditions. When appropriate, such evaluation includes a physical survey of the location of materials and equipment, and measurements of levels of radiation or concentrations of radioactive material present.

(b) Each licensee shall make or cause to be made such surveys as may be necessary for him to comply with the regulations in this part.

§ 20.202 *Personnel monitoring.* (a) Each licensee shall supply appropriate personnel monitoring equipment to, and shall require the use of such equipment by:

(1) Each individual who enters a restricted area under such circumstances that he receives, or is likely to receive, a dose in excess of 25 percent of the limits specified in Appendix A of this part;

(2) Each individual who enters a high radiation area.

(b) As used in this part,

(1) "Personnel monitoring equipment" means devices designed to be worn or carried by an individual for the purpose of measuring the dose received (e. g., film badges, pocket chambers, pocket dosimeters, film rings, etc.);

(2) "Radiation area" means any area, accessible to personnel, in which there exists radiation, originating in whole or in part within licensed material, at such levels that a major portion of the body could receive in any one hour a dose in excess of 5 millirem, or in any 5 consecutive days a dose in excess of 150 millirem;

(3) "High radiation area" means any area, accessible to personnel, in which there exists radiation originating in whole or in part within licensed material at such levels that a major portion of the body could receive in any one hour a dose in excess of 100 millirem.

§ 20.203 *Caution signs, labels, and signals.* (a) (1) Except as otherwise authorized by the Commission, symbols prescribed by this section shall use the conventional radiation caution colors (magenta or purple on yellow background). The symbol prescribed by this section is the conventional three-bladed design:

RADIATION SYMBOL

1. Cross-hatched area is to be magenta or purple.
2. Background is to be yellow.

(2) In addition to the contents of signs and labels prescribed in this section, licensees may provide on or near such signs and labels any additional information which may be appropriate in aiding individuals to minimize exposure to radiation or to radioactive material.

(b) *Radiation areas.* Each radiation area shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION [2]
RADIATION AREA

(c) *High radiation areas.* (1) Each high radiation area shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION [2]
HIGH RADIATION AREA

(2) Each high radiation area shall be equipped with a control device which shall either cause the level of radiation to be reduced below that at which an individual might receive a dose of 100 millirem in one hour upon entry into the area or shall energize a conspicuous visible or audible alarm signal in such a manner that the individual entering and the licensee or a supervisor of the activity are made aware of the entry. In the case of a high radiation area established for a period of 30 days or less, such control device is not required.

[2] Or "Danger."

(d) *Airborne radioactivity areas.* (1) As used in the regulations in this part, "airborne radioactivity area" means (i) any room, enclosure, or operating area in which airborne radioactive materials, composed wholly or partly of licensed material, exist in concentrations in excess of the amounts specified in Appendix B, Table I, Column 1 of this part; or (ii) any room, enclosure, or operating area in which airborne radioactive material composed wholly or partly of licensed material exists in concentrations which, averaged over the number of hours in any week during which individuals are in the area, exceed 25 percent of the amounts specified in Appendix B, Table I, Column 1 of this part.

(2) Each airborne radioactivity area shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION [2]

AIRBORNE RADIOACTIVITY AREA

(e) *Additional requirements.* (1) Each area or room in which licensed material is used or stored and which contains any radioactive material (other than natural uranium or thorium) in an amount exceeding 10 times the quantity of such material specified in Appendix C of this part shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION [2]

RADIOACTIVE MATERIAL(S)

(2) Each area or room in which natural uranium or thorium is used or stored in an amount exceeding one hundred times the quantity specified in Appendix C of this part shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION [2]

RADIOACTIVE MATERIAL(S)

(f) *Containers.* (1) Each container in which is transported, stored, or used a quantity of any licensed material (other than natural uranium or thorium) greater than the quantity of such material specified in Appendix C of this part shall bear a durable, clearly visible label bearing the radiation caution symbol and the words:

CAUTION [2]

RADIOACTIVE MATERIAL

(2) Each container in which natural uranium or thorium is transported, stored, or used in a quantity greater than ten times the quantity specified in Appendix C of this part shall bear a durable, clearly visible label bearing the radiation caution symbol and the words:

CAUTION [2]

RADIOACTIVE MATERIAL

(3) Notwithstanding the provisions of subparagraphs (1) and (2) a label shall not be required:

(i) If the concentration of the material in the container does not exceed that specified in Appendix B, Table I, Column 2 of this part, or

(ii) For laboratory containers, such as beakers, flask, and test tubes, used transiently in laboratory procedures, when the user is present.

(4) Where containers are used for storage, the labels required in this paragraph shall state also the quantities and kinds of radioactive materials in the containers and the date of measurement of the quantities.

§ 20.204 *Exceptions from posting requirements.* Notwithstanding the provisions of § 20.203,

(a) A room or area is not required to be posted with a caution sign because of the presence of a sealed source provided the radiation level twelve inches from the surface of the source container or housing does not exceed five millirem per hour.

(b) Rooms or other areas in hospitals are not required to be posted with caution signs because of the presence of patients containing byproduct material provided that there are personnel in

[2] Or "Danger".

attendance who shall take the precautions necessary to prevent the exposure of any individual to radiation or radioactive material in excess of the limits established in the regulations in this part.

(c) Caution signs are not required to be posted at areas or rooms containing radioactive materials for periods of less than eight hours provided that (1) the materials are constantly attended during such periods by an individual who shall take the precautions necessary to prevent the exposure of any individual to radiation or radioactive materials in excess of the limits established in the regulations in this part and; (2) such area or room is subject to the licensee's control.

§ 20.205 *Exemptions for radioactive materials packaged for shipment.* Radioactive materials packaged and labeled in accordance with regulations of the Interstate Commerce Commission shall be exempt from the labeling and posting requirements of § 20.203 during shipment, provided that the inside containers are labeled in accordance with the provisions of § 20.203 (f).

§ 20.206 *Instruction of personnel.* All individuals working in or frequenting any portion of a restricted area shall be informed of the occurrence of radioactive materials or of radiation in such portion, and shall be instructed in the hazards of excessive exposure to such materials or radiation and in precautions or procedures to minimize exposure.

§ 20.207 *Storage of licensed material.* Licensed materials stored in an unrestricted area shall be secured against unauthorized removal from the place of storage.

WASTE DISPOSAL

§ 20.301 *General requirement.* No licensee shall dispose of licensed material except:

(1) By transfer to an authorized recipient as provided in the regulations in Part 30, 40, or 70 of this chapter, whichever may be applicable; or

(2) As authorized pursuant to § 20.302; or

(3) As provided in § 20.303 or § 20.304, applicable respectively to the disposal of licensed material by release into sanitary sewerage systems or burial in soil, or in § 20.103 (Concentrations in Effluents to Unrestricted Areas).

§ 20.302 *Method for obtaining approval of proposed disposal procedures.* Any licensee or applicant for a license may apply to the Commission for approval of proposed procedures to dispose of licensed material in a manner not otherwise authorized in the regulations in this chapter. Each application should include a description of the licensed material and any other radioactive material involved, including the quantities and kinds of such material and the levels of radioactivity involved, and the proposed manner and conditions of disposal. The application should also include an analysis and evaluation of pertinent information as to the nature of the environment, including topographical, geological, meteorological, and hydrological characteristics; usage of ground and surface waters in the general area; the nature and location of other potentially affected facilities; and procedures to be observed to minimize the risk of unexpected or hazardous exposures.

§ 20.303 *Disposal by release into sanitary sewerage systems.* No licensee shall discharge licensed material into a sanitary sewerage system unless:

(a) It is readily soluble or dispersible in water; and

(b) The quantity of any licensed or other radioactive material released into the system by the licensee in any one day does not exceed the larger of subparagraphs (1) or (2) of this paragraph:

(1) The quantity which, if diluted by the average daily quantity of sewage released into the sewer by the licensee, will result in an average concentration equal to the limits specified in Appendix B, Table I, Column 2 of this part; or

(2) Ten times the quantity of such material specified in Appendix C of this part; and

(c) The quantity of any licensed or other radioactive material released in any one month, if diluted by the average monthly quantity of water released by the licensee, will not result in an average concentration exceeding the limits specified in Appendix B, Table I, Column 2 of this part; and

(d) The gross quantity of licensed and other radioactive material released into the sewerage system by the licensee does not exceed one curie per year.

Excreta from individuals undergoing medical diagnosis or therapy with radioactive material shall be exempt from any limitations contained in this section.

§ 20.304 *Disposal by burial in soil.* No licensee shall dispose of licensed material by burial in soil unless:

(a) The total quantity of licensed and other radioactive materials buried at any one location and time does not exceed, at the time of burial, 1,000 times the amount specified in Appendix C of this part; and

(b) Burial is at a minimum depth of four feet; and

(c) Successive burials are separated by distances of at least six feet and not more than 12 burials are made in any year.

RECORDS, REPORTS, AND NOTIFICATION

§ 20.401 *Records of surveys, radiation monitoring, and disposal.* (a) Each licensee shall maintain records showing the radiation exposures of all individuals subject to personnel monitoring control under § 20.202 of the regulations in this part.

(b) Each licensee shall maintain records showing the name of each individual exposed to radiation pursuant to § 20.101 (a) (2) and the weekly dose of each such individual for the 13 consecutive weeks of highest cumulative weekly dose.

(c) Each licensee shall maintain records in the same units used in the appendices to this part, showing the results of surveys required by § 20.201 (b) and disposals made under §§ 20.302, 20.303 and 20.304.

§ 20.402 *Reports of theft or loss of licensed material.* Each licensee shall report promptly to the Commission, after its occurrence becomes known to the licensee, any loss or theft of licensed material in such quantities and under such circumstances that it appears to the licensee that a substantial hazard may result to persons in unrestricted areas.

EXCEPTIONS AND ADDITIONAL REQUIREMENTS

§ 20.501 *Applications for exemptions.* The Commission may, upon application by any licensee or upon its own initiative, grant such exemptions from the requirements of the regulations in this part as it determines are authorized by law and will not result in undue hazard to life or property.

§ 20.502 *Additional requirements.* The Commission may, by rule, regulation, or order, impose upon any licensee such requirements, in addition to those established in the regulations in this part, as it deems appropriate or necessary to protect health or to minimize danger to life or property.

ENFORCEMENT

§ 20.601 *Violations.* An injunction or other court order may be obtained prohibiting any violation of any provision of the act or any regulation or order issued thereunder. Any person who willfully violates any provision of the act or any regulation or order issued thereunder may be guilty of a crime and, upon conviction, may be punished by fine or imprisonment or both, as provided by law.

NOTE: The record keeping and reporting requirements contained herein have been approved by the Bureau of the Budget in accordance with the Federal Reports Act of 1942.

APPENDIX A

PERMISSIBLE WEEKLY DOSE

Condition of exposure		Dose in critical organs (mrem)			
Parts of body	Radiation	Skin, at basal layer of epidermis	Blood forming organs	Gonads	Lens of eye
Whole body	Any radiation with half-value-layer greater than 1 mm of soft tissue.	[1] 600	[1] 300	[1] 300	[1] 300
Whole body	Any radiation with half-value-layer less than 1 mm of soft tissue.	1,500	300	300	300
Hands and forearms or feet and ankles or head and neck.	Any radiation	[2] 1,500			

[1] For exposures of the whole body to X or gamma rays up to 3 mev, this condition may be assumed to be met if the "air dose" does not exceed 300 mr, provided the dose to the gonads does not exceed 300 mrem. "Air dose" means that the dose is measured by an appropriate instrument in air in the region of highest dosage rate to be occupied by an individual, without the presence of the human body or other absorbing and scattering material.

[2] Exposure of these limited portions of the body under these conditions does not alter the total weekly dose of 300 mrem permitted to the bloodforming organs in the main portion of the body, to the gonads, or to the lens of the eye.

APPENDIX B

PERMISSIBLE CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

Material	Table I		Table II	
	Column 1 [1] Air (2)	Column 2 [2] Water (3)	Column 1 [1] Air (2)	Column 2 [2] Water (3)
A^{41}	1.6×10^{-6}	1.4×10^{-3}	5×10^{-8}	5×10^{-5}
Ag^{105}	3.6×10^{-5}	5	1.2×10^{-6}	1.6×10^{-1}
Ag^{111}	1×10^{-4}	13	3×10^{-6}	4×10^{-1}
Am^{241}	8×10^{-11}	4×10^{-4}	3×10^{-12}	1.3×10^{-5}
As^{76}	7×10^{-6}	6×10^{-1}	2×10^{-7}	2×10^{-2}
At^{211}	9×10^{-10}	6×10^{-6}	3×10^{-11}	2×10^{-7}
Au^{198}	3.4×10^{-7}	9×10^{-3}	1.1×10^{-8}	3×10^{-4}
Au^{199}	8×10^{-7}	2×10^{-2}	2.5×10^{-8}	7×10^{-4}
$Ba^{140}+La^{140}$	2×10^{-7}	6×10^{-3}	6×10^{-9}	2×10^{-4}
Be^{7}	1.3×10^{-5}	3	4×10^{-7}	1×10^{-1}
C^{14}	1.4×10^{-6}	1×10^{-2}	5×10^{-8}	3.6×10^{-4}
Ca^{45}	9×10^{-8}	1.5×10^{-3}	3×10^{-9}	5×10^{-5}
$Cd^{109}+Ag^{109}$	2×10^{-7}	2×10^{-1}	7×10^{-9}	7×10^{-3}
$Ce^{144}+Pr^{144}$	2×10^{-8}	1×10^{-1}	7×10^{-10}	3.6×10^{-3}
Cl^{36}	1×10^{-6}	7×10^{-3}	4×10^{-8}	2.4×10^{-4}
Cm^{242}	5×10^{-10}	2.7×10^{-3}	1.8×10^{-11}	1×10^{-4}
Co^{60}	3.4×10^{-6}	5×10^{-2}	1.2×10^{-7}	1.8×10^{-3}
Cr^{51}	2.4×10^{-5}	1.4	8×10^{-7}	5×10^{-2}
$Cs^{137}+Ba^{137}$	6×10^{-7}	4.5×10^{-3}	2×10^{-8}	1.5×10^{-4}
Cu^{64}	2×10^{-5}	2.5×10^{-1}	6×10^{-7}	8×10^{-3}
Eu^{154}	2×10^{-8}	1×10^{-1}	6×10^{-10}	3×10^{-3}
F^{18}	3.5×10^{-4}	2.6	1.2×10^{-5}	9×10^{-2}
Fe^{55}	1.8×10^{-6}	1.3×10^{-2}	6×10^{-8}	4×10^{-4}
Fe^{59}	5×10^{-8}	3.3×10^{-4}	1.5×10^{-9}	1.1×10^{-5}
Ga^{72}	1×10^{-5}	26	3.4×10^{-7}	9×10^{-1}
Ge^{71}	1×10^{-4}	27	3.6×10^{-6}	9×10^{-1}
H^{3} (HTO or T_2O)	7×10^{-5}	5×10^{-1}	2.5×10^{-6}	1.6×10^{-2}
Ho^{166}	1×10^{-5}	70	3×10^{-7}	2.3
I^{131}	9×10^{-9}	9×10^{-5}	3×10^{-10}	3×10^{-6}
Ir^{190}	2.2×10^{-6}	4×10^{-2}	7×10^{-8}	1.3×10^{-3}
Ir^{192}	1.5×10^{-7}	2.7×10^{-3}	5×10^{-9}	9×10^{-5}
K^{42}	6×10^{-6}	4×10^{-2}	2×10^{-7}	1.4×10^{-3}
La^{140}	4×10^{-6}	3.4	1.4×10^{-7}	1.1×10^{-1}
Lu^{177}	1.5×10^{-5}	70	5×10^{-7}	2.4
Mn^{56}	8×10^{-6}	5×10^{-1}	3×10^{-7}	1.5×10^{-2}
Mo^{99}	5×10^{-3}	40	1.8×10^{-4}	1.4
Na^{24}	5×10^{-6}	2.4×10^{-2}	1.6×10^{-7}	8×10^{-4}
Nb^{95}	1.3×10^{-6}	1.2×10^{-2}	4×10^{-8}	4×10^{-4}
Ni^{59}	5×10^{-5}	7×10^{-1}	1.6×10^{-6}	2.5×10^{-2}

See footnotes at end of table, p. 197.

APPENDIX B—Continued

PERMISSIBLE CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—continued

Material	Table I		Table II	
	Column 1 [1] Air (2)	Column 2 [2] Water (3)	Column 1 [1] Air (2)	Column 2 [2] Water (3)
P^{32}	4×10^{-7}	6×10^{-4}	1.4×10^{-8}	2×10^{-5}
Pb^{203}	2×10^{-5}	4×10^{-1}	6×10^{-7}	1.4×10^{-2}
$Pb^{103}+Rh^{103}$	2×10^{-6}	3×10^{-2}	7×10^{-8}	1×10^{-3}
Pm^{147}	6×10^{-7}	3	2×10^{-8}	1×10^{-1}
Po^{210} (soluble)	6×10^{-10}	9×10^{-5}	2×10^{-11}	3×10^{-6}
Po^{210} (insoluble)	2×10^{-10}		7×10^{-12}	
Pr^{143}	2.3×10^{-6}	1	7×10^{-8}	3.6×10^{-2}
Pu^{239} (soluble)	6×10^{-12}	4.5×10^{-6}	2×10^{-13}	1.5×10^{-7}
Pu^{239} (insoluble)	6×10^{-12}		2×10^{-13}	
$Ra^{226}+1/2$ dr	2.4×10^{-11}	1.2×10^{-7}	8×10^{-13}	4×10^{-9}
Rb^{86}	1.1×10^{-6}	9×10^{-3}	4×10^{-8}	3×10^{-4}
Re^{183}	2.4×10^{-5}	2.4×10^{-1}	8×10^{-7}	8×10^{-3}
Rh^{105}	3×10^{-6}	5×10^{-2}	1×10^{-7}	1.6×10^{-3}
$Rh^{322}+$dr	1×10^{-7}	6×10^{-6}	3.3×10^{-9}	2×10^{-7}
$Ru^{106}+Rh^{106}$	8×10^{-8}	4×10^{-1}	2.6×10^{-9}	1.3×10^{-2}
S^{35}	3×10^{-6}	1.5×10^{-2}	1×10^{-7}	5×10^{-4}
Sc^{46}	2×10^{-7}	1	7×10^{-9}	3.6×10^{-2}
Sm^{151}	4×10^{-8}	6×10^{-1}	1.3×10^{-9}	2×10^{-2}
Sn^{113}	1.7×10^{-6}	5×10^{-1}	6×10^{-8}	1.6×10^{-2}
Sr^{89}	6×10^{-8}	2×10^{-4}	2×10^{-9}	7×10^{-6}
$Sr^{90}+Y^{90}$	6×10^{-10}	2.4×10^{-6}	2×10^{-11}	8×10^{-8}
Tc^{96}	8×10^{-6}	8×10^{-2}	3×10^{-7}	3×10^{-3}
Te^{127}	3×10^{-7}	8×10^{-2}	1×10^{-8}	3×10^{-3}
Te^{129}	1.2×10^{-7}	3.3×10^{-2}	4×10^{-9}	1.1×10^{-3}
Th^{234}	2×10^{-6}	10	6×10^{-8}	3×10^{-1}
Th-natural (soluble)	5×10^{-11}	1.5×10^{-6}	1.7×10^{-12}	5×10^{-8}
Th-natural (insoluble)	5×10^{-11}		1.7×10^{-12}	
Tm^{170}	1.5×10^{-7}	8×10^{-1}	5×10^{-9}	2.5×10^{-3}
U-natural (soluble) [3]	5×10^{-11}	2×10^{-4}	1.7×10^{-12}	7×10^{-6}
U-natural (insoluble) [3]	5×10^{-11}		1.7×10^{-12}	
U^{233} (soluble)	4×10^{-10}	4.5×10^{-4}	1×10^{-11}	1.5×10^{-5}
U^{233} (insoluble)	5×10^{-11}		1.6×10^{-12}	
V^{48}	3×10^{-6}	1.5	1×10^{-7}	5×10^{-2}
Xe^{133}	1.3×10^{-5}	1.3×10^{-2}	4×10^{-7}	4×10^{-4}
Xe^{135}	5×10^{-6}	4×10^{-3}	1.7×10^{-7}	1.4×10^{-4}
Y^{91}	1.2×10^{-7}	6×10^{-1}	4×10^{-9}	2×10^{-2}
Zn^{65}	6×10^{-4}	2×10^{-1}	2×10^{-7}	6×10^{-3}
Unidentified beta or gamma emitters or any undetermined mixtures of beta or gamma emitters			1×10^{-9}	1×10^{-7}
Unidentified alpha emitters or any undetermined mixtures of alpha emitters			5×10^{-12}	1×10^{-7}

[1] Air concentrations are given in microcuries per milliliter of air.

[2] Water concentrations are given in microcuries per milliliter of water. These figures also apply to foodstuffs in microcuries per gram (wet-weight).

[3] For enriched uranium the same radioactivities per unit volume as those for natural uranium are applicable. It should be noted that the contribution of U-234 to the gross activity of enriched uranium is 20–40 times that of the U-235.

APPENDIX C

Material	Microcuries	Material	Microcuries
Ag^{105}	1	$Pd^{103}+Rh^{103}$	50
Ag^{111}	10	Pd^{109}	10
As^{76}, As^{77}	10	Pm^{147}	10
Au^{198}	10	Po^{210}	0.1
Au^{199}	10	Pr^{143}	10
$Ba^{140}+La^{140}$	1	Pu^{239}	1
Be^{7}	50	Ra^{226}	0.1
C^{14}	50	Rb^{86}	10
Ca^{45}	10	Re^{186}	10
$Cd^{109}+Ag^{109}$	10	Rh^{105}	10
$Ce^{144}+Pr^{144}$	1	$Ru^{106}+Rh^{106}$	1
Cl^{36}	1	S^{35}	50
Co^{60}	1	Sb^{124}	1
Cr^{51}	50	Sc^{46}	1
$Cs^{137}+Ba^{137}$	1	Sm^{153}	10
Cu^{64}	50	Sn^{113}	10
Eu^{154}	1	Sr^{89}	1
F^{18}	50	$Sr^{90}+Y^{90}$	0.1
Fe^{55}	50	Ta^{182}	10
Fe^{59}	1	Tc^{96}	1
Ga^{72}	10	Tc^{99}	1
Ge^{71}	50	Te^{127}	10
H^{3} (HTO or H_2^3O)	250	Te^{129}	1
I^{131}	10	Th (natural)	50
In^{114}	1	Tl^{204}	50
Ir^{192}	10	Tritum. See H^3	250
K^{42}	10	U (natural)	50
La^{140}	10	U^{233}	1
Mn^{52}	1	U^{234}-U^{235}	50
Mn^{56}	50	V^{48}	1
Mo^{99}	10	W^{185}	10
Na^{22}	10	Y^{90}	1
Na^{24}	10	Y^{91}	1
Nb^{95}	10	Zn^{65}	10
Ni^{59}	1	Unidentified radioactive materials or any of the above in unknown mixtures	0.1
Ni^{63}	1		
P^{32}	10		

NOTE: For purposes of §§ 20.203 and 20.304, where there is involved a combination of isotopes in known amounts the limit for the combination should be derived as follows: Determine, for each isotope in the combination, the ratio between the quantity present in the combination and the limit otherwise established for the specific isotope when not in combination. The sum of such ratios for all the isotopes in the combination may not exceed "1" (i. e., "unity").

EXAMPLE: For purposes of § 20.304, if a particular batch contains 2,000 μc of Au^{198} and 25,000 μc of C^{14}, it may also include not more than 3,000μc of I^{131}. This limit was determined as follows:

$$\frac{2{,}000\,\mu c}{10{,}000\,\mu c}Au^{198}+\frac{25{,}000\,\mu c}{50{,}000\,\mu c}C^{14}+\frac{3{,}000\,\mu c}{10{,}000\,\mu c}I^{131}=1.$$

The denominator in each of the above ratios was obtained by multiplying the figure in the table by 1,000 as provided in § 20.304.

Dated at Washington, D. C., this 16th day of January 1957.

For the Atomic Energy Commission.

K. E. FIELDS,
General Manager.

PART 20—AMENDMENTS

Reporting Requirements

The following amendments add reporting requirements to this regulation. They are designed, among other things, to give the AEC prompt notice of potentially serious accidents involving licensed material in order that appropriate steps may be taken to protect against further hazard to life or property. For these reasons the Atomic Energy Commission has found that general notice of proposed rule making and public procedure thereon are impracticable and that good cause exists why these amendments should be made effective without the customary period of notice. The Commission will, however, give consideration to any com-

ments or suggestions concerning these reporting requirements. All interested persons who desire to submit written comments and suggestions relating to the following amendments should send them to the United States Atomic Energy Commission, Washington 25, D. C., Attention: Director, Division of Civilian Application.

Effective upon publication Title 10, Chapter 1, Part 20, Code of Federal Regulations entitled "Standards for Protection Against Radiation" is amended in the following respects:

1. Section 20.402 is amended to read as follows:

Sec. 20.402 *Reports of Theft or Loss of Licensed Material.* Each licensee shall report by telephone and telegraph to the Manager of the nearest Atomic Energy Commission Operations Office listed in Appendix "D," immediately after its occurrence becomes known to the licensee, any loss or theft of licensed material in such quantities and under such circumstances that it appears to the licensee that a substantial hazard may result to persons in unrestricted areas.

2. The following new section is added:

Sec. 20.403 *Notifications and Reports of Incidents.*

(a) *Immediate notification.* Each licensee shall immediately notify the Manager of the nearest Atomic Energy Commission Operations Office listed in Appendix "D" by telephone and telegraph of any incident involving licensed material possessed by him and which may have caused or threatens to cause:

(1) Exposure of any individual to 25 rems or more of radiation, including any radioactive material taken into the body; or

(2) The release of radioactive material in concentrations which, if averaged over a period of 24 hours, would exceed 5,000 times the limits specified for such materials in Appendix "B," Table 2; or

(3) A loss of one working week or more of the operation of any facilities affected; or

(4) Damage to property in excess of $100,000.

(b) *Twenty-four hour notification.* Each licensee shall within 24 hours notify the Manager of the nearest Atomic Energy Commission Operations Office listed in Appendix "D" by telephone and telegraph of any incident involving licensed material possessed by him and which may have caused or threatens to cause:

(1) Exposure of any individual to 3 rems or more of radiation, including any radioactive material taken into the body; or

(2) The release of radioactive material in concentrations which, if averaged over a period of 24 hours, would exceed 500 times the limits specified for such materials in Appendix "B," Table 2; or

(3) A loss of one day or more of the operation of any facilities affected; or

(4) Damage to property in excess of $1,000.

(c) *Thirty-day Reports.* Each licensee shall make a report in writing within 30 days to the Director, Division of Civilian Application, United States Atomic Energy Commission, Washington 25, D. C., of each incident involving licensed material possessed by him which appears to have resulted in the exposure of an individual to radiation or to concentrations of radioactive material, or to have resulted in levels of radiation or concentrations of radioactive material, in excess of any applicable limits set forth in these regulations or in the licensee's license. Each report required under this paragraph shall describe the nature of the incident, the extent of exposure of persons to radiation or to radioactive material, the levels of radiation and concentrations of radioactive material involved, the cause of the incident, and corrective steps taken or planned to assure against a recurrence of the incident. A copy of each report shall be transmitted to the Manager of the nearest Atomic Energy Commission Operations Office listed in Appendix "D."

3. Appendix "D" is added to read as follows:

APPENDIX D

UNITED STATES ATOMIC ENERGY COMMISSION OPERATIONS OFFICES

	Mail address	Telegraph address
Albuquerque Operations Office	P. O. Box 5400, Albuquerque, N. Mex.	Albuquerque, N. Mex.
Chicago Operations Office	P. O. Box 59, Lemont, Ill	Lemont, Ill.
Grand Junction Operations Office.	Grand Junction, Colo	Grand Junction, Colo.
Hanford Operations Office	P. O. Box 550, Richland, Wash	Richland, Wash.
Idaho Operations Office	P. O. Box 1221, Idaho Falls, Idaho	(Telegram) 550 Second St., Idaho Falls, Idaho (Teletype) Idaho Falls, Idaho
New York Operations Office	70 Columbus Avenue New York 23, N. Y.	(Telegram) 70 Columbus Avenue. New York 23, N. Y. (Teletype) New York, N. Y.
Oak Ridge Operations Office	P. O. Box E Oak Ridge, Tenn	Oak Ridge, Tenn.
San Francisco Operations Office	518 17th St., Oakland 12, Calif	518 17th St., Oakland 12, Calif.
Savannah River Operations Office.	P. O. Box A, Aiken, S. C	Augusta, Ga.
Schenectady Operations Office	P. O. Box 1069, Schenectady, N. Y.	(Telegram) Knolls Atomic Power Laboratory, Schenectady, N. Y. (Teletype) Schenectady, N. Y.

PART 60—DOMESTIC URANIUM PROGRAM

URANIUM PROSPECTING PERMITS AND MINING LEASES ON LANDS ADMINISTERED BY FEDERAL AGENCIES WHICH DO NOT HAVE AUTHORITY TO LEASE SUCH LANDS

Notice is hereby given that the following regulations have been adopted by the Atomic Energy Commission, effective upon publication in the Federal Register.

§ 60.9 *Uranium prospecting permits and mining leases on lands administered by Federal agencies which do not have the authority to lease such lands*—(a) *What this section does.* This section provides for the issuance by the United States Atomic Energy Commission of uranium prospecting permits and mining leases covering certain lands of the United States which are not open to the location of mining claims under the United States mining laws and which are not subject to lease for prospecting or mining purposes by the Federal agencies administering such lands or by the Department of the Interior. The program for which provision is made in this section will be administered by the Atomic Energy Commission with the assistance and cooperation of the Bureau of Land Management of the Department of the Interior.

NOTE: Permits or leases will not be issued under this section for lands administered by the United States for national park, monument or wildlife purposes. (See section 67, Public Law 703, 83d Congress.)

(b) *Statutory authority.* The Atomic Energy Act of 1954 (68 Stat. 919) is authority for this section.

(c) *Eligibility of applicants.* Uranium prospecting permits and mining leases under this section will be issued only to (1) citizens of the United States, (2) associations of such citizens, (3) corporations organized under the laws of the United States or of any State or Territory thereof. Uranium prospecting permits and mining leases under this section will not be issued to persons under twenty-one (21) years of age nor to employees of the Commission or the Department of the Interior.

(d) *Applications.* There is no required form of application for a permit or lease under this section but the application should:

(1) Name the Government agency administering the land and, where practicable, the particular unit thereof concerned.

(2) Contain an accurate description of the land.

In the States under the public land rectangular system, if surveyed, the description should be by legal subdivision, section, township, and range; if unsurveyed, by a similar description based upon the premise of its location when surveyed and by courses and distances connected to a corner of the public land rectangular system. In those States not covered by the public land rectangular system, the description should be the description in the deed of conveyance of the tract to the United States, or, if a portion of such tract, by courses and distances connected with an identifiable and established corner of an existing survey recognized by the laws of the State. Upon request, applicant must submit satisfactory evidence that the Government has title to the minerals in said land and the right to their removal.

(3) Include an accurate map or plan of the lands prepared from the survey thereof or other reliable map source, unless the lands are surveyed under the public land system of surveys.

(4) Contain a statement of applicant's name, address and citizenship (if a corporation, the State of incorporation and a statement of the applicant's authority to hold a prospecting permit or mining lease under its corporate powers) and a statement of applicant's interests, direct or indirect, in prospecting permits and mining leases and application for such permits and leases under these regulations for uranium in Federal lands in the same State. No permit or lease will be issued where such interests exceed 1,920 acres.

(5) The application shall be filed in triplicate in the land office of the Bureau of Land Management for the State where the land is situated. In States in which there are no land officers, applications shall be forwarded to the Director, Bureau of Land Management, Washington 25, D. C., except that applications covering lands in the following States should be forwarded to the land offices named: North and South Dakota, land office at Billings, Montana; Nebraska and Kansas, at Cheyenne, Wyoming; Oklahoma and Texas, at Santa Fe, New Mexico. Applications must be accompanied by a filing fee of $10 which is not returnable.

(e) *Issuance and supervision of permits and leases.* Permits and leases will be executed by the Commission. Although priority in filing an application will normally be the controlling factor where more than one application has been filed for a permit or lease, consideration may be given to equities and right is reserved to offer the lands competitively in appropriate cases. The right is also reserved to refuse to issue a permit or lease or extension thereof. It is the objective under this section to issue permits and leases containing uniform terms and conditions. However, since the lands affected by this section are administered by other Government agencies having responsibilities in connection with the administration of the land, it probably will be necessary to include in particular permits and leases additional terms and conditions designed to permit the agencies involved to fulfill appropriately their functions and obligations or to refrain from issuing permits or leases or extensions thereof where it is concluded that issuance is contrary to the interests of the United States. The term of each permit or lease and extensions thereof will also be subject to such considerations.

(f) *Prospecting permits terms and conditions.* (1) Prospecting permits will be issued for a period not exceeding two years (see paragraph (e) of this section) and will grant the permittee the right to prospect on the lands described therein to determine the existence of, or workability of, uranium deposits. Only such material may be removed from the land as is necessary to demonstrate the existence of uranium in commercial quantities. The permittee may sell such quantities of uranium-bearing material as may be approved by the Commission.

(2) A prospecting permit may not include more than 1,920 acres of land which must be reasonably compact.

(3) Payment of an annual rental of 25 cents per acre of land or fraction thereof covered by the permit will be required. Such rental will be payable annually in advance; payment of the first full year's rental will be required with the filing of the application and the balance of the rental will be payable on or before the first anniversary of the effective date of the permit. Failure to pay such rental when due will result in automatic termination of the permit. The permittee may also be required to furnish a performance bond.

(4) Permits issued under this section may be assigned to those eligible under paragraph (c) of this section, subject to approval of the Commission as to all or any of the lands subject to permit. To procure such approval all instruments of transfer of the permit must be filed at the proper land office of the Bureau of Land Management within 90 days after execution and must contain all of the terms and conditions agreed upon by the parties thereto. The application for approval of assignment must be accompanied by (i) a statement of the proposed assignee setting forth his qualifications to hold a permit and his agreement to be bound by the terms and conditions of the permit, (ii) a filing fee of $10 which is not returnable.

(g) *Extension of permit.* (1) Subject to the provisions of paragraph (e) of this section, a prospecting permit may be extended for one additional term not exceeding two years upon written application made by the permittee and filed in triplicate in the proper land office of the Bureau of Land Management at least 90 days prior to the expiration date of the permit. Such application must be accompanied by a filing fee of $10 which is not returnable, and the third year's rental. In support of application for extension of a prospecting permit, the permittee must show that he has diligently performed prospecting activities on the land during the period for which the permit was issued or that any failure to do so arose from conditions beyond the permittee's control.

(2) Upon failure of the permittee to file an application for extension within the specified period, the permit will expire at the end of its primary term without notice to the permittee and the land will thereupon become subject to new application for prospecting permits.

(h) *Preference right lease; terms and conditions.* (1) Upon discovery of a valuable deposit of uranium by a permittee, subject to paragraph (e) of this section, he shall be entitled to a preference right lease covering any or all of the lands in the permit. (Issuance of a prospecting permit must precede an application for a preference right lease.) An application for a preference right lease must be filed in accordance with paragraph (d) (5) of this section not later than 30 days after the expiration date of the permit and must describe the lands, disclose any change in the information contained in the application for the permit, specify fully the extent and mode of occurrence of the mineral deposit as disclosed by prospecting and show that a valuable deposit of uranium was discovered before the expiration of the permit.

(2) Leases will be issued subject to royalty and rental payments as set forth in subdivisions (i) and (ii) of this subparagraph and to such other terms and conditions for protection of the surface of the land as may be required.

(i) Royalty shall be at the rate of 10 percent of gross receipts, including initial production bonus paid pursuant to § 60.6 (Domestic Uranium Program Circular 6) but exclusive of any haulage and development allowances paid pursuant to §§ 60.5 and 60.5a (Domestic Uranium Program Circular 5, Revised), or equivalent haulage and development allowances from the sale of uranium-bearing ore produced from the leased premises.

(ii) Rental shall be at the rate of $1.50 per acre per year payable annually in advance. Such advance rentals shall be

credited on the royalty due from the sale of uranium-bearing ore during that lease year.

(3) A lease issued under this section will be for a term not exceeding 5 years (see paragraph (e) of this section) and will be renewable in the discretion of the Commission as to any and all tracts for not more than 3 additional periods of not exceeding 3 years each upon written application therefor by the lessee at least 90 days prior to the expiration of the lease or any extension thereof. The application for renewal must be accompanied by a filing fee of $10.00 which is not returnable. Renewals may include such revisions of or additions to the lease terms as may be required.

(4) Leases issued under this section will become effective when signed on behalf of the Commission.

(5) A lease or any of the tracts under a lease may be relinquished by the lessee by written notification sent to the proper land office of the Bureau of Land Management subject to continued liability to the United States for any payments then due and subject to compliance with the terms of the lease. Relinquishment shall take effect on the date such notification is received by the Bureau of Land Management, as evidenced by the written acknowledgment of the Bureau of Land Management.

(6) Should the lessee fail to comply with any of the terms and conditions of the lease within 30 days after receipt of written notice specifying such failure and requesting compliance, the Commission shall have the right to terminate the lease.

(7) Leases issued under this section may be assigned to those eligible under paragraph (c) of this section, subject to approval of the Commission as to all or any of the leased tracts. To process such approval, all instruments of transfer of the lease must be filed at the proper land office of the Bureau of Land Management within 90 days after execution and must contain all of the terms and conditions agreed upon by the parties thereto. The application for approval of assignment must be accompanied by (i) a statement of the proposed assignee setting forth his qualifications to hold a lease and his agreement to be bound by the terms and condition of the lease, (ii) a filing fee of $10.00 which is not returnable.

(i) *Initial production bonus.* Leases issued under this section shall provide that lessees otherwise meeting the requirements of § 60.6 (Domestic Uranium Program Circular 6) shall be eligible for initial production bonus payments under that section notwithstanding the reference to properties leased by the Commission in paragraph (g) (3) (vi) thereof.

(j) *Reservation of rights.* The right is reserved to the Commission to revise, modify or terminate these regulations at any time without prejudice to rights of permit holders or lease holders established under existing permits or leases.

(k) *Definition used in this section.* "Commission" means the Atomic Energy Commission created by the Atomic Energy Act of 1954, as amended, or its duly authorized representative.

(*l*) *Decisions.* The Atomic Energy Commission has duly authorized the Bureau of Land Management to assist it in the administration of this program and, ordinarily, the decisions of the Director of the Bureau of Land Management will be final, but the Atomic Energy Commission may choose to give further consideration to any matter.

(60 Stat. 755—775; 42 U. S. C. 1801—1819)

Dated at Washington, D. C., this 4th day of February 1957.

K. E. FIELDS,
General Manager.

I concur.

Dated at Washington, D. C., this 15th day of February 1957.

FRED A. SEATON,
Secretary of the Interior.

APPENDIX 8

Production and Utilization Facility Licenses Applied for and Issued

New applications were received as follows:

Aerojet-General Nucleonics, San Ramon, Calif., for construction and operation of twelve (12), 100-milliwatt, Model AGN–201 reactors, serial numbers 109 through 120. These reactors are for ultimate sale or lease to properly licensed institutions. A notice was published in the *Federal Register* on June 19, proposed issuance of a permit authorizing construction of these twelve and an additional five reactors of the same type, the application for the latter having been filed in a previous reporting period. One of the reactors is for 5-watt operation and the balance for 100-milliwatt operation.

Aerojet General Corp., Azusa, Calif., for licenses to acquire title to research reactors Model AGN–201, serial numbers 101 through 103 and 104 through 108, respectively. The transfer of titles does not involve physical transfer of the reactors or any change in technical personnel or operating procedures. A license authorizing AGC to acquire title to the first three reactors was issued June 17, 1957.

Atomics International, A Division of North American Aviation, Inc., Canoga Park, Calif., for construction and operation of a 5-watt, homogeneous solution-type research reactor at the company's Vanowen Facility, Canoga Park, Calif. This reactor is a prototype of a small laboratory reactor (Model L–47) which the company plans to build in quantity for sale to properly licensed institutions.

Battelle Memorial Institute, Columbus, Ohio, for amendments to the existing license covering the Institute's research reactor.

General Electric Co., San Jose, Calif., for a license to construct and operate at the company's Vallecitos Atomic Laboratory, Alameda County, Calif., a 30,000-kilowatt pressurized water test reactor. The applicant proposes to design and construct the reactor to provide facilities capable of irradiating a wide variety of fuel and reactor components under environmental conditions.

General Electric Co., also for authorization to assemble components of the Spanish Swimming Pool Reactor and perform nuclear checkout tests at the company's Vallecitos Atomic Laboratory prior to export.

Oklahoma Agricultural and Mechanical College, Stillwater, Okla.; the Texas Agricultural and Mechanical College System, College Station, Tex.; University of Akron, Akron, Ohio; and the *University of Utah, Salt Lake City, Utah;* each for a license to acquire, possess, and operate, on their respective campuses, a small research reactor. The applicants plan to use the reactors for educational purposes.

Ordnance Materials Research Office, Watertown Arsenal, Watertown, Mass., for a license to construct and operate a 1000-kilowatt, light water moderated and cooled, pool-type research reactor at the Watertown Arsenal. The applicant proposes to use the facility in research and development work on Ordnance Corps materials.

The University of Buffalo, Buffalo, N. Y., for construction and operation of a 1-megawatt, pool-type research reactor on its campus. The applicant plans to

use the reactor (which is to be designed and built by AMF Atomics) for industrial research and training in the field of atomic energy.

The University of Virginia, School of Engineering, Charlottesville, Va., for construction and operation of a 1-megawatt, pool-type research reactor at a site just west of Charlottesville City Limits. The applicant plans to use the reactor for research and educational purposes in the University's nuclear engineering program.

Union Carbide Nuclear Co., A Division of Union Carbide Corp., New York, N. Y., for construction and operation of a 5-megawatt, pool-type research reactor at Sterling Forest, Orange County, N. Y. The applicant plans to use the reactor for general industrial research and development purposes.

U. S. Naval Hospital, National Naval Medical Center, Bethesda, Md., for a license to acquire, possess and operate at the Medical Center a 5-watt Model AGN–201M research reactor. The applicant plans to use the reactor for medical therapy and research.

Export license applications received and actions taken during the reporting period were as follows.

ACF Industries, Inc., New York, N. Y., on May 16, was issued a license authorizing the export of a 5-megawatt tank-type research reactor to the Italian National Committee for Nuclear Research. *ACF Industries* also filed two additional applications, one for the export of a 30-megawatt tank-type research and test reactor to the Swedish Atomic Energy Commission; the other for export of a 20-megawatt MTR tank-type research reactor to the Reactor Centrum Nederland, The Netherlands.

AMF Atomics, Inc., New York City, on February 1, 1957, was issued a license authorizing export of a 10-kilowatt, pool-type research reactor to the Ministry of Education, Kingdom of the Netherlands, for the International Exhibition "Het Atoom," Amsterdam.

AMF Atomics, Inc., on March 15, 1957, was also issued a license authorizing export of a 1-megawatt, pool-type research reactor to the Laboratorium fur Technische Physik der Technischen Hochschule Munchen, Munich, Federal Republic of Germany.

AMF Atomics also filed applications for the export of two additional 1-megawatt research reactors, one to Hamilton College, McMaster University, Hamilton, Ont., Canada; the other to the Greek Atomic Energy Commission, Athens, Greece.

The Babcock & Wilcox Co., New York City, on January 22, 1957, was issued a license authorizing export of a 5-megawatt, pool-type research reactor to Conselho Nacional de Pesquisas do Brasil, for Comissao de Energia Atomica, University of Sao Paulo, Sao Paulo, Brazil.

The Babcock & Wilcox Co., on June 10, 1957, was issued a license to export a 5-megawatt, pool-type research reactor to the Society for the Utilization of Nuclear Energy in Shipbuilding and Navigation, Inc., Hamburg, Federal Republic of Germany.

Foster Wheeler Corp., New York City, applied for and on April 4, 1957, was issued a license authorizing the export of a 5-megawatt, tank-type research reactor to the Danish Atomic Energy Commission, Christiansborg, Copenhagen, Denmark.

430209—57——15

Intercontinental Chemical Corp., New York City, applied for and on June 11, 1957, was issued a license to export a 50-kilowatt, solution-type research reactor (Atomics International Model L–54) to Farbwerke Hoechst AG, Frankfurt, a.M.—Hoechst, Federal Republic of Germany.

International General Electric Co., New York, N. Y., applied for a license to export a 3-megawatt pool-type research reactor to Junta de Energia Nuclear, Madrid, Spain.

Loretz & Co., Los Angeles, Calif., applied for and on April 4, 1957, was issued a license authorizing the export of a 500-watt, solution-type, research reactor to the Danish Atomic Energy Commission, Christiansborg, Copenhagen, Denmark.

James Loudon & Co., Inc., Los Angeles, Calif., applied for a license to export a 50-kilowatt, solution-type research reactor to the Senate of the Land Berlin, West Berlin, Germany.

Additional actions on facility license applications were taken as follows:

Aerojet-General Nucleonics, San Ramon, Calif., on February 22, 1957, was issued a construction permit authorizing construction, at its San Ramon plant, of three (3) 100-milliwatt, Model AGN–201, research reactors, serial numbers 101, 102 and 103. Licenses were issued on February 23, March 14 and March 29, 1957, authorizing operation of these three reactors. On February 26, 1957, AGN was authorized to transfer the reactor designated as serial No. 101 to Philadelphia, Pa., and to operate it in Convention Hall at the Atomic Exposition and Nuclear Congress held March 11 thru 15, 1957. On June 11, 1957, AGN was authorized to transfer its serial no. 102 reactor to the Oklahoma Fair Grounds, Oklahoma City, Okla., and to operate and display the reactor at the Oklahoma Semi-Centenial during the period June 19, through July 7, 1957.

Aerojet-General Nucleonics was issued amendments to the three facility licenses referred to above authorizing AGN to transfer title or possession, or both, to the licensed reactors to any person licensed to acquire such possession or title, or both. A notice was published in the *Federal Register* on June 18, proposed action for modification of one of these reactors to increase the operating level to 5 watts.

Aerojet-General Corporation, Azusa, Calif., on March 7, 1957, was issued a license to acquire title to the Model AGN–201 research reactor, serial No. 100 which was constructed and licensed for operation by Aerojet-General Nucleonics. The acquisition of title does not involve a relocation of the reactor or any change in technical personnel or operating procedures.

AMF Atomics, Inc., New York City, on January 22, 1957, was issued a construction permit authorizing construction of a 5,000 kilowatt, pool-type research reactor in Plainsboro Township, New Jersey. The applicant plans to use the reactor for applied research for a group of industrial firms.

The Babcock & Wilcox Co., New York City, on March 20, 1957, was issued a license authorizing operation of its critical experiment facility at Lynchburg, Virginia. Initially, the license authorizes performance of critical experiments related to the Consolidated Edison power reactor. Also, the B&W Co. filed an amendment to its original application requesting authorization to construct a new addition which will essentially duplicate the critical experiment facility now licensed to operate.

Curtiss-Wright Corp., Clifton, N. J., on June 20, was issued a construction permit authorizing construction of a 1000-kilowatt pool-type research reactor at the company's Research and Development Center, Quehanna, Pa.

General Dynamics Corp., San Diego, Calif., on June 18, 1957, was issued a construction permit authorizing construction of a critical experiment facility at Torrey Pines Mesa, San Diego, Calif.

Lockheed Aircraft Corp., Van Nuys, Calif., on March 14, 1957, was issued a construction permit authorizing construction of a critical experiment facility on the campus of Stanford University, Palo Alto, Calif.

The Martin Co., Baltimore, Md., on May 13, 1957, was issued a construction permit authorizing construction of a critical experiment facility at Middle River, Md.

North Carolina State College, Raleigh, N. C., on March 6, 1957, was issued a construction permit authorizing modification of its research reactor. On May 1, 1957, an amended license was issued authorizing operation of the modified reactor at a power level of 500 watts.

U. S. Naval Postgraduate School, Monterey, Calif., on April 29, was issued a license authorizing USNPS to acquire, possess and operate at Monterey the first 100-milliwatt reactor constructed by and licensed for operation by Aerojet-General Nucleonics. The facility license previously issued to AGN was terminated on completion of the reactor transfer to USNPS.

APPENDIX 9

Special Nuclear Material Licenses Applied for and Issued

New applications received and licenses issued are listed below:

Aerojet-General Nucleonics, San Ramon, Calif., applied for a license to receive 600 grams of uranium 235 contained in four spent MTR fuel elements for use in research and development work, processing AGN–201 reactor cores, and for industrial radiation purposes.

Aerojet-General Nucleonics also applied for and was issued a license to receive from other licensees up to 500 grams of uranium 235 contained in samples of uranium metal and compounds of various enrichments for performing non-destructive analytical tests in the AGN–201 reactor.

AMF Atomics, Inc., New York, N. Y., applied for and was issued a license authorizing receipt for storage only of up to 100 grams of contained uranium 235 in fission counters and encapsulated heat melt specimens for analysis and assay purposes by other licensees.

American Lava Corp., Chattanooga, Tenn., applied for a license authorizing receipt of special nuclear material in the form of uranium oxide enriched to 20 percent in the isotope Uranium 235 for the fabrication of fuel elements.

American Machine & Foundry Co., Advanced Research Dept., Alexandria, Va., was issued a license authorizing receipt of up to 1,400 grams of uranium 235, and the plutonium and byproduct material contained in eight irradiated MTR or ETR fuel elements, to be used as gamma radiation sources in research work. Four spent fuel elements will be used at one time and will be exchanged approximately every four months.

Amherst College, Amherst, Mass., applied for and was issued a license authorizing receipt of 80 grams of plutonium contained in five Pu-Be sources to be used as a neutron source for training students in nuclear chemistry.

The Babcock & Wilcox Co., Lynchburg, Va., requested and was granted an allocation of 2 kilograms of highly enriched UF_6 for the production of UO_2 samples to be inserted in the B&W test loop at the MTR.

Bailey Meter Co., Cleveland, Ohio, was issued an amended license increasing to 8 grams the amount of Uranium 235 contained in fission counters which the licensee is authorized to possess.

Baker & Co., Inc., Newark, N. J., applied for and was issued a license authorizing receipt of special nuclear material in connection with the processing of uranium 235 scrap at the company's commercial scrap refining plant. The company plans to receive this material from AEC and licensed users for purification and return to them.

Berea College, Department of Physics, Berea, Ky, applied for a license to receive 0.1 microcurie of plutonium contained in a plutonium 239 source to be used in research on the "W-values of gases."

Boeing Airplane Company, Seattle, Wash., applied for a license to receive 10 grams of plutonium and 10 grams of Np-237 for use in Boeing's research and develop-

ment program in conjunction with radiation damage studies being done on semi-conductor devices for the Bomarc missile.

Boston University Graduate School, Boston, Mass., was issued a license authorizing receipt of 5 milligrams of uranium 233 for use as a tracer for testing the completeness of separation of uranium from bismuth by various chemical methods and for the determination of the extraction ratio of uranium.

California Institute of Technology, Pasadena, Calif., was issued a license authorizing receipt of 50 milligrams of plutonium contained in ten encapsulated samples for use in scientific research.

The College of Wooster, Wooster, Ohio, applied for a license authorizing receipt of the plutonium contained in a Pu-Be neutron source to be used for educational purposes.

Colorado State University, Ft. Collins, Colo., applied for a license to receive a Pu-Be neutron source for use with an AGN research reactor which the University plans to purchase.

Cook Electric Co., Chicago, Ill., applied for a license to receive special nuclear and source materials contained in dosimeters, and the byproduct and special nuclear materials produced by irradiation of these dosimeters, their containers and supporting structures, for the purpose of developing a dosimeter system for the Navy Department.

Curtiss-Wright Corp., Quehanna, Pa., applied for and was issued a license authorizing receipt of 10 grams of uranium 235 contained in five fission chambers to be used in the control system of the Curtiss-Wright research reactor.

Fairchild Camera & Instrument Corp., Long Island, N. Y., applied for and was issued a license authorizing receipt of a fission counter containing 2.1 grams of uranium 235 for use in research work in developing electronic nuclear reactor control instrumentation.

General Dynamics Corp., San Diego, Calif., was issued a license and allocation authorizing receipt of 4 kilograms of uranium metal (over 90 percent Uranium 235), and 33 kilograms of uranium metal (20 percent uranium 235) for fuel element fabrication; and 10 grams of uranium 235 contained in uranium-zirconium alloy, and the plutonium produced during irradiation of the alloy in connection with fuel element research.

General Electric Co., Atomic Power Equipment Dept., San Jose, Calif., applied for and was issued an amended license authorizing allocation and receipt of 7 grams of highly enriched UO_2 at its Vallecitos Atomic Laboratory for fabrication into suitable test capsules and post-irradiation examination in connection with a Navy Department contract.

General Electric Co., San Jose, Calif., was also issued amended licenses authorizing receipt of an additional 3,500 pounds of uranium dioxide containing uranium enriched to 2.3 percent in the isotope uranium 235; 22 kilograms of uranium metal (over 90 percent uranium 235); 45 kilograms of uranium metal (20 percent uranium 235); and 125 grams of uranium 235 contained in 8 MTR type fuel plates, for use in the fabrication of fuel elements.

General Electric Co., San Jose, Calif., also filed two additional applications; one for a license to receive and possess for storage only 3.83 kilograms of uranium 235 contained in fuel elements for the nuclear test reactor to be constructed by General Electric, and the other for a license authorizing receipt of 1.25 grams of

uranium 235 contained in standards for spectrographic use in the isotopic analysis of uranium 235.

Georgia Institute of Technology, Atlanta, Ga., applied for and was issued a license authorizing receipt of 10 milligrams of uranium 235 contained in fissior counters for laboratory experiments in the Institute's graduate program of nuclear science and engineering.

Harvard College, Lyman Laboratory of Physics, Cambridge, Mass., applied for and was issued a license authorizing receipt of 0.0053 gram of uranium 235 in oxide form for use in lecture demonstrations of nuclear fission and laboratory experiments for quantitative measurements of energy release under slow neutron bombardment.

Haverford College, Haverford, Pa., applied for a license authorizing receipt of approximately 1.6 grams of plutonium contained in a Pu-Be neutron source to be used for laboratory research.

Iowa State College, Ames, Iowa, applied for and was issued a license authorizing receipt of 80 grams of plutonium contained in five Pu-Be sources to be used in a subcritical assembly used in the College's nuclear engineering educational program.

Mallinckrodt Chemical Works, St. Louis, Mo., requested and was issued ar amended license authorizing the company to convert at its Hematite, Missouri, plant enriched UF_6 to uranyl sulfate (in addition to producing uranium oxide, as previously authorized).

The Martin Co., Baltimore, Md., was issued an amended license and allocation authorizing receipt of one additional kilogram of uranium 235 for use in fuel element research.

Massachusetts Institute of Technology, Cambridge, Mass., applied for and was issued a license authorizing receipt of 80 grams of plutonium contained in five Pu-Be neutron sources to be used for instructional purposes in MIT's nuclear engineering educational program.

Massachusetts Institute of Technology also applied for and was issued a license authorizing receipt of 1 gram of uranium 235 contained in a fission counter to be used as a neutron detector in the MIT research reactor.

Massachusetts Institute of Technology also applied for a license authorizing receipt of 3 kilograms of uranium 235 for the fabrication of fuel elements for the MIT research reactor.

Minnesota Mining & Manufacturing Co., St. Paul, Minn., applied for a license authorizing receipt of four spent MTR or ETR fuel elements and use in a gamma irradiation facility to be used in research and development programs.

MSA Research Corp., Callery, Pa., applied for a license authorizing receipt of 1200 grams of uranium 235 contained in highly enriched uranium, for use in core meltdown experiments for the Navy.

Metals & Controls Corp., Attleboro, Mass., requested and was issued a revised license and allocation authorizing receipt of up to 110 kilograms of uranium 235 which the company may have in its possession at any one time for the fabrication of fuel elements. Metals & Controls was allocated 15 kilograms of uranium 235 (in uranium enriched to over 90 percent) for this purpose.

National Spectrographic Laboratories, Inc., Cleveland, Ohio, applied for and was issued a license authorizing possession of up to 300 grams of uranium 235 at any one time in connection with commercial services the company will perform. The licensee was allocated 10 grams of uranium 235 which is to be made into a series of analytical standards.

North American Philips Co., Inc., Instruments Division, Mount Vernon, N. Y., applied for and was issued a license authorizing receipt of up to 10 grams of uranium 235 contained in three samples to be used in the investigation of isotopic analytical procedures. The licensee later advised that its Instruments Division was being transferred to *Philips Electronics, Inc.,* which company applied for and was issued a license in its own name. The license issued to North American Philips was accordingly cancelled.

North Carolina State College, Raleigh, N. C., was issued a license authorizing receipt of 80 grams of plutonium contained in five Pu-Be sources to be used as a neutron source in the operation of a subcritical assembly.

Nuclear Electronics Corp., Philadelphia, Pa., applied for and was issued a license authorizing receipt of 0.2 milligram of uranium enriched in the isotope uranium 235 for use in calibrating continuous alpha air monitors manufactured by the company.

Nuclear Engineering Co., Inc., San Francisco, Calif., applied for a license to receive at any one time up to 500 grams of special nuclear material contained in waste products generated by various companies and shipped to Nuclear Engineering Co. for disposal at sea.

Nuclear Instrument & Chemical Corp., Chicago, Ill., requested and was issued a revised license authorizing possession of 25 grams of uranium enriched to 20 percent in the isotope uranium 235, for radiation chemistry experiments.

Nuclear Metals, Inc., Cambridge, Mass., was issued a license authorizing receipt of up to 275 grams of uranium 235 contained in uranium-molybdenum alloy for preparation of a rod to be used by APDA for tensile moderation tests. Nuclear Metals subsequently requested and was issued a revised license increasing the licensed quantity of special nuclear material to 350 grams of uranium 235, for use in the preparation of four U-Mo rods.

Nuclear Metals also applied for and was issued a license authorizing receipt of 5 grams of uranium 235 in uranium-zirconium rod, for use in swaging operations and return to another licensee.

Pennsylvania State University, University Park, Pa., applied for and was issued a license authorizing receipt for storage only of 6 kilograms of uranium 235 contained in fuel elements fabricated by Babcock & Wilcox Co., and destined for the University of Sao Paulo research reactor. Penn State also requested and was granted an amendment to its facility license to authorize the use of this material in conducting a critical experiment to determine the water-reflected critical mass.

Pennsylvania State University also applied for and was issued a license authorizing receipt and use of 13 grams of uranium 235 contained in four zirconium-uranium alloy plates in conducting a series of irradiation measurement experiments in the Penn State reactor.

Princeton University, Palmer Physical Laboratory, Princeton, N. J., applied for a license authorizing receipt of 2 grams of uranium 235 contained in seven fission chambers to be used for neutron detection and monitoring.

Reed College, Department of Chemistry, Portland, Oreg., applied for and was issued a license authorizing receipt of 80 grams of plutonium contained in five Pu-Be sources for a subcritical assembly which is to be used in the College's nuclear engineering program.

Stanford Research Institute, Menlo Park Calif., was issued an amended license and allocation authorizing receipt of up to 450 grams of uranium 235 contained in uranium enriched to 20 percent in the isotope uranium 235; 16 grams of plutonium contained in a Pu-Be neutron source and up to 100 micrograms of plutonium produced by irradiation of normal uranium, for use in processing of reactor core pieces, calibration purposes and research and development activities.

Sylvania-Corning Nuclear Corp., Bayside, N. Y., a newly formed company comprised of contributions by Sylvania Electric Products, Inc., and the Corning Glass Works, applied for and was issued a license authorizing possession of uranium 235 in metallic form for the fabrication of fuel elements at its Hicksville, Long Island plant for other licensees. The license previously issued to Sylvania Electric Products, Inc., for this purpose was accordingly cancelled.

Sylvania-Corning Nuclear Corp. also applied for a license to receive special nuclear material in the form of metal, oxide or other chemical compound, enriched to various degrees in the isotope uranium 235, for the fabrication of fuel elements for other licensees at its Bayside plant.

The University of Minnesota, Department of Chemical Engineering, Minneapolis, Minn., was issued a license authorizing receipt of 64 grams of plutonium contained in encapsulated Pu-Be sources for use in a graphite, natural uranium exponential assembly to be used in nuclear engineering training and education.

The University of Minnesota, School of Physics, applied for and was issued a license authorizing receipt of 16 grams of plutonium contained in a Pu-Be source to be used in laboratory exercises involving the measurement of short-lived radioactive materials.

The University of Puerto Rico, Mayaguez, P. R., applied for and was issued a license authorizing receipt of 80 grams of plutonium contained in five Pu-Be sources to be used as neutron sources for a graphite heterogeneous exponential assembly.

The University of Toledo, Toledo, Ohio, applied for and was issued a license authorizing receipt of 80 grams of plutonium contained in five Pu-Be sources for use in a subcritical assembly to be used for laboratory demonstration, experiment and instruction in the University's nuclear engineering program.

The University of Washington, Seattle, Wash., applied for a license to receive and use a Pu-Be neutron source in conjunction with an exponential assembly used to ascertain maximum neutron yields from uranium source material.

The University of Washington also applied for a license to receive metal foils containing plutonium and uranium 233 for use in physical research work.

Washington University, St. Louis, Mo., applied for and was issued a license authorizing receipt of 250 grams of uranium 235 contained in uranium enriched to 20 percent in the isotope uranium 235 for use in radiochemical studies of fission processes.

Westinghouse Electric Corp., Pittsburgh, Pa., requested and was issued a revised license authorizing possession of an additional 200 grams of uranium 235 contained in isotopic standards to be used at the company's Commercial Power Activity Spectrochemical Laboratory. The licensee was allocated 110 grams of contained uranium 235 for this purpose. The license and allocation were later amended to authorize receipt of an additional 5.5 grams of uranium 235 contained in three fisson chambers for the Westinghouse Test Reactor.

Westinghouse Electric Corp., Pittsburgh, Pa., applied for and was issued a license authorizing receipt of 16 grams of plutonium contained in a Pu-Be neutron source for use in conjunction with conducting critical experiments at the Westinghouse Reactor Evaluation Center (WREC), Waltz Mill, Westmoreland County, Pennsylvania.

The University of Wisconsin, Madison, Wis., was issued a license authorizing receipt of 16 grams of plutonium contained in a Pu-Be neutron source for use in the University's nuclear engineering research program.

APPENDIX 10

Health and Safety Procedures Established for 1957 Series of Nuclear Tests in Nevada

Safeguarding the public health and safety again will be a primary consideration in the Plumbbob series of nuclear tests, scheduled to begin about May 16, 1957 at the U. S. Atomic Energy Commission's Nevada Test Site.

As a result of improved controls and procedures, radioactive fall-out in the area around the Test Site is expected to be even lower than the levels which have resulted from previous tests in Nevada. For the United States as a whole, average exposures will be small in comparison with the radiation dosages normally received from natural "background" radiation. Fall-out levels in other parts of the world as a result of the tests generally will be lower than those in the United States.

Systems of detecting and measuring fall-out radioactivity have been expanded and improved in order to provide more extensive data for scientific purposes and for informing the public. Radiological monitoring will be conducted by several networks of stations extending from the Test Site region to locations around the world.

A major goal of the series will be the further development of weapons for the defense of this country in the event of a nuclear attack. Additional information on effects of nuclear weapons also will be obtained for use in improving both military and civil defense plans and procedures, which must be maintained pending ultimate agreement on safeguarded disarmament.

Each test scheduled for Operation Plumbbob has been carefully evaluated to determine that it is necessary for achievement of the overall objective of strengthening the military and civil defense of the United States and the Free World.

Only devices of relatively low yield, or explosive energy, will be detonated during the series.

The Nevada Test Organization, which is in charge of conducting the tests, has advised the Atomic Energy Commission that:

1. None of the shots in the Plumbbob series is expected to produce as much fall-out on the nearby region as did some of the shots in the 1955 Teapot series.
2. The total fall-out on the region around the Test Site from all shots in the new series is expected to be less than that for any Nevada test series since 1952.

REDUCTION OF FALL-OUT

Controls and procedures for the test series are designed to assure that exposure of the public in the Test Site region for the entire series will be below the Commission's basic guide of 3.9 roentgens of whole-body exposure to gamma rays. In its day-to-day operations, the Test Organization will strive to hold public exposure to fall-out as near zero as possible.

Procedures for keeping fall-out at a minimum include the following:

1. The Test Organization has established criteria defining the maximum permissible yield for devices exploded at specified altitudes. If the fireball produced by any detonation is expected to reach the surface of the Test Site, drawing up

dust and debris into the atomic cloud and thereby increasing local fall-out, there will be severe restrictions on the weather conditions considered acceptable for the test. Such tests will be conducted only when predicted weather conditions will not produce significant fall-out on any inhabited locality. Improved weather forecasting techniques and high-speed electronic methods of predicting fall-out paths and intensity will be utilized.

2. There has been a continuing effort in the weapons laboratories to design devices of the lowest possible yield which will provide the desired scientific data. Decreasing the yield of a device has the effect of decreasing the amount of radioactive fission products which can descend as fall-out.
3. Improved techniques will be utilized to keep the fireballs of the detonations away from the surface of the testing area. Relatively little local fall-out results from detonations in which the fireball does not approach close to the surface.

The most important new technique of keeping the fireball away from the ground will be the use of anchored balloons for several detonations. These cannot be used for every detonation, since in some instances the relative positions of the nuclear device and the instruments used to record data must be known very accurately. However, operating procedures and recording instruments have been developed which will make the use of balloons practical for some shots at altitudes of 500 to 2,000 feet.

The use of balloons not only will keep the fireball away from the surface, but also is expected to provide less material to be vaporized and drawn into the atomic cloud than is the case when devices are detonated from towers.

Towers will be used for some shots in the new series. The height of towers has increased from 100 feet in 1946 and 1951 to 500 feet in the last Nevada series in the spring of 1955. At least one shot in the Plumbbob series will be fired on a newly designed 700-foot tower.

A possible technique for eliminating airborne fall-out will be tested in the new series. A device of very low kiloton yield is scheduled for firing in an underground tunnel. It is believed that this method of firing will prevent escape of radioactive materials into the atmosphere. Conventional high explosives with small amounts of radioactive tracers have been fired in underground tunnels at the Test Site to provide information on the feasibility of an underground shot. The low-yield underground test will provide data on seismic and underground contamination effects which will determine the feasibility of further underground shots.

Several safety experiments also will be conducted in underground shafts which will contain any resulting low-yield nuclear detonation and will prevent any on-site surface contamination.

WARNING PROCEDURES

As in past series, every effort will be made to warn people away from the Test Site and the Las Vegas Bombing and Gunnery Range. A Civil Aeronautics officer again will be assigned to the Test Organization to provide for closure of air space if necessary to prevent exposure of persons in aircraft.

Persons in the Test Site area also will be advised of precautions to take against the brilliant flash of light and the shock wave from the detonations. No member of the public has suffered eye damage in past series from the light flash. Minor damage from the shock wave occurred in some nearby communities, principally in the earlier series.

RADIATION EXPOSURE LEVELS

Many thousands of measurements of fall-out radioactivity have been made in the Test Site area since the beginning of testing in Nevada in 1951. These measurements have confirmed that Nevada test fall-out has not caused illness or detectable injury to health.

The highest fall-out level noted to date in an inhabited place outside of the test site occurred in 1953 at a motor court near Bunkerville, Nev., where about 15 people might have accumulated 7 to 8 roentgens if they had continued to live there indefinitely. The highest estimated total exposure to a community has been 4.3 roentgens at Bunkerville.

Most of the communities in the Test Site area have received less than one roentgen total estimated exposure as a result of the 6 years of testing in Nevada.

Outside the Test Site region, the total dose since the beginning of nuclear testing generally has been a very small fraction of a roentgen—considerably less than the average exposure to natural "background" radioactivity which persons have received over the same time period. Roughly speaking, the additional exposure resulting from test fall-out outside the Test Site region has been about equivalent to the additional exposure to background radiation which a person would receive by moving from sea level to a locality a few hundred feet higher in altitude. (Background radiation levels increase with altitude because of an increase in cosmic ray intensity.)

Fall-out radioactivity noted in other countries has been even less. Except for some of the Pacific islands, the cumulative gamma dose at foreign monitoring stations from October 1951 to September 1955 ranged from four to 23 thousandths of one roentgen.

Many measurements of the strontium 90 content of soil, food and feed crops, milk, meat and human bones have been made, since strontium 90 is considered to be potentially the most hazardous fall-out material when taken into the body. None of these measurements has disclosed a dangerous concentration of strontium 90 from Nevada tests outside of the controlled areas of the Test Site.

RADIOLOGICAL MONITORING

The Test Organization's monitoring programs will be concentrated largely in the region up to 200 miles from the Test Site. Outside of this area, other monitoring networks will provide information on levels of radioactivity in the United States and in other parts of the world. The U. S. Public Health Service, the U. S. Weather Bureau, the U. S. Department of Agriculture, and 11 Commission installations will cooperate in this monitoring activity.

Monitoring programs are being expanded in several respects to provide more detailed information on the distribution of fall-out and the exposures resulting from it.

The monitoring stations will detect whatever radioactivity is present in their localities, whether it results from the Plumbbob tests or from foreign nuclear tests. Therefore, if foreign tests are held during the series, the readings may represent fall-out from these as well as from the U. S. tests.

CLOUD-SAMPLING, CLOUD-TRACKING AND AIRBORNE MONITORING

Aircraft will be used to take samples of the atomic clouds and to track them from the Test Site for about 600 miles, by which time they will have dispersed into completely invisible, widely diffused air masses.

Aircraft also will be used after each shot to determine the fall-out pattern on the ground and to provide estimates of the radiation intensity. Three planes, equipped with instruments of the type developed by Oak Ridge National Laboratory to locate uranium ore deposits from the air, will take part in this operation.

MONITORING TEAMS IN TEST SITE AREA

Seventeen monitoring teams of U. S. Public Health Service regular and reserve officers will be stationed in communities near the Test Site throughout the series. They will be responsible for monitoring in zones in and around the communities. Teams will be stationed at Las Vegas, Alamo, Caliente, Pioche, Ely, Tonopah, Mercury, Lincoln Mine, Overton, Mesquite, and Eureka, Nev.; St. George, Cedar City and Beaver, Utah; Barstow and Bishop, Calif.; and Kingman, Ariz.

In addition, at least eight two-man mobile monitoring teams of U. S. Public Health Service personnel will be available for post-shot monitoring in downwind areas after each detonation. They will assist the teams stationed in communities or will monitor more isolated areas between the community zones.

Twelve fixed-station teams and four mobile teams were utilized during the 1955 Nevada series.

The monitors will distribute and collect film badges (used for measurement of radiation dosage), monitor radioactivity on the ground and in the air, collect water and milk samples, and answer public inquiries regarding test fall-out.

FILM BADGES

Since photographic film is extremely sensitive to radiation, badges containing film have been used extensively in the atomic energy program to measure radiation exposure.

During the 1955 series, badges were placed on the interiors and exteriors of buildings in the Test Site area, on trees, posts and fences in communities and in the open country. In addition, some of the residents of the nearby area wore badges as a means of aiding the Test Organization in determining the radiation exposures actually experienced by persons in the area. A total of 555 such film badge "stations" were used in the 1955 series.

At least 1,000 film badge stations will be established during the 1957 series. In several small communities near the Test Site, all residents except infants and small children will be asked to wear badges throughout the series. (Infants and small children are likely to chew or otherwise damage the badges, making it impossible to obtain accurate measurements.)

A more detailed program is planned at Alamo, a town of about 400 persons located 55 miles northwest of the Yucca Flat firing area. Alamo was chosen as a representative town of the Test Site region.

In addition to wearing film badges, Alamo residents will be asked to report their movements inside the region and to other localities, and also to provide information on other activities which might affect radiation dosage, such as the amount of time spent indoors as compared with outdoors. Each person also will be asked for details of his previous exposure to radiation, such as medical X-rays.

This project has two major purposes:

1. To obtain information on how fall-out radiation exposures are affected by movement, shielding provided by buildings, weathering of the fall-out material by wind and rain, and other factors.

2. To obtain information on the problems which might be encountered in attempting to record the radiation exposure of a relatively large group of persons through the use of film badges.

OTHER DATA COLLECTING PROJECTS

Several hundred fall-out trays, coated with water proof adhesive, will be distributed in areas generally adjacent to the Test Site. The contents will be collected regularly and analyzed for beta particle fall-out.

At least 20 continuous radiation recorders will be placed in nearby communities to record the time of arrival of any fall-out, its intensity, and in some cases the effect of shielding by structures.

The Atomic Energy Project of the University of California at Los Angeles will utilize the test series to continue studies of the uptake of fission products in plant and animal life and the distribution of fall-out particles. The Project has conducted such studies in connection with all continental tests since the first one in 1945.

UCLA scientific personnel will obtain soil and plant samples and will hunt and trap wildlife and rodents in fall-out areas from the Test Site out to about 160 miles. They also will study the distribution of fall-out particles of different sizes with the objective of providing information which can be used in the prediction of fall-out patterns.

If fall-out is recorded in areas within California, Utah or Nevada where crops are grown, samples of soil, forage crops, vegetables and milk will be collected to learn more about the biological availability of fission products.

MONITORING IN CONTINENTAL U. S.

Outside of the area within about 200 miles of the Test Site, monitoring activities will be conducted in cooperation with the U. S. Weather Bureau, the U. S. Public Health Service, and 11 Atomic Energy Commission installations. These operations will not be conducted in the expectation of possible hazard, but for scientific purposes and to keep the public informed on levels of radioactivity.

As in past test series, a network of U. S. Weather Bureau stations will collect dust samples. The stations will expose sheets of film covered with adhesive outdoors on a tray each 24 hours, and then mail them to the Commission's Health and Safety Laboratory in New York. There, the samples will be reduced to ashes and the radioactivity will be measured with extremely sensitive instruments.

Ninety-three Weather Bureau sampling stations will be in operation during Operation Plumbbob. Their locations are given in Table I, which is attached.

Although this collection system provides important scientific data, it does not provide immediate information on fall-out levels, since the samples must be mailed to the Health and Safety Laboratory and counted there. Information will be provided more quickly by two other monitoring networks, one consisting of 38 stations established by the U. S. Public Health Service and the other consisting of monitors at 11 Commission installations. Their locations are listed in Tables II and III.

The Public Health Service established its countrywide monitoring system in 1956 in connection with the Redwing series of tests at the Commission's Eniwetok Proving Ground. The system has been reactivated for the new Nevada series.

The Public Health Service monitoring stations will make daily readings of radioactivity and will forward the data to a central collection office in Washington.

The stations also will report data to the State Health Officers of the states in which the stations are located. Under a contract between the Public Health Service and the Commission, the monitoring system will operate throughout the series and for some weeks thereafter.[1]

The primary purposes of the system are to give state and local health departments more experience in studying fall-out and normal background radiation levels, and to obtain daily records of radioactivity. The stations will be manned by trained technicians from state health departments, local universities, and scientific institutions.

MEASUREMENTS OF RADIOACTIVITY OUTSIDE THE U. S.

Dust samples will be collected at 73 stations outside of the continental United States and extending around the world.[1] Their locations are given in Table IV.

Soils also will be sampled on a world-wide basis, and samples of other materials such as milk and cheese, field crops and human and animal bones will be taken for analysis of their strontium 90 content. This program is part of the Commission's Project Sunshine, a study of the world-wide distribution and uptake of fall-out.

[1] Probably the most useful absolute measurements of fall-out are given by open pots continuously exposed in the open and the contents emptied and measured either after each rain or periodically, as once per month. Whereas the gummed paper technique is simple and cheap, its efficiency is less than 100 percent and probably depends on weather. It is now known that offsite fall-out is carried down by rain. A system of pot collecting stations has been established in the United States and abroad.

TABLE I

U. S. Weather Bureau Fall-out Sampling Stations in Operation During Operation Plumbbob

Abilene, Tex.
Albany, N. Y.
Albuquerque, N. Mex.
Alpena, 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.

TABLE II

U. S. Public Health Service Monitoring Stations During Operation Plumbbob

Albany, N. Y.	Juneau, Alaska
Anchorage, Alaska	Klamath Falls, Oreg.
Atlanta, Ga.	Lansing, Mich.
Austin, Tex.	Lawrence, Mass.
Baltimore, Md.	Little Rock, Ark.
Berkeley, Calif.	Los Angeles, Calif.
Boise, Idaho	Minneapolis, Minn.
Cheyenne, Wyo.	New Orleans, La.
Cincinnati, Ohio	Oklahoma City, Okla.
Denver, Colo.	Phoenix, Ariz.
El Paso, Tex.	Pierre, S. Dak.
Gastonia, N. C.	Portland, Oreg.
Harrisburg, Pa.	Richmond, Va.
Hartford, Conn.	Salt Lake City, Utah
Honolulu, T. H.	Sante Fe, N. Mex.
Indianapolis, Ind.	Seattle, Wash.
Iowa City, Iowa	Springfield, Ill.
Jacksonville, Fla.	Trenton, N. J.
Jefferson City, Mo.	Washington, D. C.

TABLE III

AEC Monitoring Stations During Operation Plumbbob

Berkeley, Calif	Radiation Laboratory, University of California.
Cincinnati, Ohio	General Electric Company—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.

430209—57——16

TABLE IV

Monitoring Stations Outside Continental U. S. During Operation Plumbbob

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.
Moncton, 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, Taiwan.
Thule, Greenland.
Tokyo Air Base, Japan.
Truk.
Wake Island.
Wellington, New Zealand.
Wheelus AFB, Tripoli.
Winnipeg, Manitoba, Canada.
Yap.

APPENDIX 11

Remarks Prepared by Dr. Willard F. Libby, Commissioner, for Delivery Before the American Physical Society, Washington, D. C., April 26.

Radioactive Fall-Out

I. Introduction

The radioactivity produced by the fission reaction changes its characteristics continuously and rapidly following the explosion of an atomic weapon and the conditions of firing are of extreme importance in determining the rate of which the radioactivity descends to earth. As a result there are in general three different kinds of radioactive fall-out, the relative importance of which is determined by the nature of the weapon, principally its yield, and the conditions of firing. These three types are: First, *the local fall-out*, which is insignificant unless the fireball touches or comes close to the ground, but which in case the fireball does touch the ground, can amount to a major fraction, in some instances as much as 80 percent of the total debris. This type of fall-out consists of radioactivity which is carried down by the larger particles. It consists largely of matter drawn up into the fireball from the surface which is either totally or partially vaporized. Under these conditions so much matter is vaporized by virtue of the fireball's touching the ground that the particle sizes formed in the freshly cooled vapor are large.

The second and third types of radioactive fall-out are world-wide in nature and consist of finer material and are divided according to whether the material happens to lie in the lower part of the atmosphere, the troposphere, where rain and weather phenomena occur, or the higher part of the atmosphere, the stratosphere, which is free of such precipitating mechanisms. The *tropsopheric fall-out* occurs in a matter of two or three weeks or a month or so. It occurs largely as a result of rain and snow, and water precipitation in general, and falls in the general latitude of the test site. The *stratospheric fall-out*, in contrast, takes years. We are not completely certain, but it appears that an average time of something like 10 years, or perhaps somewhat less, is a reasonable figure, and during this time the distribution becomes nearly worldwide. When the stratospheric fall-out manages finally to pass into the troposphere it is quickly removed by the same type of mechanism that brings down the worldwide tropospheric fall-out, namely rain and moisture.

The precipitating mechanisms consist in general of the collision of the tiny particles with moisture droplets in clouds, together with the interception of particles by falling raindrops. The first mechanism was recently suggested by Dr. Greenfield in connection with Sunshine problems—the study of worldwide fall-out is called Project Sunshine. In addition to the scavenging action of rains and fogs, there is definite evidence for a considerable probability of pick-up on direct contact of air with surfaces such as the leaves of grass and trees. Frequently, grasses are found to have higher strontium 90 content than would correspond to the soils in which they grow, and this is due undoubtedly to direct pick-up.

The dissemination of strontium 90 and all fall-out is greatly dependent upon the firing conditions. There is every evidence that important factors include not only

contact of the fireball with the surface, but the nature of the surface, whether it be land or water and the type of soil and the composition of the water, whether fresh or sea water. Also, the height to which the fireball rises is important, in particular the height relative to the tropopause, the dividing layer between the troposphere and the stratosphere. Yield is the main consideration here. A rough rule is that megaton weapons push through the tropopause into the stratosphere, and kiloton weapons stay below the tropopause in the troposphere.

Thus, we see immediately that kiloton weapons deposit their fission products much more quickly than do megaton weapons. Of course this is of less importance in so far as the long-lived fission products, such as strontium 90 and cesium 137, are concerned, but it is of more importance for the shorter-lived fission products. As a general rule, an air-fired kiloton weapon will deposit its radioactive fall-out in a period of between 2 weeks and 1 month on the average after the detonation, whereas an air-fired megaton weapon will deposit its radioactive fall-out over many years—on the average about 10 years. Thus, the effects which are due to the short-lived fission products are larger for a given amount of fission energy release in kiloton weapons than they are for air-fired megaton weapons. Considering the average age of the kiloton fission products to be 1 month, the external gamma ray exposure from one megaton of fission fired as say 50 bombs of 20 kilotons each would be 30 times that for a single bomb giving one megaton of fission energy—if both were fired well up in the air. The fission products from the small bombs fired in Nevada would fall in the latitudes 10°N. to 60°N. in about 1 month, while the larger bomb would give fall-out over essentially the whole earth in about 10 years. For strontium 90 effects there is relatively little difference per unit fission yield since even the residence time in the stratosphere is small compared to the 28 year half-life of radioactive strontium and the 27 year half-life of radioactive cesium, which is produced at slightly higher yield than strontium 90, and which appears to be disseminated in about the same way.

The content of radiostrontium and radiocesium in the stratosphere is by direct measurement shown to be roughly the same though the radiocesium is somewhat higher possibly due to the slightly higher fission yield. The content of radiocesium in rainwater is comparable to that of strontium 90. Also, the content of radiocesium in the human body as measured by Marinelli at Argonne and Anderson and Langham at Los Alamos, agrees well with the fact that it has an average residence time in the human body of about 5 months as compared to many years for strontium 90. The radiocesium data are very interesting because of their bearing on the fall-out dissemination mechanism and the confidence with which we can establish the probable future behavior of radioactive strontium. The data confirm previous suggestions as to the dissemination mechanism, that is, we find that radiocesium fall-out except of the local variety is carried down very largely in the form of moisture droplets and that there is some direct pick-up by leaves and grass on surfaces. It is captured and held tightly by the top two inches of most soils, so the water which falls and runs off in the form of rivers is clean by the time it has drained a short distance through soil. All of this is very similar to the radiostrontium behavior.

The plants pick the strontium 90, and radiocesium to a lesser extent, out of the soil and also off of their leaves and take it into their systems. There appears to be a discrimination mechanism which operates in most plants so that the strontium 90 content of the plant is considerably less relative to its calcium content than in the case of the soil. On the average, the discrimination factor between the top soil and plants against strontium relative to calcium seems to be about

1.4. When the cows eat grass they further discriminate by about a factor of 7 in making milk so there is an overall protection factor for strontium 90 from the top soil to milk of about 1.4 x 7 or 10. Also, there is a further discrimination factor against strontium relative to calcium in the human body. This factor is not known too well, but is known definitely to be at least as large as 2 and is thought possibly to be as high as 8. Researches are now in progress to settle this. Therefore, there is a series of protective factors which makes the concentration of radiostrontium derived from milk relative to calcium in human bone not over $\frac{1}{20}$ and possibly as little as $\frac{1}{80}$ of that in the top soil. Of course, it should be pointed out that there is a considerable part of the fall-out which is picked up directly on the leaves and to this the factor of 1.4 does not apply, so for this fraction of the fall-out the protective factor may be reduced to 14. Since milk is the source of most of our calcium, this means that the actual ratio of radiostrontium concentration in new human bones relative to that in the top soil should approach these numbers.

It must be realized that though only a small part of the calcium is derived from vegetables and meat, a similar calculation must be made from this portion and the total average ratio obtained. It seems that the meat-vegetable overall discrimination factor is about 10; so, if 20 percent of the calcium is derived from such sources on the average, the average overall factor will be between $\frac{1}{13}$ and $\frac{1}{30}$. The experimental data on new human bone in children appear to give a smaller figure, $\frac{1}{60}$, as mentioned later.

A matter of importance in connection with the amount of strontium 90 which one would expect to be deposited in human bone as a result of atomic weapon detonations is the calcium concentration in the top soil. Since calcium is so similar to strontium, it seems very likely, and the evidence confirms this, that high available calcium content of the soil will reduce the probability of strontium 90 being taken up into the plants. Of course this probably does not have nearly as great an effect on the uptake of the material which is picked up directly on the leaves. We might expect therefore that soils which are particularly low in calcium might show higher strontium 90 contents for the grasses grown on them. This is, in fact, so, and sheep and goats and cattle feeding on such pasture display a higher strontium 90 bone content.

How such calcium deficiencies in the soil should affect the strontium 90 uptake by the human population is a most important question. One sees immediately that food distribution systems are such that the food supply is derived from large areas, and that there is consequently a sharp reduction in the sensitivity of the human population to calcium deficiencies in local soils. This is brought out particularly well by the data on the radium contents of human bones and their obvious lack of strong dependence on the radium contents of local waters. But for people who consistently drink milk from cows grazing on such ground there should be a definite effect on the amount of radiostrontium uptake and the effect should be proportional to the radiostrontium content of the milk. So the question resolves itself largely into "What are the strontium 90 contents of the foods people in such regions actually consume?" We find on inspection of the food eating habits and calculation of the strontium 90 intake relative to calcium, that the increase in average strontium 90 concentration of the food due to the low calcium content of the particular soils can hardly be more than 5-fold for a soil calcium deficiency of 50-fold. That is, whereas normal soil carried about 20 grams of available calcium in the top 2.5 inches, a region with soil of only 0.4 gram per square foot would produce a human body burden equilibrium of about five times that which the normal soil would produce.

In order to understand the hazard of radiostrontium, which is generally agreeed to be the most hazardous of the long-lived fission products, we try to establish the maximum permissible concentration both for occupational workers and for the population in general. These numbers have been set at 1 microcurie and 0.1 microcurie for the standard man, respectively. That is, an occupational worker may carry 1 microcurie of strontium 90 in his body, whereas the general public should not have over 0.1 of a microcurie of strontium 90 in the average standard adult. This last figure corresponds to a concentration of 100 micromicrocuries per gram of body calcium or what we call 100 Sunshine Units, that is, 1 micromicrocurie of strontium 90 per gram of body calcium is defined as 1 Sunshine Unit.

Now, we must try to see in some other way how our normal experiences can be brought to bear on the question: "How dangerous is atomic weapons testing from the point of view of radioactive fall-out?" At the present time we have in our bodies about 0.1 or 0.2 of a Sunshine Unit and children have about one-half of a Sunshine Unit. In a few minutes I will speak about the question of the variation from these average values, but assuming at the moment that these are the values, what is the threat or the hazard from these quantities? Obviously, they are much smaller than the 100 Sunshine Unit tolerance figure mentioned above. To obtain a comparison with normal experience, let us consider the fact that we know in a general way the magnitude of the radiation levels to which we are normally subjected by the cosmic rays, potassium in our own bodies, and the uranium, thorium and potassium in the ground and in our surroundings. We know these quantities amount to something like 150 milliroentgens per year for an average person in this latitude. But we also know that there are considerable variations with conditions.

For example, a person living in a brick house may very well get 25 to 50 milliroentgens per year more than one living in a wooden house, because of the natural radioactivity of the bricks. It is also very well known that whereas at sea level in this latitude the cosmic ray dosage is 37 milliroentgens per year, at 5,000 feet altitude as in Denver, Colo., the dosage from cosmic rays is 60 milliroentgens per year, or a difference of 23 milliroentgens per year. What is this in terms of strontium 90 body burden?

First, we must consider what part of the natural radiation, if any, is similar to the radiation of strontium 90 in biological effect so we can say without doubt and hesitancy that the physiological effects, whatever they are, will be the same for the same energy absorbed. Fortunately, the cosmic rays seem to fit this bill. In other words, we are at liberty to compare the cosmic ray radiation dosages with the dosages from radiostrontium in our bone structure. The reason this is permissible is that the ionization density along the tracks of the mu-mesons which are the principal cosmic ray components at sea level and at altitudes of 5,000 feet are nearly the same as those of the yttrium 90 beta rays, the principal radiation which radiostrontium emits; that is, radiostrontium has a radioactive daughter, yttrium 90, which emits a very energetic beta ray and the ionization density along the track of this radiation is very similar to that of the mu-mesons of the cosmic rays and their disintegration electrons, and it is generally accepted by health physicists and radiobiologists that radiations of the same ionization density have very similar, if not identical biological effects for the same energy absorbed. The high energy of the yttrium 90 gives it an average distance of penetration in tissue of 2 millimeters so any effect of local non-uniformity of deposition of strontium 90 in the bone is removed. The cosmic ray exposure is, of course, uniform throughout the bone structure. Therefore, we can equate cosmic ray dosage with strontium 90 dosage and thus it is possible for us to say

that the difference between one altitude and another is equal in effect, other effects being equal, to a certain number of Sunshine Units in bone. Now to follow this thought through, 1 Sunshine Unit is equal to 3 milliroentgens per year. Therefore, the difference in annual cosmic ray radiation dosage between Washington, D. C., or any place at sea level in this latitude, and Denver, Colo. is equal to 8 Sunshine Units, that is, 16 times the present body burden of equilibrium bone or bone near equilibrium as we see it in young children who are growing now.

Therefore, we must examine whether anything in our experience indicates that these differences are significant in terms of the occurrence of the principal effects expected of radiostrontium, namely leukemia and bone cancer. Now of course when one looks for such vital statistics, one finds that they are very hard to acquire. However, the National Institutes of Health and the Department of Health, Education and Welfare, have given us statistics for the occurrence of leukemia and bone cancer for the year 1947 for the three cities, New Orleans, San Francisco, and Denver. They are shown in Table I.

TABLE I

Occurrence of Bone Cancer and Leukemia

(*New cases per year per 100,000 population*)

	Bone cancer	*Leukemia*
Denver	2. 4	6. 4
New Orleans	2. 8	6. 9
San Francisco	2. 9	10. 3

It is clear from this table there is no obvious effect of altitude, and it is also clear that there are other factors which are noticeably more important than cosmic ray dosage. Of course there may still be a considerable effect of altitude hidden in large fluctuations caused by other factors, which presumably are largely unknown and we cannot say that this *proves* anything. It does, however, give us some assurance from normal experience that the effect of eight Sunshine Units will not cause a detectable increase in bone cancer or leukemia.

This fits well with the laboratory data on animals and the limited experience on humans with radium. That is, 1 microcurie being 1,000 Sunshine Units, is still considered to be pretty safe on the basis of the laboratory data. It is set as a tolerance for occupational workers and it is therefore reasonable that eight Sunshine Units should give an effect so small as to be very, very difficult to detect. It is, I think, helpful for us, however, to realize that the present body burden of strontium 90 in new bone from the weapons tests that have occurred in the past is equal to the increase in cosmic ray intensity that goes with an increase of some 400 feet in altitude, a very small fraction of the difference in cosmic radiation intensity between Denver and sea level. Therefore, at the same time that we consider the possible effects of strontium 90 from such concentrations, we may deduce from our everyday ordinary experience limits on the effects to be expected. None of the evidence on the occurrence of bone cancer or leukemia as a function of altitude has given us any reason to believe that the present tolerance limits are in any way in error. The present body burdens in new bones are small compared to these limits.

Separate from the strontium 90 effects are the effects of general gamma radiation, the radiation that is received mainly from outside the human body, and which comes mainly from the very young fission products in the local fall-out area, but which can come in smallest part from radiocesium accumulating on the ground in the case of the stratospheric fall-out, or more importantly, from the shorter-lived

fission products deposited by the tropospheric fall-out. Of course, weapons tests are so conducted as to avoid exposures to local fall-out, so our present discussion of the effects of weapons will be restricted to the much smaller gamma ray doses from the offsite tropospheric and stratospheric types of fall-out. In time of war, of course, it would be the local fall-out which would be of more direct concern, next to blast and thermal effects, and it is to this aspect of fall-out which FCDA addresses itself in the main. In regard to nuclear tests, we have to study the effects on human genetics and the possible effects of such doses of radiation on health. Let us again apply the criterion of normal human experience to this. Measurements have shown that the general average intensity of fall-out gamma rays from tests is 1 to 5 milliroentgens per year. Now the general magnitude of the effects to be expected from this can be compared with the natural radiation intensity. We find, as mentioned earlier, that such things as living in a brick house instead of a wooden house can amount to as much as 25 to 50 milliroentgens extra dosage per year, that there are certain areas in the world where the average dose in this country of 150 milliroentgens per year is exceeded by ten-fold, that people living on granitic rock as compared to those living on sedimentary rock receive about 70 milliroentgens per year more dosage due to the higher content of uranium and thorium in these rocks and that people living at higher altitudes have a higher natural cosmic ray dosage. Also, of course, we know that medical uses of X-rays can be considerably larger than any of these fall-out dosages.

We do have experience and valid evidence that the somatic effects other than cancer and leukemia, that is, the effects of radiation on ordinary human health, require dosages which are very much larger, of the order of 25 to 50 roentgen units in order to be observed as changes in the blood and 100 to 200 roentgens for injury symptoms; whereas the dosages we are speaking of from test fall-out are about one-hundred-thousand-fold smaller.

As for genetic effects, these are extremely difficult to evaluate, since there is so little known about human genetics. But judging from experience with plants, insects, animals, and lower organisms, there is every reason to expect some genetic effects of radiation. The question is how much radiation is required for a given level of effect. There are a certain number of mutations in every new human generation. Are these largely induced by natural radiation or are they mainly of chemical, or rather biochemical origin, or both? From a chemical point of view, it seems likely that not all the spontaneous mutations in the human or any other species are caused by radiation effects, because it seems likely that radiation acts in inducing mutations mainly via molecules which it generates in the human cell, and that the mutations are caused by these chemicals and therefore in a sense are chemical in nature. Now if this be so, and the radiation induced mutations are nearly always caused by chemicals which are produced in the first instance by radiation, then chemicals themselves which are not produced by radiation but have other origins, can cause mutations, so it seems likely that a major part of the natural or spontaneous mutations in any species is not radiation induced. This point is an important one to settle, for the reason that we have to compare the effects of fall-out radiation with the fraction of the natural spontaneous mutations which is due to the radiation we are normally subjected to. In other words, if the normal mutations are all due to radiation, then the effects of the additional radiation from general test fall-out, or from other sources of radiation such as atomic power, or the medical uses of isotopes and X-ray, will be larger. It seems likely, and many genetic authorities agree on genetic grounds with this conclusion, that a major portion of the spontaneous mutations of the human species is not due to radiation but due to other causes. Therefore, a

fraction of the spontaneous mutations in the human species is taken as being due to irradiation. Now, what this fraction is, it is difficult to say, but Professor H. J. Muller has estimated that this might be 10 percent. Therefore, one estimates the 150 milliroentgens per year from natural radiation now causes about 10 percent of the spontaneous mutations, and therefore, that the test fall-out if continued indefinitely will, at the present level of about 1 to 5 milliroentgens per year, cause an increase in the natural spontaneous mutation rate of something like $\frac{1}{50}$ of ten percent, or 0.2 of a percent of the spontaneous mutations. In the extreme, if it should prove that all of the spontaneous mutation rate is radiation induced despite the chemical arguments, the effect would be ten times as great, or two percent. Dr. Dunning of the Division of Biology and Medicine of the AEC estimated 1.4 percent in 1955 on similar assumptions (the Scientific Monthly *81*, 265—December 1955). This effect is one which is comparable to moving to a slightly different locality and is much less serious than changing from one house to another or doing any of a dozen things. The only important point is that genetic effects show only if large numbers of people are subjected to them. Therefore, we would expect that the effects of large populations changing their environment, such as living at a higher altitude, or living in a region of naturally higher radioactivity, should cause genetic effects, if test fall-out does so. An examination of vital records should be made to test for such effects and the Atomic Energy Commission is doing so as best it can. The United Nations Scientific Committee on the Effects of Atomic Radiation has been comparing the data on natural background dosages, and it is hoped that this study will be continued and that the search will be made for observable effects of variations in the natural background dosage, for it is certain that any effects due to gamma rays from fall-out must be already present in much larger measure due to the natural dosage.

II. Variation in Individual Strontium 90 Burdens

What is the likelihood that even though the average strontium 90 content be well within tolerance limits, that a few individuals should exceed tolerance limits? Let us consider first the case which will ultimately hold, the situation of complete equilibrium with the environment in so far as the strontium 90 burden is concerned. The only way we can make judgments about the expected individual variations from the mean concentration is by direct experiment on human body composition, not only for strontium 90 but for other analogous constitutents. Most of the recent data on the strontium 90 body burden are from odd bits of bone removed during surgical operations, but fortunately we have actual data for the strontium 90 content of the entire bodies of some several dozen stillborn children [1] in the city of Chicago in the year 1953. A strenuous effort is now being made on the Sunshine Project to continue this series and also to check the human bone data by analyses of complete skeletons. We present the distribution of the strontium 90 data for the stillborn children in Figure 1. Data for the occurrence of ordinary nonradioactive strontium in human bones also have been published.[2] These obviously refer to the full steady state condition and are obviously at least as nearly in equilibrium with the environment as the fall-out radioactive strontium ever will be. These data are presented in Figure 2. The occurrence of radium in the human body also has been used since it is chemically similar to both calcium and strontium, and therefore is a bone seeker and because it is obviously also in steady state equilibrium. The

[1] W. F. Libby, "Radioactive Strontium Fallout," Proc. Nat. Acad. Sci. *42*, No. 6, 365–390 (1956); University of Chicago, Project Sunshine Bulletin No. 12, August 1, 1956.
[2] K.ur K. Tekian and J. L. Kulp, Science *124*, 405 (1956).

data used were those by Palmer and Queen [3] in Figure 3. And, finally, we use the recent data on occurrence of normal potassium in human bodies as determined by Anderson and Langham [4] at the Los Alamos Scientific Laboratory as presented in Figure 4. All of these data show a normal frequency distribution as indicated by the theoretical curves. The respective widths of the curves (standard deviations) are 36 percent for radiostrontium, 40 percent for normal strontium, 40 percent for radium and 18 percent for natural radiopotassium. It is completely clear from these data that they agree with one another in general shape and that the magnitude of the distribution of the strontium 90 contents of the Chicago stillborn babies was not in any way anomalous. Therefore, we shall take the distribution curve for radiostrontium to be the same as for the normal strontium data. The occurrence of nonradioactive normal ordinary strontium in the bones should certainly tell us what the equilibrium distribution will be for radioactive strontium, and from it we should be able to learn the points about distribution which we cannot yet learn in any detail from the radioactive strontium itself. Turekian and Kulp noted in their study of normal strontium in human bone that in a given region the deviation from the average was about 34 percent of the average, that is, for human bone from the regions Colorado, Texas, Cologne, Bonn, Venezuela, Chile, Vancouver, China and India. In each instance the ratio of the standard deviation from the mean itself was taken and the average calculated to obtain 34 percent. Therefore, we take 34 percent as the expected standard deviation from the mean *for a given locality* for the eventual strontium 90 equilibrium burden in human bones.

With this result we can, assuming a normal error curve shape of the distribution of probabilities, answer the immediate question: What is the probability of an individual exceeding the tolerance even though the mean does not? On the basis of this analysis we find that at steady state and in equilibrium the variation from the mean will constitute an error curve with a shape corresponding to the standard deviation, being ⅓ of the mean. Therefore, at steady state among people living in a given locality, only one person in about 700 will have more than twice the average strontium 90 burden, and the chances of anyone having as much as three times the normal burden will be about one in twenty million.

Now what about the non-equilibrium distribution, when the strontium 90 is finding its way into the biological system? Obviously, the burden will be much lower here, but the deviation from the mean will probably be much higher percentagewise, particularly in adults where most of the bone has been deposited before strontium 90 was produced. The present strontium 90 content of adults depends very much on the growth rate and the metabolic activity of the various bones in the given individual's body which happens to be sampled. However, the specific concentration of the strontium 90 deposited will not exceed that in new bone developed entirely in the present biological environment, i. e., the local concentration in adult bone will not exceed that for the whole bone in young children, whose total bodies are composed of the mixture of strontium 90 and calcium which now is present in food. Since the present ratio for children to adults is about four to one for average total strontium 90 content, the factor of concentration in adults' active bone regions may be as much as four-fold greater than the whole body average. Thus the apparent spread for random bone samples taken from adults should be very large compared to the true equilibrium spread for these reasons. As equilibrium is approached, however, the spread must decrease very, very markedly.

[3] Hanford Report, HW-31242.
[4] E. C. Anderson, R. L. Schuch, W. R. Fisher, and W. Langham, "Potsassium and Cesium Radioactivity in People and Foodstuffs." (In press.)

The data on human bones indicate a very wide scatter, but it seems extremely clear that the variation is a reflection of the fact that the main skeleton of adult individuals is not in equilibrium with the present food supply, and that the variations reflect the different rates at which the various bones in the bodies of individuals are coming into equilibrium with the food supply in the general biological environment. A study of whole skeletons taken from one given locality which is now under way as a part of Project Sunshine will clarify the point about the variations among individuals in their rate of coming into equilibrium with the general biological environment. This study is under way in Dr. Kulp's laboratory.

It should appear from these studies that the variation from the mean of adults will be larger than the factor of one-third which apparently is normal for the types of equilibrium distribution considered above. It is, of course, very important to establish the truth of this prediction clearly. However, the general agreement in shape of the distribution curves for such widely different materials as normal potassium in whole bodies, radium, and normal elementary strontium in fragmentary human bone, and actual fall-out radioactive strontium in the whole bodies of stillborn children, give us good reason to believe that there is nothing extraordinary in the distribution of radiostrontium in human bone.

III. Variation of the Strontium 90 Body Burden With Locality

Most important of the causes of variation of the strontium 90 content of individuals with locality is, of course, the amount of fall-out in a given region. The general rules about the intensity of fall-out have been described above. For air-fired megaton weapons our present indication is that the fall-out is almost worldwide and for reasons of simplicity and in the absence of better information at the present time, we work on the model that this is a uniform distribution, over the entire world, of material that falls from the stratosphere. Further evidence and data on this point are rapidly being collected which will undoubtedly settle the stratospheric horizontal mixing question.

At the present time, the general latitudes in the Northern Hemisphere which are between 10° and 60° North have the highest strontium 90 content. In the United States, which because of our proximity to the Nevada Test Site has unusually high fall-out, there are at the present time about 25 millicuries per square mile of strontium 90. For average soil this means a concentration in the top soil of about 50 Sunshine Units. With the factors of discrimination mentioned above, this means that an equilibrium body burden between 1.7 Sunshine Units and 3.9 Sunshine Units is to be expected. Actually, the present body burden in young children indicates that the lower value is probably more realistic. The present body burden in children—about 0.5 Sunshine Units—probably was derived from an average strontium 90 content in the top soil of something like 15 millicuries per square mile, or about 25 to 30 Sunshine Units during the time the strontium 90 was being acquired. Thus we find that the experimental value for the ratio between the body burden of young children and the average concentration in the top soil is about 50 to 1; rather closer to the higher range of the laboratory results than to the lowest range.

Table II contains the latest data for the total strontium 90 fall-out as measured in United States soils, and Figure 5 displays these data graphically.

The Northern part of the United States has about 20 to 30 millicuries of strontium 90 per square mile, the Southern States are somewhat lower. The low figure of 7 millicuries per square mile for Grand Junction, Colo., is probably due to local climatic and sample site conditions.

TABLE II

Health and Safety Laboratory 1956 Survey of U. S. Soils for Strontium 90 Samples taken between October 8 and 13, 1956. Strontium extracted with 6N HCl at room temperature. Replicates represent individual soil aliquots taken after sampling and air drying. Each error term represents one standard deviation due to counting error

Sampling site	Depth	d/m/gm soil	mc/mi²	mc/mi²	
				Average	Total
Albuquerque, N. Mex	0–2″	0.078±0.001	7.5±0.1	7.3	
		0.075±0.001	7.2±0.1		
	2–10½″	0.008±0.002	4.4±0.9	3.4	11
		0.005±0.002	2.4±0.8		
Atlanta, Ga	0–2″	0.35 ±0.007	14 ±0.3	15	
		0.42 ±0.009	16 ±0.4		
	2–6″	0.018±0.004	2.8±0.6	3.0	18
		0.021±0.003	3.3±0.5		
Binghamton, N. Y	0–2″	0.32 ±0.007	17 ±0.4	18	
		0.35 ±0.007	18 ±0.4		
	2–6″	0.019±0.003	4.4±0.8	5.0	23
		0.024±0.005	5.6±1.1		
Boise, Idaho	0–2″	0.23 ±0.006	20 ±0.6	22	
		0.26 ±0.006	23 ±0.6		
	2–6″	0.012±0.002	3.1±0.6	3.5	26
		0.015±0.002	4.0±0.6		
Des Moines, Iowa	0–2″	0.31 ±0.007	23 ±0.5	23	
		0.31 ±0.007	23 ±0.5		
	2–6″	0.028±0.002	7.6±0.7	7.1	30
		0.024±0.003	6.6±0.7		
Detroit, Mich	0–2″	0.26 ±0.006	20 ±0.5	20	
		0.27 ±0.006	20 ±0.5		
	2–6″	0.038±0.003	7.3±0.5	7.8	28
		0.044±0.003	8.4±0.6		
Grand Junction, Colo	0–2″	0.10 ±0.001	7.8±0.1	7.0	
		0.091±0.001	7.1±0.1		
		0.11 ±0.019	8.2±1.4		
		0.070±0.013	5.1±1.0		
	2–10½″	≤0.002	≤0.45	≤0.48	7
		0.002	≤0.51		
Jacksonville, Fla	0–2″	0.11 ±0.009	7.3±0.6	7.3	
	2–6″	0.013±0.004	2.7±0.9	3.4	11
		0.020±0.005	4.0±1.0		
Los Angeles, Calif	0–2″	0.12 ±0.008	6.9±0.5	7.5	
		0.14 ±0.009	8.0±0.5		10
	2–7″	0.009±0.002	3.3±0.9	2.8	10
		0.006±0.002	2.2±0.7		
Memphis, Tenn	0–2″	0.27 ±0.006	15 ±0.4	15	
		0.26 ±0.006	15 ±0.4		
	2–6″	0.028±0.003	6.5±0.7	6.6	22
		0.029±0.003	6.6±0.7		
New Orleans, La	0–2″	0.24 ±0.006	8.8±0.2	8.6	
		0.22 ±0.006	8.3±0.2		
	2–6″	0.009±0.002	3.3±0.9	2.8	11
		0.006±0.002	2.2±0.7		
New York, N. Y	0–2″	0.21 ±0.006	10 ±0.3	12	
		0.29 ±0.007	14 ±0.3		
	2–6″	0.072±0.004	14 ±0.8	14	26
		0.068±0.004	14 ±0.8		
Philadelphia, Pa	0–2″	0.17 ±0.005	12 ±0.4	12	
		0.16 ±0.005	11 ±0.4		
	2–6″	0.029±0.003	7.3±0.8	6.8	19
		0.026±0.003	6.4±0.7		
Rapid City, S. Dak	0–2″	0.29 ±0.006	20 ±0.4	22	
		0.34 ±0.006	23 ±0.4		
	2–6″	0.053±0.004	12 ±1.0	11	33
		0.045±0.003	10 ±0.7		
Rochester, N. Y	0–2″	0.22 ±0.006	16 ±0.4	16	
	2–6″	0.013±0.002	2.5±0.4	2.5	19
		0.013±0.002	2.5±0.4		
Salt Lake City, Utah	0–2″	0.32 ±0.007	22 ±0.5	22	
		0.33 ±0.007	23 ±0.5		
		0.31 ±0.007	22 ±0.5		
	2–8″	0.016±0.002	5.7±0.7	5.8	28
		0.016±0.002	5.9±0.8		
Seattle, Wash	0–2″	0.46 ±0.011	17 ±0.4	17	
		0.44 ±0.010	16 ±0.4		
	2–6″	0.051±0.007	9.4±1.2	9.5	27
		0.052±0.004	9.6±0.7		

The differential rates at which the fall-out has been occurring probably are best measured by the so-called "pot collection" method. A bucket with vertical walls of appreciable height is placed out in the open and allowed to collect the total fall-out for a given period including the rain, snow, dust, etc. The bucket is left out whether it has rained or not and covers the total fall-out for a given period. Figures 6 and 7 give the curves so obtained for New York and Pittsburgh areas together with the estimated errors of measurement. It is interesting to note the changes in slope and to correlate them with the occurrence of test activities and the relatively short-lived tropospheric fall-out. The minimum slopes which appear during quiet periods when no one is testing are the stratospheric fall-out of which we have spoken and these slopes when we have enough pots operating all over the world will, when taken together with the results of the measurements of the amounts of radiostrontium and radiocesium in the stratosphere, give an accurate value for the stratospheric residence time and settle the mixing question.

In addition to the intensity of fall-out, the question of the fraction of the radiostrontium, and, for tropospheric fall-out, the radioiodine of eight-day half-life, that is in assimilable form is an important one. So far most fall-out strontium appears to be completely water soluble and therefore most assimilable, though continued tests on this point should be made. Direct leaf pick-up of course promotes assimilation of the strontium because the plant differentiation against strontium when it assimilates it from soil thus is avoided. Another factor is, of course, the concentration of available calcium in the soil. By available calcium we mean calcium which is available to plants and not the total calcium in the soil. It is known that soils which are high in available calcium produce plants of lower radioactive strontium content; that is, the radioactive strontium to calcium ratio in the plant is lower as a direct consequence of the lower concentration of radiostrontium in the available soil calcium. In addition, as mentioned previously, plants tend to prefer calcium to strontium with a discrimination factor of about 1.4. Sheep which grow in certain areas of Wales have shown concentrations in their bones approaching 150 Sunshine Units, while sheep and cattle growing in the U. S. have hardly ever exceeded one-fifth of this. The Welsh soil in certain areas is very low in calcium and as a result grows grasses of high radiostrontium content. Of course, it is clear that fertilization with calcium will immediately relieve this difficulty, but in the absence of such fertilization, the question is: How serious is the effect of calcium deficiency in promoting strontium 90 pick-up through the food chain?

As was remarked earlier, there is an averaging which occurs in food distribution systems and calcium deficient soils are naturally rather poor producers and as a consequence the weight of the food so produced is less than for a good well fertilized, well balanced soil. This factor reduces the flow into the general food system of material of exceptionally high strontium 90 content. It therefore will probably be sufficient to consider the radiostrontium of milk, since milk is the main source of calcium, in order to test for the radiostrontium content of the food in given areas. Direct measurements have shown that a factor of five encompasses the total variation due to all factors including calcium deficiencies in acid soils.

The general intake must depend on the food distribution pattern and the relatively small fluctuation in milk contents must reflect this. The number of individuals who rely totally on the food output of soil of very low calcium content is very small indeed, but it must be true that these individuals if they grew up on such a provincial, isolated farm would have as much as ten to 50 times the normal

average strontium 90 content. The normal calcium concentration in soils in the United States is about 20 grams per square foot for the top 2.5 inches and about the poorest soil known has about 0.4 gram available calcium per square foot for the top 2.5 inches—a deficiency factor of 50.

It is clear from a detailed examination made by the author for people living in calcium deficient areas with normal food distribution patterns, that a factor of 5 is about as large an effect as can be expected from a fifty-fold deficiency of calcium in the soil. The food from outside of the calcium deficient area reduces by a factor of about ten the increase in strontium 90 pick-up rate which would be expected from the calcium deficiency in the soil if people lived entirely off the soil for their whole growing period of 20 years or so.

The food of lowest strontium 90 content is fish flesh, because of the great dilution the fall-out receives by the hundred meters of sea water above the thermocline, which rapidly mix with the fall-out within a few hours or days. This means that the specific concentration of radioactive strontium, or any other fall-out constituent in sea water, is relatively very much lower than it would be in soil. For example, 100 meters of sea water has 370 grams of dissolved calcium per square foot as compared to the average of 20 grams per square foot for the top 2.5 inches of soil which absorbs and holds the fall-out radiostrontium. Therefore, in principle sea food and fish are lowest among foods in content of radiostrontium fall-out.

IV. Effects of Continued Testing and General Conclusions

In summary, then, we see that the present body burden of strontium 90 from atomic weapons tests in the United States corresponds to the radiation dosage to the bones which would result from a few hundred feet increase in altitude, and the present vital statistics show no observable effect on the occurrence of bone cancer or leukemia of much larger changes in altitude. The tolerance figure of 100 Sunshine Units, or 0.1 of a microcurie for an average individual, or 100 micromicrocuries per gram of body calcium, that is recommended now is about two hundred times the present level for new bone in the U. S., and it will not be exceeded by fall-out from weapons tests in any foreseeable circumstances.

The distribution of strontium 90 burdens among individuals *for a given locality* will be a normal error curve with a standard deviation of about one-third of the average concentration. This means that about one individual in 300 will have more than twice the normal average value for a given locality, and that about 1 in several million will have three times the average value.

The effect of locality is more important, however, particularly in the effect of calcium deficiency in the soils. Careful consideration of this question indicates that there will be very few individuals who show a strontium 90 content which is strictly inversely proportional to the available calcium concentration of the soil in their region. This is due to the fact that food distribution systems automatically average over a wide area and people assimilate their calcium slowly. Most people drink milk and eat cheese and other calcium-bearing foods from a rather wide area, and this effect reduces by an estimated factor of ten the potential effect of calcium deficiency in the local soils.

On the basis of laboratory experiments the human body concentration of strontium 90 at equilibrium will be between 13 and 30 times less than that in the top soil. The present data indicate that the higher figure is closer to the truth, and so we will be conservative in taking the figure of 20 for this ratio. Therefore,

the present burden of 50 Sunshine Units in the top soil of the United States may eventually lead to as much as 2.5 Sunshine Units in the human bones, but more likely will lead to about 1.7.

Of course, as testing continues and more fall-out occurs, the levels will rise. In the United States the strontium 90 that still resides in the stratosphere at the present will fall out according to our expectations at a rate which just about compensates for the decay of the material already deposited, so that no great additional increase from this source is to be expected from weapons fired in the past. If the testing should continue at about the same rate as it has averaged over the last 5 years, then we should at equilibrium, after an infinite time, approach a level of 8 times the present rate, since the average life of strontium 90 is 40 years. This assumes that the future testing will be conducted so as to give in each future 5-year period the same as the last 5 have. And so we would expect in the United States at that time an average human strontium 90 concentration of 20 Sunshine Units with the conservative factor of 20 between the top soil concentration and the concentration in human bone, or 5 Sunshine Units if the factor of 80 is used. In other words, in the United States something between 5 and 20 Sunshine Units would be the equilibrium concentration of human bones if testing continued indefinitely at the average rate of the past 5 years. This level would be approached only after a few decades. After 28 years the level would be half of this equilibrium value, and after another 28 years, 56 years total, from an arbitrary beginning which we have set as 1952, we would expect in the year 2008 three-fourths of the equilibrium figures. So somewhere between 4 and 15 Sunshine Units of strontium 90 in human bones in the United States might result from the present type of testing being continued for the next 50 years.

In those certain areas in the world where the soil is low in calcium, this level might go five-fold higher. At the present rate of testing we might indeed approach the figure of 100 Sunshine Units, the tolerance limit for large populations, at the beginning of the 21st century for these certain limited regions in the world. The observed conditions in these regions could be relieved, however, by fertilization of the soil with calcium, either calcium nitrate or lime being used, as appropriate from other considerations.

The Sunshine Project continues to study the problems of worldwide fall-out—the stratospheric inventory of radiostrontium and radiocesium, the occurrence of these isotopes in the soils and water and the biosphere all over the earth, the biological effects at certain levels of contamination with strontium 90, and to a lesser degree with cesium 137, and the possible genetic effects of the low gamma ray dosages associated with worldwide fall-out from atomic tests. All of these are studied not only with the point in mind of devising methods of protection against atomic warfare, but also with the thought of possible application in the remote event of industrial accidents which may happen in connection with certain of the peaceful uses of atomic energy, particularly atomic power. Certainly an understanding of the basic principles of worldwide fall-out is applicable to the control and safe-handling of isotopes. All of this is done in collaboration with the United Nations Scientific Committee on the Effects of Atomic Radiation, and it is to be hoped that as the data appear all of the countries in the world will join together in this international effort to understand better the effects of the great new fact in life, the nuclear atom.

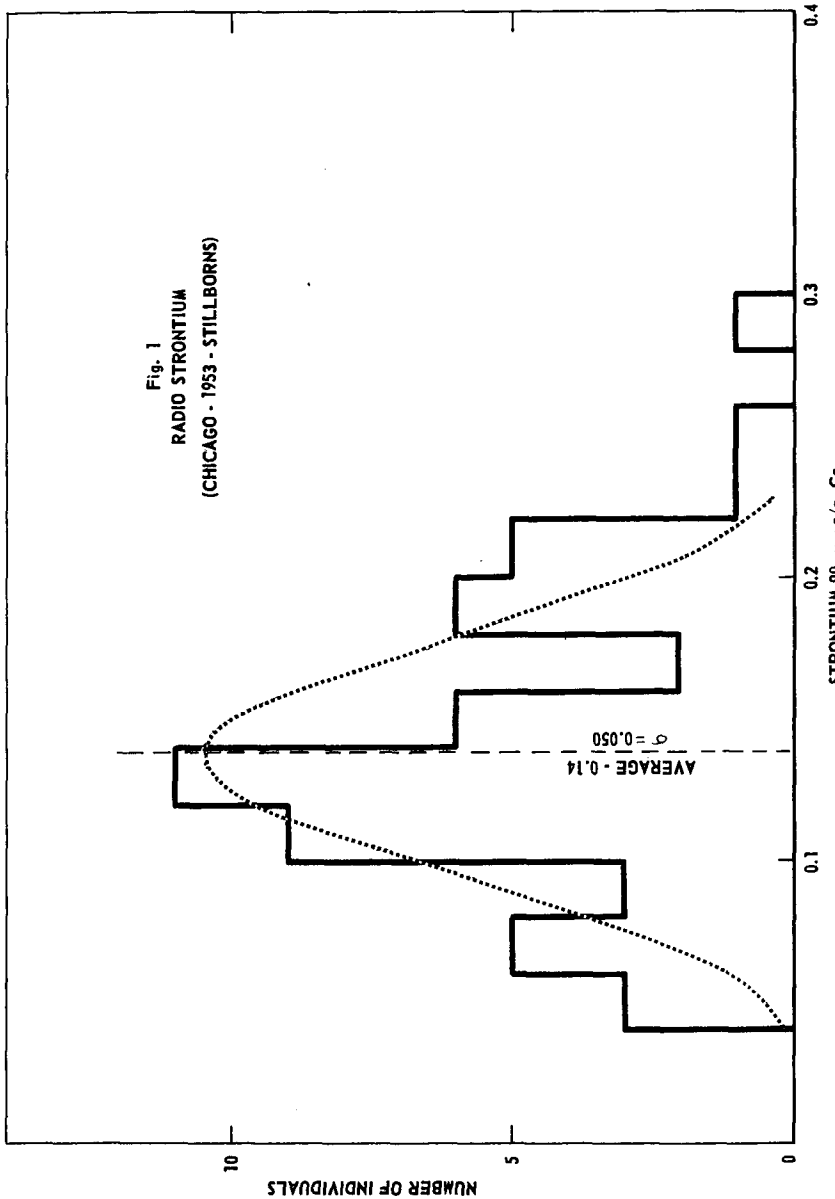


Fig. 1
RADIO STRONTIUM
(CHICAGO - 1953 - STILLBORNS)
AVERAGE - 0.14
σ = 0.050
NUMBER OF INDIVIDUALS
0
5
10
0.1
0.2
0.3
0.4
STRONTIUM-90 μμc/g. Ca

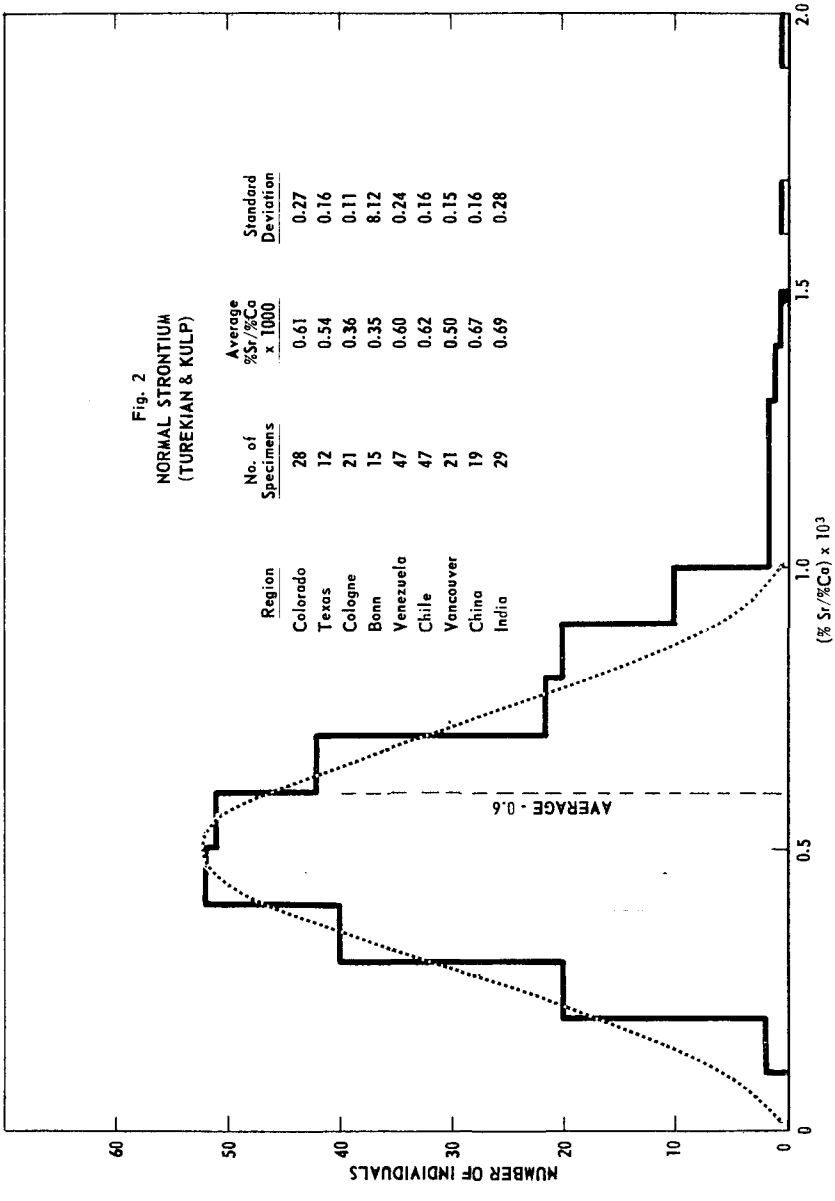


Fig. 2
NORMAL STRONTIUM
(TUREKIAN & KULP)
Region
No. of Specimens
Average %Sr/%Ca x 1000
Standard Deviation
Colorado 28 0.61 0.27
Texas 12 0.54 0.16
Cologne 21 0.36 0.11
Bonn 15 0.35 8.12
Venezuela 47 0.60 0.24
Chile 47 0.62 0.16
Vancouver 21 0.50 0.15
China 19 0.67 0.16
India 29 0.69 0.28
AVERAGE - 0.6
NUMBER OF INDIVIDUALS
0
10
20
30
40
50
60
0
0.5
1.0
1.5
2.0
(% Sr/%Ca) x 10³

430209—57——17

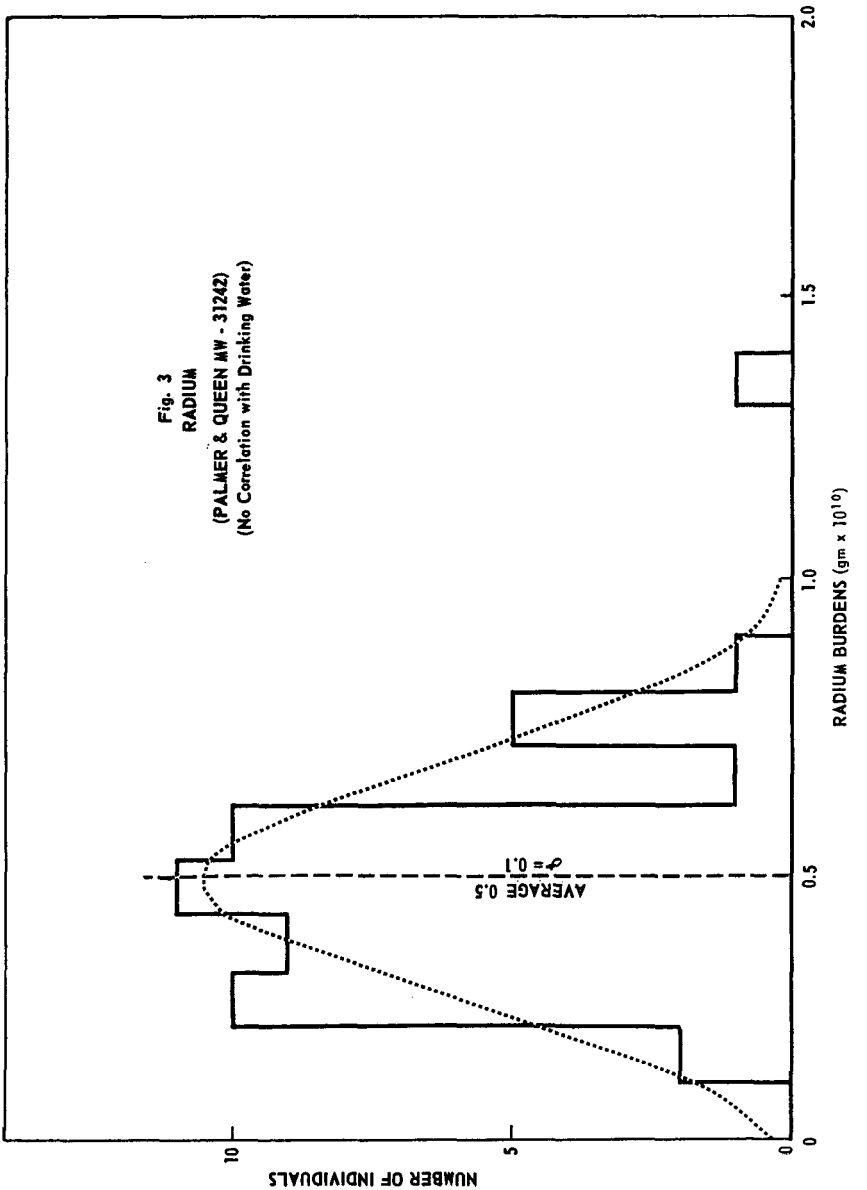


Fig. 3
RADIUM
(PALMER & QUEEN MW - 31242)
(No Correlation with Drinking Water)
AVERAGE 0.5
σ = 0.1
NUMBER OF INDIVIDUALS
0
5
10
0
0.5
1.0
1.5
2.0
RADIUM BURDENS (gm x 10^10)

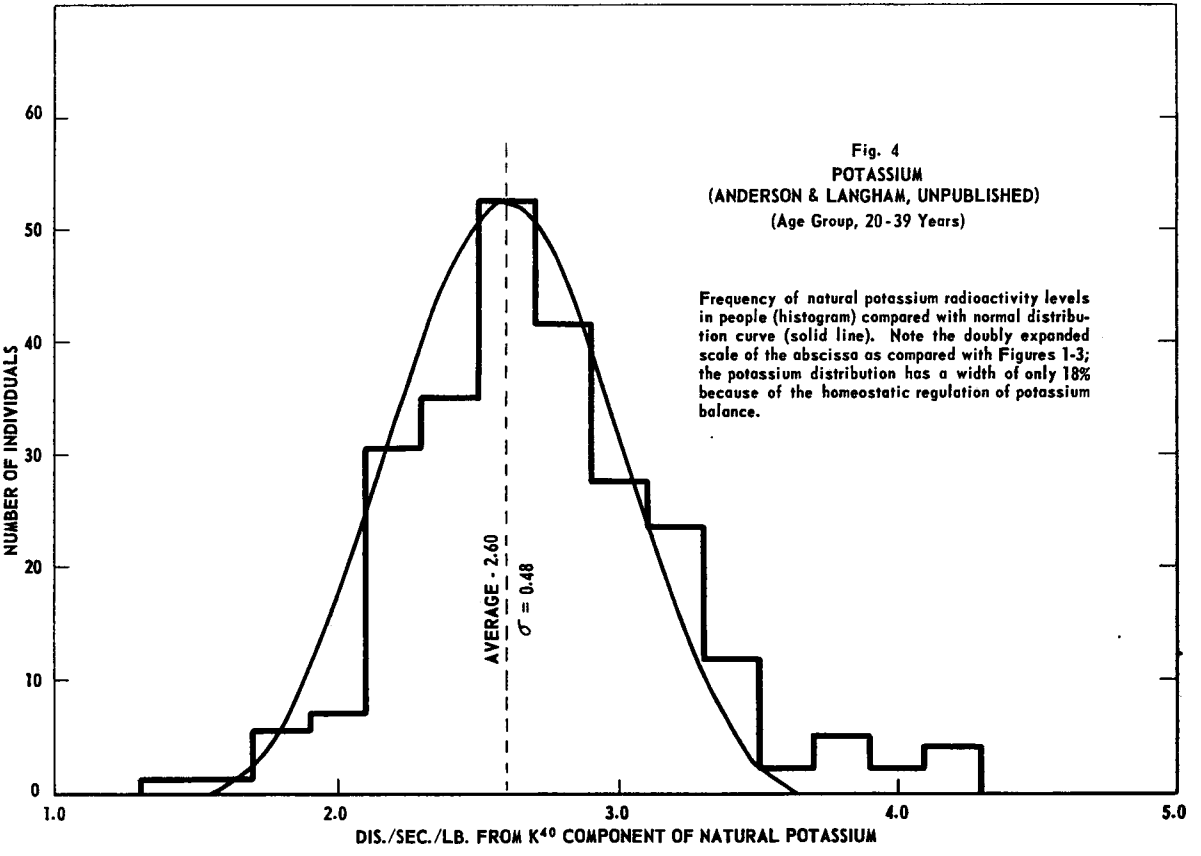
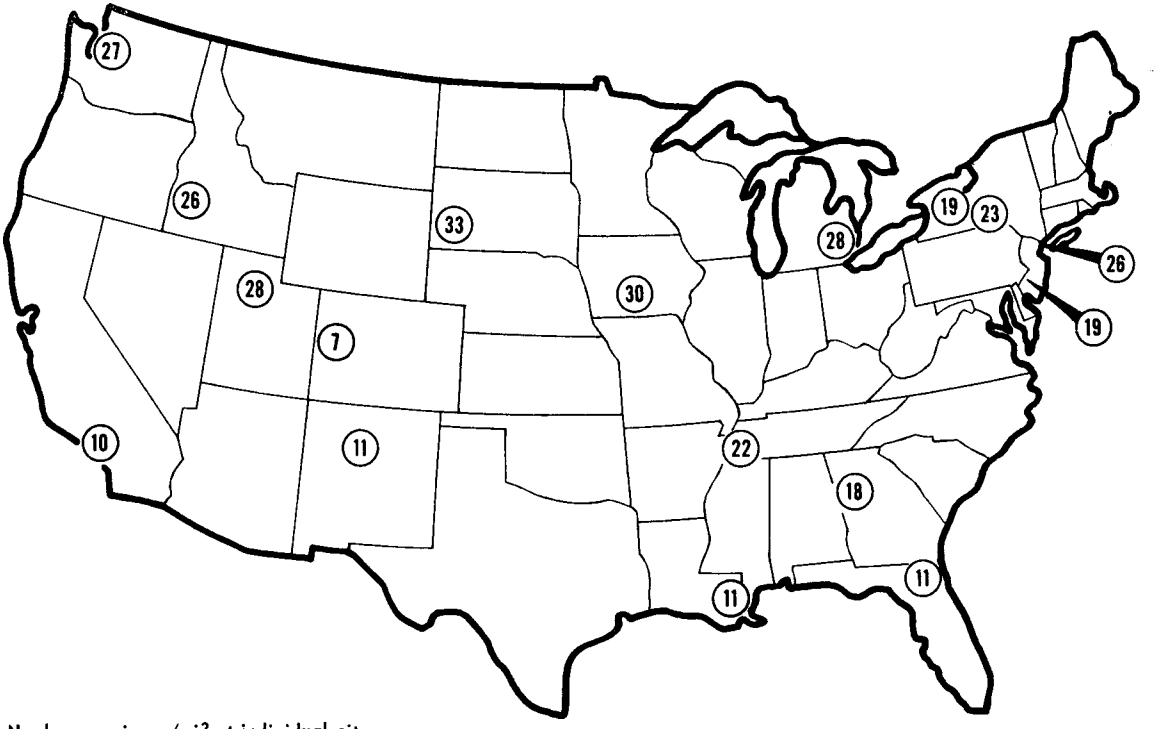


Fig. 4
POTASSIUM
(ANDERSON & LANGHAM, UNPUBLISHED)
(Age Group, 20-39 Years)

Frequency of natural potassium radioactivity levels in people (histogram) compared with normal distribution curve (solid line). Note the doubly expanded scale of the abscissa as compared with Figures 1-3; the potassium distribution has a width of only 18% because of the homeostatic regulation of potassium balance.

Fig. 5

Sr^{90} IN U. S. SOIL (HASL - OCT. 8, 1956) (HCl EXTRACTION METHOD)



Numbers are in mc/mi^2 at individual site.

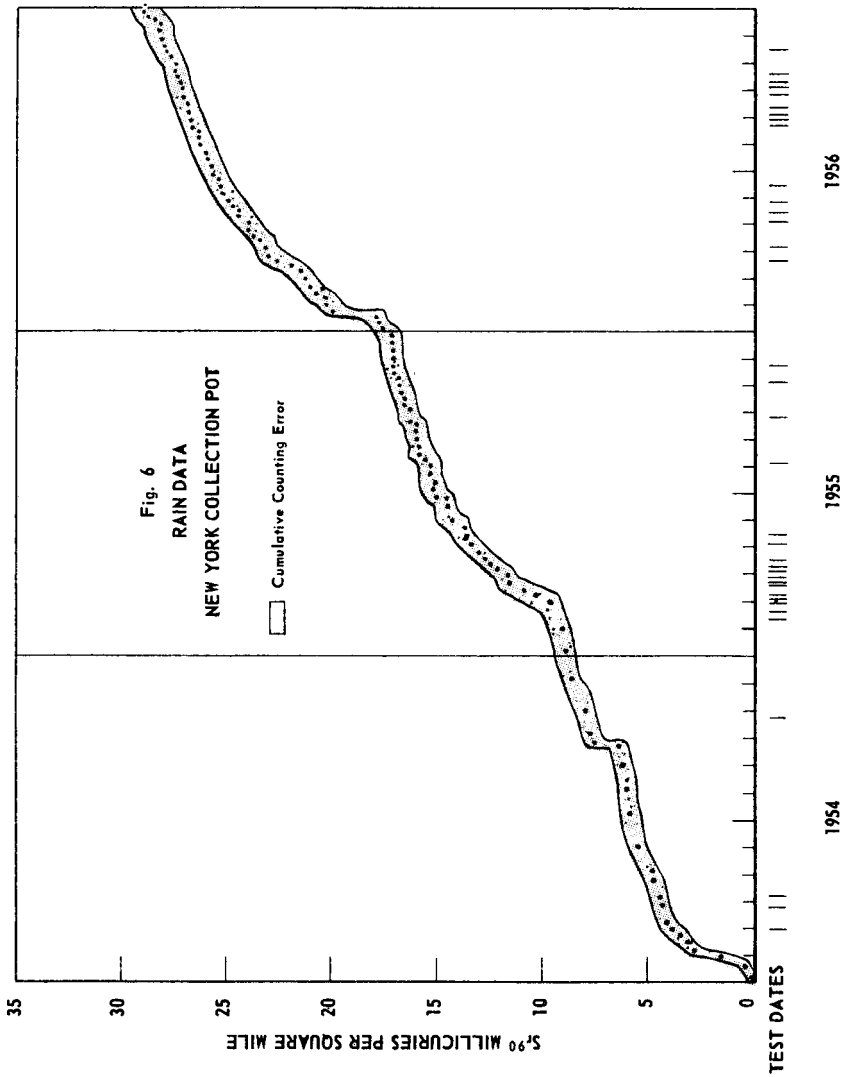


Fig. 6
RAIN DATA
NEW YORK COLLECTION POT
Cumulative Counting Error
S_r^{90} MILLICURIES PER SQUARE MILE
35
30
25
20
15
10
5
0
TEST DATES
1954
1955
1956

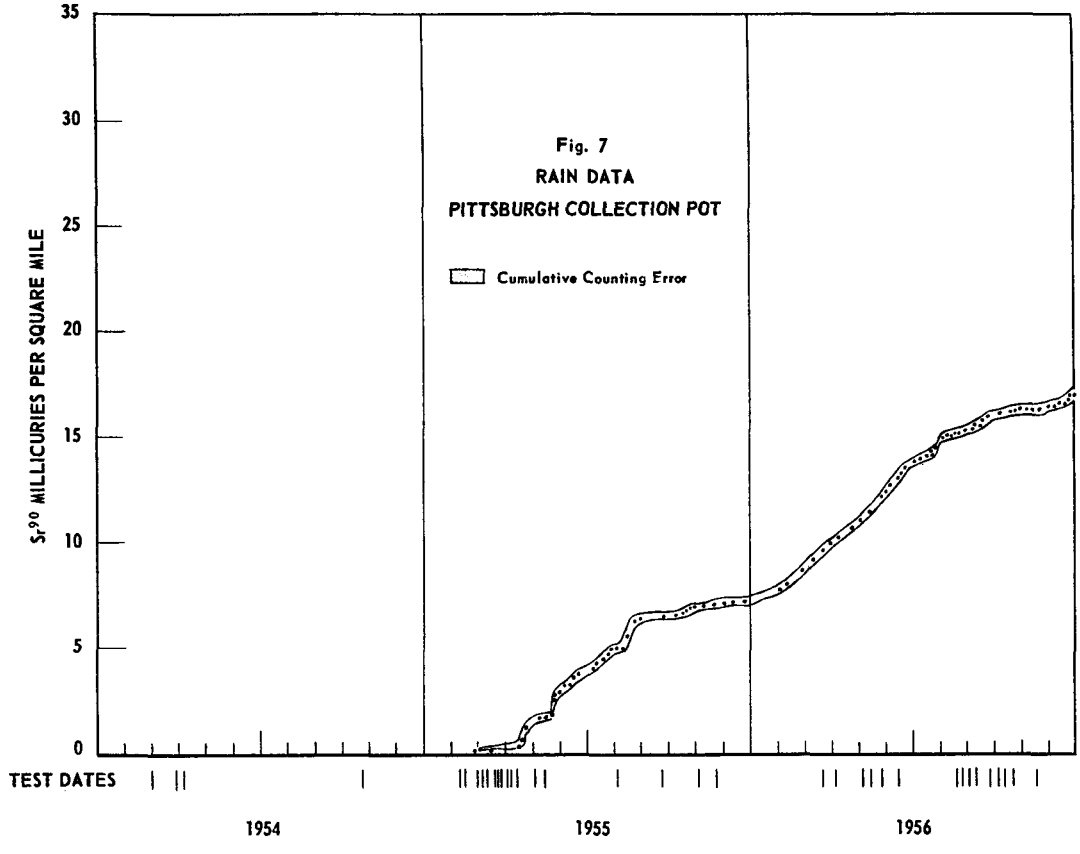


Fig. 7
RAIN DATA
PITTSBURGH COLLECTION POT
Cumulative Counting Error
Sr⁹⁰ MILLICURIES PER SQUARE MILE
35
30
25
20
15
10
5
0
TEST DATES
1954
1955
1956

APPENDIX 12

Nuclear Reactors Built, Building or Planned in the United States as of June 30, 1957

The following tabulation is a compilation of facilities built, building, or planned in the United States as of June 30, 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.

In the case of experimental facilities in which many reactor core designs may be tested during the life of the facility the general practice has been to make only one entry on the list. In these instances, as in those of certain critical experiments and zero power reactors, the factor controlling the number of entries is the number of "hot cells" or control panels, whichever is less; in other words, the number of simultaneous controlled nuclear chain reactions possible.

Start-up dates refer to the year of first criticality. Start-up dates shown for projects not yet in service are estimates based on the best available information. The dates for non-AEC 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.
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 or public announcement is made, whichever is first.
c) Reactors for foreign locations—when public announcement is made.

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 below.

Abbreviation	*Name of Principal Contractor*
AC	Allis-Chalmers Manufacturing Co.
ACF	ACF Industries, Inc.
AG	Aerojet-General Corp. or Aerojet-General Nucleonics
Alco	Alco Products, Inc.
AMF	AMF Atomics, Inc., a subsidiary of American Machine & Foundry Co.
ANL	Argonne National Laboratory, operated by the University of Chicago
ARSS	American Radiator and Standard Sanitary Corp.
B&W	Babcock & Wilcox Co., The
BAC	Bendix Aviation Corp.
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.
DuPont	E. I. DuPont de Nemours & Co.
FW	Foster Wheeler Corp.
GDC	General Atomic Division of General Dynamics Corp.
GE	General Electric Co.
GNE	General Nuclear Engineering Co.
HKF	H. K. Ferguson Co., The
IP	Isotope Products, Inc.
KE	Kaiser Engineers, Division of Henry J. Kaiser Co.
LASL	Los Alamos Scientific Laboratory, operated by University of California
Lockheed	Lockheed Aircraft Corp.
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
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.
PPC	Phillips Petroleum Co.
P&W	Pratt and Whitney Aircraft Division, United Aircraft Corp.
West	Westinghouse Electric Corp.

NUCLEAR REACTORS BUILT, BUILDING, OR PLANNED IN THE UNITED STATES AS OF JUNE 30, 1957

Category	Operated, later dismantled	Operated	Being built	Planned	Total
A. High Temperature Power Producing Reactors:					
A.1. Full scale civilian power reactors, United States locations			5	17	22
A.2. Full scale civilian power reactors, foreign locations				8	8
A.3. Civilian power reactor experiments	6	4	4	4	18
A.4. Full scale military power reactors		2	16	9	27
A.5. Military prototypes and experiments, unclassified	3	2	5	1	11
A.5.(c) Military prototypes and experiments, classified (not listed)		1	2	2	5
Total, high temperature	9	9	32	41	91
B. Low Temperature Reactors (*not useful for power generation*):					
B.1. Research and training reactors, United States locations	6	18	7	31	62
B.2. Research and training reactors, foreign locations		2	8	11	21
B.3. Reactors for general testing		1	2	2	5
B.4. Reactors for specialized testing		11	5	3	19
B.5. Critical experiments, unclassified	9	26	11	4	50
B.5.(c) Critical experiments, classified (not listed)		4	1	1	6
B.6. Production reactors		13			13
Total, low temperature	15	75	34	52	176
Grand total	24	84	66	93	267

NUCLEAR REACTORS BUILT, BUILDING OR PLANNED IN THE UNITED STATES AS OF JUNE 30, 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
Being built:					
General Electric Co. and Pacific Gas & Electric Co	Pleasanton, Calif	GE	Boiling water	5,000	1957
Pressurized Water Reactor (AEC and Duquesne Light Co.)	Shippingport, Pa	West.	Pressurized water	60,000	1957
Commonwealth Edison Co., et al	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.[2]	Monroe, Mich	Owner	Fast breeder	100,000	1960
Planned:					
Rural Cooperative Power Association [3 4]	Elk River, Minn	AMF	Boiling water	22,000	1959
Yankee Atomic Electric Co.[2]	Rowe, Mass	West.	Pressurized water	134,000	1960
Wolverine Electric Cooperative [3 4]	Hersey, Mich	FW	Aqueous homogeneous	10,000	1961
Consumers Public Power District [3]	Beatrice, Nebr	NAA	Sodium graphite	75,000	1962
Florida Nuclear Power Group [4]	Florida	GNE	Gas cooled, heavy water moderated.	136,000	1962
Northern States Power Co., et al [5]	Minnesota	AC	Boiling water	66,000	1962
Pennsylvania Power & Light Co	Eastern Pennsylvania	West.	Aqueous homogeneous	150,000	1962
West Penn Group, Reactor No. 1	Ohio Valley			13,000	1962
New England Electric System	New England			200,000	1964
West Penn Group, Reactor No. 2	Ohio Valley			200,000	1965
Carolinas-Virginia Nuclear Power Associates, Inc				10-30,000	
Chugach Electric Association, Inc., and Nuclear Development Corp. of America.[5]	Anchorage, Alaska	NDA	Sodium, heavy water	10,000	
Pacific Gas & Electric Co	California				
City of Piqua, Ohio [3]	Piqua, Ohio	NAA	Organic moderated	12,500	
AEC and Puerto Rico Water Resources Authority	Puerto Rico			15-20,000	
Merchant Ship Reactor (AEC) [7]	Shipboard	B&W	Pressurized water	20,000SHP	1960
Isotope Products, Inc.[8]		IP	Boiling water	No elec.	1958

A.2. FULL SCALE CIVILIAN POWER REACTORS. FOREIGN LOCATIONS

Planned:					
Belgium (Syndicat d'Etude de l'Energie Nucleaire—SEEN)	Mol	West.	Pressurized water	11,500	1959
Brazil (American and Foreign Power Co.) [9]		GE	Boiling water	10,000	
Cuba (American and Foreign Power Co.) [9]		GE	Boiling water	10,000	
Dominican Republic, Government of [9]		Martin	Pressurized water	12,000	
Italy (Edisonvolta) [9]	Milan	West.	Pressurized water	134,000	1961
Mexico (American and Foreign Power Co.) [9]		NAA	Organic moderated	10,000	
Philippines (General Public Utilities Corp.) [9]	Manila		Pressurized water	60,000	
Peru, Government of	Near Lima	B&W	Pressurized water	21,000	

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	Liquid metal	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	3,400	1955	1956
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	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	6,500	1957	
Being built:							
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	300–1,000	1957	
Los Alamos Power Reactor Experiment No. 2	LAPRE-2	Los Alamos, N. Mex.	LASL	Aqueous homogeneous	No elec	1957	
Los Alamos Molten Plutonium Reactor Experiment No. 1.	LAMPRE-1	Los Alamos, N. Mex.	LASL	Fast molten plutonium	No elec	1958	
Planned:							
Experimental Breeder Reactor No. 2	EBR-2	NRTS, Idaho	ANL	Fast breeder	20,000	1959	
Liquid Metal Fuel Reactor Experiment	LMFRE		B & W	Liquid metal	No elec		
Argonne Boiling Reactor Facility	ARBOR	NRTS, Idaho		Boiling water	No elec		
Plutonium Recycle Reactor	PURR	Hanford, Wash.	GE	Heavy water	No elec		

See footnotes at end of table, p. 254.

NUCLEAR REACTORS BUILT, BUILDING OR PLANNED IN THE UNITED STATES AS OF JUNE 30, 1957—Con.

A. High Temperature Power Producing Reactors—continued

A.4. FULL SCALE MILITARY POWER REACTORS

Name and/or owner	Designation	Designer	Type	Start-up
Operated:				
Submarine USS Nautilus (USN)	SSN571	West.	Pressurized water	1955
Submarine USS Seawolf (USN)	SSN575	GE	Sodium	1956
Being built:				
Submarine Skate (USN)	SSN578	West.	Pressurized water	
Submarine Swordfish (USN)	SSN579	West.	Pressurized water	
Submarine Sargo (USN)	SSN583	West.	Pressurized water	
Submarine Seadragon (USN)	SSN584	West.	Pressurized water	
Submarine Skipjack (USN)	SSN585	West.	Pressurized water	
Submarine Triton, 2 reactors (USN)	SS(R)N586	GE	Pressurized water	
Submarine Halibut (USN)	SS(G)N587	West.	Pressurized water	
Submarine Scamp (USN)	SSN588	West.	Pressurized water	
Submarine Scorpion (USN)	SSN589	West.	Pressurized water	
Submarine Sculpin (USN)	SSN590	West.	Pressurized water	
Submarine Shark (USN)	SSN591	West.	Pressurized water	
Submarine Snook (USN)	SSN592	West.	Pressurized water	
Submarine (not named) (USN)	SSN593	West.	Pressurized water	
Guided Missile Cruiser, Long Beach, (2 reactors) (USN)	CG(N)160	West.	Pressurized water	
Planned:				
Army Package Power Reactor No. 1a (USA) [10]	APPR-1a	Alco	Pressurized water	1959
Aircraft Carrier, 8 reactors (USN)	CVA(N)	West.	Pressurized water	

A.5. MILITARY PROTOTYPES AND EXPERIMENTS

Name and/or owner	Designation	Location	Principal contractor	Type	Power (electric kilowatts)	Start-up	Dismantled
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			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			
Submarine Advance 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	
Planned:							
Gas Cooled Reactor Experiment (AEC)	GCRE	NRTS, Idaho	AG	Gas cooled		1959	

See footnotes at end of table, p. 254.

NUCLEAR REACTORS BUILT, BUILDING OR PLANNED IN THE UNITED STATES AS OF JUNE 30, 1957—Con.

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 Eng. 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. M	LASL	Homogeneous	1944	1944
High Power Water Boiler, rebuilt as SUPO (AEC)	HYPO	Los Alamos, N. M	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. M	LASL	Homogeneous	1951	
North American Aviation Water Boiler Neutron Source (AEC).	WBNS	Van Nuys, Calif	NAA	Homogeneous	1952	
Livermore Water Boiler (AEC)	LIWB	Livermore, Calif	NAA	Homogeneous	1953	
North Carolina State College (Raleigh Research Reactor).[12]	RRR	Raleigh, N. C	Owner	Homogeneous	1957	
Argonne Research Reactor (AEC)	CP-5	Lemont, Ill	ANL	Heavy water	1954	
Pennsylvania State University		Univ. Park, Pa	Owner	Pool	1955	
U. S. Naval Post Graduate School[13]	AGN-201-100	Monterey, Calif	AG	Homogeneous solid	1956	
Catholic University of America[13]	AGN-201-101	Washington, D. C	AG	Homogeneous solid	1957	
Oklahoma A&M College[13]	AGN-201-102	Stillwater, Okla	AG	Homogeneous solid	1957	
Aerojet-General Corporation	AGN-201-103	San Ramon, Calif	AG	Homogeneous solid	1957	
Armour Research Foundation		Chicago, Ill	NAA	Homogeneous	1956	
Battelle Memorial Institute		West Jefferson, Ohio	AMF	Pool	1956	
Naval Research Laboratory (USN)		Washington, D. C	NRL	Pool	1956	
Omega West Reactor (AEC)	OWR	Los Alamos, N. M	LASL	Tank	1956	
Argonne Naught Power Reactor	Argonaut	Lemont, Ill	ANL	Graphite/water	1957	
Being built:						
Livermore Pool Type Reactor (AEC)	LPTR	Livermore, Calif	FW	Pool	1957	
Oak Ridge Research Reactor (AEC)	ORR	Oak Ridge, Tenn	ORNL	Tank	1957	
Brookhaven Medical Reactor (AEC)		Brookhaven Lab	Daystrom	Tank	1957	
University of Michigan		Ann Arbor, Mich	B&W	Pool	1957	
Massachusetts Institute of Technology	MITR	Cambridge, Mass	ACF	Heavy water	1959	
Industrial Research Laboratories, Inc		Plainsboro, N. J	AMF	Pool	1958	
Curtiss-Wright Corporation		Quehanna, Pa	Daystrom	Pool	1957	
Planned:						
Aerojet-General (12 reactors)[14]	AGN-201	San Ramon, Calif	AG	Homogeneous solid	1957–1958	
University of Utah[15]	AGN-201	Salt Lake City, Utah	AG	Homogeneous solid	1957	
Texas A & M College[14]	AGN-201	College Station, Texas	AG	Homogeneous solid	1957	
University of California[15]	AGN-201	Berkeley, Calif	AG	Homogeneous solid	1957	
Colorado State University[15]	AGN-201	Fort Collins, Colo	AG	Homogeneous solid	1957	
National Naval Medical Center[14]	AGN-201M	Bethesda, Md	AG	Homogeneous solid	1957	

Dow Chemical Co.[14]	Midland, Mich.		Liquid metal	1958	
University of California at Los Angeles Medical Reactor.[14]	Los Angeles, Calif.	NAA	Homogeneous		
State College of Washington[14]	Pullman, Wash.	GE	Pool	1958	
Daystrom Nuclear Division of Daystrom, Inc.[14]	West Caldwell, N. J.	Daystrom	Graphite/water	1957	
Stanford Research Institute	Palo Alto, Calif.				
University of Buffalo [14]	Buffalo, N. Y.	AMF	Pool	1958	
Watertown Arsenal [14]	Watertown, Mass.		Pool	1959	
University of Virginia [14]	Charlottesville, Va.		Pool	1958	
Union Carbide Nuclear Company [14]	Orange County, N. Y.	AMF	Pool	1958	
American Radiator and Standard Sanitary Corp.	Redwood City, Calif.	ARSS	Graphite/water	1957	
Atomics International [14]	Canoga Park, Calif.	NAA	Homogeneous	1957	
University of Florida	Gainesville, Fla.	Owner	Graphite/water	1958	
University of Oklahoma	Norman, Okla.	NAA	Homogeneous	1958	
Rice Institute	Houston, Tex.	NAA	Homogeneous	1958	

B.2. RESEARCH AND TRAINING REACTORS, FOREIGN LOCATIONS

Owner	Location	Principal contractor	Type	Start-up	Dismantled
Operated:					
Switzerland, Government of [16]	Wuerenlingen	ORNL	Pool	1955	
Netherlands, Government of (International Exhibit)	Amsterdam	AMF	Pool	1957	
Being built:					
Brazil, Government of (University of Sao Paulo)	Sao Paulo	B&W	Pool	1957	
Denmark, Government of (Atomic Energy Commission)	Risoe	FW	Tank	1957	
Denmark, Government of (Atomic Energy Commission)	Risoe	NAA	Homogeneous	1957	
Germany, Federal Republic of (Farbwerke Hoechst, AG)	Frankfurt	NAA	Homogeneous	1957	
Germany, Federal Republic of (Society for the Utilization of Nuclear Energy in Shipbuilding & Navigation, Inc.).	Hamburg	B&W	Pool	1957	
Germany, Federal Republic of (Technische Hochschule Muenchen)	Munich	AMF	Pool	1957	
Italy, Government of (National Committee for Nuclear Research)	Ispra	ACF	Heavy water	1958	
Japan, Government of (Atomic Energy Research Institute)	Tokai-mura	NAA	Homogeneous	1957	
Planned:					
Argentina, Government of	Buenos Aires				
Canada (McMaster University)	Hamilton, Ont.	AMF	Pool		
Greece, Government of (Atomic Energy Commission) [9 17]	Near Athens	AMF	Pool	1958	
Israel		AMF	Pool		
Italy (Societe Ricerche Impienti Nucleari)		AMF	Pool		
Japan, Government of (Atomic Energy Research Institute)	Tokai-mura	AMF	Heavy water	1958	
Netherlands, Government of (Reactor Center) [17]	Petten	ACF	Tank		
Spain, Government of (Junta de Energia Nuclear) [17]	Near Madrid	GE	Pool		
Sweden (*Aktiebolaget Atomenergi*)	Studsvik	ACF	Tank		
Venezuela, Government of (Institute for Neurology and Brain Research)	Near Caracas	GE	Tank	1958	
West Berlin, Senate of Land Berlin (Institute for Nuclear Research).[9 17]	West Berlin	NAA	Homogeneous	1957	

See footnotes at end of table, p. 254.

NUCLEAR REACTORS BUILT, BUILDING OR PLANNED IN THE UNITED STATES AS OF JUNE 30, 1957—Con.

B. Low Temperature Reactors (Not Useul for Power Generation)—Continued

B.3. REACTORS FOR GENERAL TESTING

Name and/or owner	Designation	Location	Principal contractor	Type	Start-up	Dismantled
Operated:						
Materials Testing Reactor (AEC)	MTR	NRTS, Idaho	Fluor	Tank	1952	
Being built:						
Engineering Test Reactor (AEC)	ETR	NRTS, Idaho	KE	Tank	1957	
Westinghouse Testing Reactor	WTR	Waltz Mill, Pa.	Owner	Tank		
Planned:						
National Advisory Committee for Aeronautics [14]	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	DuPont	Graphite	1953	
Hanford 305 Test Reactor (AEC)	HEW-305	Hanford, Wash.	DuPont	Graphite	1944	
Process Development Pile (AEC)	PDP	Savannah River	DuPont	Heavy water	1953	
45' Thermal Test Reactor (AEC)	SP	Savannah River	DuPont	Graphite	1953	
Thermal Test Reactor (AEC) [18]	TTR	Hanford, Wash.	GE	Graphite	1951	
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, Texas	Convair	Pool	1953	
Aircraft Shield Test Reactor (USAF)	ASTR	Fort Worth, Tex.	Convair		1954	
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	
Kinetic Experiment on Water Boilers No. 2 (AEC)	KEWB-2	Santa Susana, Calif.	NAA	Homogeneous	1958	
Radiation Effects Reactor (USAF)	RERL	Marietta, Ga.	Lockheed	Pool	1958	
Planned:						
Food Irradiation Reactor (AEC)	FIR	Stockton, Calif.		Pressurized water	1959	
Shielding Experiment Facility Reactor (AEC)	SEFR	NRTS, Idaho	GE			
Tower Shielding Facility Reactor No. 2 (AEC)	TSFR-2	Oak Ridge, Tenn.	ORNL	Tank	1958	

B.5. CRITICAL EXPERIMENTS [19]

Operated, later dismantled:						
Zero Power Reactor No. 1 (AEC)	ZPR-1	Lemont, Ill.	ANL	Light water	1950	1953
Zero Power Reactor No. 2 (AEC)	ZPR-2	Lemont, Ill.	ANL	Heavy water	1952	1955
Zero Power Reactor No. 4 (AEC)	ZPR-4	Lemont, Ill.	ANL	Light water	1953	1956
Army Package Power Reactor Critical (AEC)	APPR-OR	Oak Ridge, Tenn.	ORNL	Pressurized water	1955	1956

X-10 Critical	X-10-200	Oak Ridge, Tenn	ORNL	Homogeneous	1946	1948
Spare Plate Critical Assembly (AEC)	SPCA	Pittsburgh, Pa	West.	Light water		1956
Test Reactor Assembly—2	TRA-2	Cincinnati, Ohio				
Test Reactor Assembly—3	TRA-3	Cincinnati, Ohio				
Danger Coefficient Test Facility (AEC)	DCTF	Pittsburgh, Pa	West.	Homogeneous	1953	1957
Operated:						
Zero Power Reactor No. 3 (AEC)	ZPR-3	NRTS, Idaho	ANL		1955	
ORNL Critical Experiment Facility No. 1 (AEC)	ORNL-1	Oak Ridge, Tenn	ORNL		1950	
ORNL Critical Experiment Facility No. 2 (AEC)	ORNL-2	Oak Ridge, Tenn	ORNL		1950	
Fast Exponential Experiment (AEC)	FEE	Lemont, Ill	ANL		1954	
Physical Constants Test Reactor (AEC)	PCTR	Hanford, Wash	GE	Graphite	1955	
PWR Flexible Critical Assembly (AEC)	PWR-FA	Pittsburgh, Pa	West.	Light water	1954	
PWR Mockup (AEC)	PWR-Mockup	Pittsburgh, Pa	West.	Light water	1954	
Two Region Critical Assembly (AEC)	TRX	Pittsburgh, Pa	West.	Light water	1953	
Preliminary Pile Assembly (AEC) [20]	PPA	Schenectady, N. Y	GE	Plastic	1948	
SAR Flexible Plastic Reactor (AEC)	FPR	Schenectady, N. Y	GE	Plastic	1955	
Flexible Critical Experiment (AEC)	S1C-FC	Windsor, Conn	CE	Plastic	1956	
Evendale Critical Experiment Facility No. 1 (USAF).	GEANP-1	Evendale, Ohio	GE	Plastic		
APPR Zero Power Facility	APPR-s	Schenectady, N. Y	Alco	Pressurized water	1956	
Reactivity Measurement Facility (AEC)	RMF	NRTS, Idaho	PPC	Light water	1954	
Zero Power Reactor No. 5 (AEC)	ZPR-5	Lemont, Ill	ANL	Light water	1956	
Evendale Critical Experiment Facility No. 2 (USAF).	GEANP-2	Evendale, Ohio	GE		1957	
Babcock & Wilcox Co		Lynchburg, Va	B&W		1957	
S3W/S4W Flexible Critical Assembly and Clean Critical Assembly (AEC).	SFR-FA-FC	Pittsburgh, Pa	West.	Light water	1954	
S5W Flexible Critical Assembly (AEC)	S5W-FA	Pittsburgh, Pa	West.	Light water	1956	
A1W Core No. 1 Flexible Critical Assembly and Mockup (AEC).	A1W-FA & Mockup-1	Pittsburgh, Pa	West.	Light water	1956	
A1W Core No. 2 Flexible Critical and Mockup (AEC)	A1W-FA & Mockup-2	Pittsburgh, Pa	West.	Light water	1957	
Plastic Mockup Assembly (AEC)	PMA	Schenectady, N. Y	GE	Plastic	1954	
Advanced Test Reactor (SAR Critical) (AEC)	ATR	Schenectady, N. Y	GE	Light water	1954	
S1C Advanced Critical Experiment (AEC)	S1C-AC	Windsor, Conn	CE	Light water	1956	
Production Test Facility (AEC)	PTF	Pittsburgh, Pa	West.	Light water	1956	
Brookhaven Critical Experiment Facility		Upton, L. I	BNL	Light water	1956	
Being built:						
CANEL Nuclear Physics Lab. (USAF)	CANEL-1	Middletown, Conn	P&W		1957	
Battelle Memorial Institute	BMI-CX	West Jefferson, Ohio			1957	
General Electric Co		Pleasanton, Calif	GE		1957	
Nuclear Development Corp. of America	NDA-CX	Pawling, N. Y	NDA		1957	
Low Power Test Facility (AEC)	LPTF	NRTS, Idaho	GE		1958	
Lockheed Aircraft Co		Palo Alto, Calif			1957	
Zero Power Facility (Martin Co.)		Middle River, Md	Martin	Pressurized water	1957	
APPR Critical Experiment Facility (Martin Co.)		Middle River, Md	Martin	Pressurized water	1957	
General Atomic Division of General Dynamics Corp.		San Diego, Calif	GDC		1957	
Proof Test Reactor (SAR Critical) (AEC)	PTR	Schenectady, N. Y	GE	Light water	1958	
Cold Water Assembly (DIG Critical) (AEC)	CWA	Schenectady, N. Y	GE	Light water	1957	
Planned:						
Zero Power Reactor No. 6 (AEC)	ZPR-6	Lemont, Ill	ANL			
Babcock & Wilcox Facility Addition [14]		Lynchburg, Va	B&W		1957	
High Temperature Test Facility	HTTF	Pittsburgh, Pa	West.	Light water	1957	
Westinghouse Electric Corp		Waltz Mill, Pa	Owner			

See footnotes at end of table, p. 254.

NUCLEAR REACTORS BUILT, BUILDING OR PLANNED IN THE UNITED STATES AS OF JUNE 30, 1957—Con.

B. Low Temperature Reactors (Not Useful for Power Generation)—Continued

B.6. PRODUCTION REACTORS

Designation	Builder	Type	Location
Operated:			
B Reactor	DuPont	Graphite	Hanford, Wash.
D Reactor	DuPont	Graphite	Hanford, Wash.
F Reactor	DuPont	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	DuPont	Heavy water	Savannah River, S. C.
P Reactor	DuPont	Heavy water	Savannah River, S. C.
K Reactor	DuPont	Heavy water	Savannah River, S. C.
L Reactor	DuPont	Heavy water	Savannah River, S. C.
C Reactor	DuPont	Heavy water	Savannah River, S. C.

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] Approved as a basis for Commission contract negotiations under Power Demonstration Reactor Program.
[4] About 20 percent of total capacity shown will be non-nuclear.
[5] 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.
[6] Submitted under Power Demonstration Reactor Program.
[7] Contract awarded by Commission under Maritime Reactors Program.
[8] Reactor designed for production of process steam and cobalt 60.
[9] Bilateral agreements for cooperation prerequisite to supplying reactors have not been executed.
[10] To be located in Alaska; Alco is principal contractor.
[11] Classified information.
[12] Original 10 kw reactor was started up in 1953 and dismantled in 1955. Reactor was reactivated with 500 kw core in March 1957. A second reactor which at first will use the same instrumentation is now planned.
[13] These three reactors were operated under license to Aerojet-General Corp. Transfer to the listed institution has been made in the case of AGN-201-100, and is expected in the other cases.
[14] License application received by Commission.
[15] License application received by Commission from Aerojet-General for these reactors.
[16] Geneva Conference Reactor which is being rebuilt at Wuerenlingen.
[17] Export license application received by Commission.
[18] Started up at Knolls Atomic Power Laboratory, Schenectady, N. Y. in 1951. Relocated at Hanford in 1955.
[19] Critical experiments at Los Alamos and other weapons sites not included.
[20] Formerly located at Sacondago, N. Y.

APPENDIX 13

Statements and Additional Details Issued in Designating Fuel for Reactors

Statement by the President, July 3, 1957

In my statement on February 22, 1956, announcing the designation of 40,000 kilograms of uranium 235 for research and development purposes and for fueling nuclear power reactors at home and abroad, I stated that the Atomic Energy Commission would recommend that more supplies be made available for sale or lease as necessary in the future for additional nuclear power projects.

At the recommendation of the Chairman of the Atomic Energy Commission, in which the Secretaries of State and Defense concur, I have determined under Section 41b of the Atomic Energy Act of 1954 that 59,800 kilograms of uranium 235, in addition to previous allocations, may be made available for peaceful uses at home and abroad under conditions prescribed by the United States Government.

The additional quantities of uranium 235 which will be made available for distribution over a period of years are:

a. 30,000 kilograms in the United States, through lease for all licensed civilian purposes, principally for power reactors.

b. 29,800 kilograms outside the United States, through sale or lease, to Governments of individual nations or to groups of nations with which the United States concludes Agreements for Cooperation.

Distribution of special nuclear material will be subject to prudent safeguards against diversion of the materials to nonpeaceful purposes.

Added to the 40,000 kilograms of uranium 235 designated on February 22, 1956, and the 200 kilograms designated earlier, this designation brings to 100,000 kilograms the total amount of this material to be made available as required for peaceful purposes, divided equally between domestic and foreign uses.

At current prices, established by the Atomic Energy Commission last November, the value of 100,000 kilograms of uranium 235 to be sold or leased is about $1.7 billion.

I am gratified that the advance toward power and knowledge from the atom is proceeding at a pace which requires provision of additional supplies of the basic atomic fuel.

Further details concerning the new determinations of availability of uranium 235 are set forth in the attached statement by the Chairman of the Atomic Energy Commission.

Statement by the Chairman, Atomic Energy Commission, July 3, 1957

In accordance with the President's statement on February 22, 1956, announcing the availability of 40,000 kilograms of uranium 235 for distribution at home and abroad for research and development purposes and for fueling nuclear power reactors, the Atomic Energy Commission has recommended to the President that substantial additional supplies of uranium 235 be designated at this time for distribution for peaceful uses. The President has approved this recommendation.

The Commission's recommendation is due to the progress of nuclear power development. The point has been reached where licenses granted or under consideration by the Commission for nuclear power plants in the United States

require more than the initial 20,000 kilograms of uranium 235 made available for domestic use by the President's determination of February 22, 1956. The growing nuclear power programs in friendly nations also require additional supplies of atomic fuel.

The President's current action therefore is another important step in furthering both domestic and foreign applications of atomic energy for peaceful purposes.

The present and previous determinations by the President make the uranium 235 available in equal amounts for domestic and foreign distribution. This does not necessarily create a pattern for any subsequent designations that may be recommended.

Each allocation of uranium 235 to atomic power projects in the United States must cover the initial fuel-loading, the estimated amount that will be burned by the reactor during the period for which reactor operation is licensed, and the estimated "pipeline" requirements, that is, the uranium 235 that will be committed in the manufacture of fuel elements, the cooling of irradiated fuel, and the reprocessing of the used fuel to recover the unfissioned uranium 235. Under the Atomic Energy Act of 1954, the Atomic Energy Commission may issue licenses to domestic reactor operators for fixed periods. Allocations under such licenses now approximate 17,000 kilograms. The new Presidential determination makes a total of 50,000 kilograms available as required for such domestic allocations. The physical transfers of material will be spread over the periods of the licenses.

Plans of those nations which have concluded or which are now negotiating power agreements with the United States indicate that their needs also will exceed the 20,000 kilograms of uranium 235 previously made available for such use. Their needs are calculated on a basis that includes the initial fuel loading, "pipeline" requirements, and consumption during the term of the agreement for cooperation. The new Presidential determination makes a total of 50,000 kilograms available as required for distribution abroad.

Seven agreements for cooperation with friendly nations in various parts of the world providing for power reactors are now in effect, 7 more are about to be concluded, and a number of others are under negotiation. Twenty-nine agreements for cooperation providing for research reactors are now in effect. Negotiations have been completed on eight additional research agreements and it is expected that they will become effective within the next year.

The terms of distribution are similar to those in previous determinations. No agreements for cooperation under the Atomic Energy Act of 1954 are made by the United States with the Soviet Union or its satellites.

Additional Details Concerning Statements Made by the President and the Chairman

The President announced today that 100,000 kilograms of uranium 235 is to be made available for domestic and foreign peaceful uses. This amount of material is based on the output of highly enriched uranium from U. S. production plants. However, most of the enriched uranium to be made available will contain less than 20 percent of uranium 235. The lower the percentage of uranium 235 in the material that is withdrawn from the production plants for distribution, the smaller the effect there is on the amount of highly enriched material that otherwise would be produced. Therefore the total uranium 235 *content* of the material to be made available under the determinations announced today will be greater than 100,000 kg.

The simplest way of estimating this is to consider the dollar value of such materials according to the price schedule announced by the AEC on November 18, 1956. Under that schedule equal dollar values of material withdrawn at any uranium 235 percentage mean equal reductions in the output of highly enriched uranium. The value of 100,000 kilograms of highly enriched uranium would be about $1.7 billion. This total value is the same regardless of the particular uranium 235 percentages and corresponding prices of the material actually distributed.

For example, if all of the enriched uranium were made available at 20 percent uranium 235, the value of uranium 235 according to the price schedule at that percentage is $16,120 per kilogram and 1.7 billion dollars' worth would be 106,000 kilograms of contained uranium 235. For 2 percent uranium 235, the value is $11,000 per kilogram and the amount would be 155,000 kilograms of contained uranium 235.

The amount for any other percentage of uranium 235 can be calculated in the same way from the price schedule.

Put in other terms, the relation is that the uranium 235 content at 2 percent corresponds to 1.465 times the uranium 235 content at 20 percent.

U. S. GOVERNMENT PRINTING OFFICE: 1957