UNITED STATES ATOMIC ENERGY COMMISSION

Twenty-first Semiannual Report

OF THE

ATOMIC ENERGY COMMISSION

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LETTER OF SUBMITTAL

WASHINGTON, D. C.,
30 January 1957.

SIRS: We have the honor to submit herewith the Twenty-first Semi-annual 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.
THOMAS E. MURRAY.
HAROLD S. VANCE.
JOHN VON NEUMANN.
LEWIS L. STRAUSS, *Chairman*

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

CONTENTS

APPENDIXES

FOREWORD

The Nation made substantial progress during the last 6 months of 1956 in expanding the peaceful uses of atomic energy as well as in the basic production of nuclear materials and the development of essential applications for defense purposes.

International Activities

In the international field, the Atoms for Peace program initiated by the President in his memorable address before the United Nations December 8, 1953, moved nearer fulfillment with the adoption of a statute for the International Atomic Energy Agency by an 82-nation conference in New York on October 26.

On November 18, the President and the Commission Chairman Lewis L. Strauss announced charges for uranium 235 and buy-back prices for fissionable products of power reactors built by other nations under agreements for cooperation with the United States.

Carrying forward the proposal of the President made last July 22 at the Panama Conference that work be initiated to . . . "hasten the beneficial use of nuclear forces throughout the hemisphere, both in industry and in combatting disease," the Commission has undertaken three such programs. It is supporting development of the University of Puerto Rico as a nuclear training center for Spanish-speaking peoples, contributing to nuclear research and training at the Inter-American Institute of Agricultural Sciences at Turrialba, Costa Rica, and convening early next year a symposium in which scientists and atomic energy officials of the 21 American States will exchange information and ideas.

Four additional agreements for cooperation became effective, and three other new agreements for cooperation were negotiated, including one covering power reactors, making a total of 41 agreements made with 39 countries. An additional 22—14 of them including power reactors—were being discussed. As of the year's end, 32 agreements, of which four covered power, had completed all necessary approvals and were in effect.

Ten cooperating countries so far have announced plans to build 15 reactors, of which 3 would produce power.

Exchanges of documentary information with cooperating countries continued at a high rate, as did reciprocal visits between the United States and a total of 47 other countries.

The Commission opened overseas offices in London, England, and Paris, France, to assist the international program.

International Agency

The International Atomic Energy Agency, first proposed by the President in his December 1953, United Nations address, will become operative when the adopted statute is ratified by 18 nations, including three of the five major atomic energy powers—Canada, France, the Union of Soviet Socialist Republics, the United Kingdom, and the United States. Representatives of 72 nations signed the statute after it was voted by the conference in New York.

At the closing session, October 26, Commission Chairman Strauss delivered a message from the President announcing that the United States was prepared to make available to the international agency (contingent upon ratification by the Senate), 5,000 kilograms of uranium 235 from the 20,000 kilograms allocated last February by this country for distribution abroad. The United States will match allocations of special nuclear material made to the agency by all other member nations, for a period ending June 30, 1960. (Text in Appendix 10.)

Domestic Industrial Programs

Power Reactors

The program of developing nuclear reactors for commercial power continued to move ahead.

Two more industrial groups announced their intentions of designing and constructing nuclear electric powerplants without financial assistance from the Government, making a total of seven reactors planned on this basis.

Under the Commission's Power Demonstration Program, in which the Government pays for new technology developed, contract negotiations were in progress with three groups. Proposals of three other groups were rejected as infeasible at this time, or promising too small a technical contribution.

In the Commission's Experimental Power Reactor Program, construction moved ahead on the Shippingport Pressurized Water Reactor. Among the experimental reactors—a preliminary stage to the building of prototypes—the Experimental Boiling Water Reactor went critical November 30. Both of these reactors are expected to generate electric power in 1957.

The Commission began contract negotiations for design and construction of a powerplant for the first nuclear-powered merchant ship, under a direction from the President that the Commission and the Maritime Administration of the Department of Commerce, proceed as rapidly as possible with construction. A pressurized water reactor is planned—of the general type used in the submarine USS

Nautilus. The land-based prototype of the *Nautilus* reactor, during this reporting period completed a nonstop full-power run of 66 days, believed the longest full-power run ever completed by any type of propulsion plant.

The Commission and the Maritime Administration let contracts for feasibility studies of five other types of reactors to power merchant ships for possible future application in this promising field.

As of December 31, a total of 90 reactors had been built in the United States, of which 17 had served their purposes and been dismantled. Of the 73 nuclear reactors now operating or licensed, 27 were either testing or research reactors, 24 were critical experiments and zero power reactors, 13 were production reactors, 5 were military power reactors, and 4 were Commission civilian power reactor experiments. Of 45 reactors being built as of that date in the United States, 21 were in the research and testing category (including 10 critical experiments and zero power), 15 were military power reactors, and 9 were civilian power reactors. Thirty-three research and testing reactors were planned in the United States as of December 31 (including 7 critical and zero experiments), and, in the field of power, the Government planned to build 23 military power reactors and 5 civilian power experiments, and United States companies had announced plans for 12 civilian power reactors. (See Appendix 14.)

The Commission received 8 applications for permits to construct nuclear reactors for research, 4 to construct power reactors. Two construction permits were issued on a provisional basis, one to the Power Reactor Development Corp., Detroit, Mich., for a large power reactor. Three licenses were issued to operate reactors. Hearings were scheduled for January 8, 1957, on a petition to intervene against the granting of the Michigan permit. A new basic regulation was issued prescribing standards for protection against radiation hazards.

Broadening Participation

Continuing its program of increasing private participation in the Commission's industrial activities, the Commission selected a company proposal for the manufacture of uranium fluoride, one of the feed materials for its plants that produce special nuclear materials. This will help meet Federal requirements for increased capacity. Demonstrating the value of increased participation on a competitive basis by private enterprise concerns, the company's proposal suggested a new process which by-passes a step now used in Commission plants.

After 75 firms expressed interest in the project, the Commission in November issued its anticipated invitation for companies to bid for purchase of uranium-magnesium-fluoride slag from Federal feed materials plants. The Government would purchase extracted uranium at pre-established prices.

During the reporting period, the Commission contracted to buy a million pounds of reactor-grade beryllium from two concerns over a five-year period.

The first reactor fuel elements ever supplied commercially by private industry were delivered to the Commission in July.

Patents

The Commission added 111 atomic energy patents to its list of those available for licensing on a nonexclusive, royalty-free basis, making a total of 1,100. About 580 nonexclusive licenses have been granted to private industry.

On September 24, Canada, the United Kingdom and the United States entered a patent and patent application interchange agreement. Under the agreement, the United States may grant royalty-free licenses to United States industry with respect to United States patents and patent applications, as of November 15, 1955, which it would acquire from the United Kingdom and Canadian Governments. The reverse arrangement holds good for Canada and the United Kingdom. Each Government undertakes to acquire all rights in atomic energy inventions in its own country and assign to the other two Governments the rights which it owns in the other two countries.

Nearly all Industrial Information Declassified

One of the major actions of the year both for the domestic industrial program and for the overseas Atoms for Peace program was the Commission's action in December, declassifying additional information required for peaceful applications of atomic energy.

This action will strengthen the Atoms for Peace program of cooperation with friendly foreign nations. Much more can be accomplished through unclassified agreements for cooperation when the new policies are applied.

Equally broad advance became possible in the domestic atomic energy development with the essential information available for industrialists, their service organizations and the industrial and engineering press, and the technical book publishers, as well as the faculties in charge of curricula and writers and publishers of text books for the secondary schools, colleges and universities.

Effectively, with this declassification action, the Commission has brought into the open literature and the realm of open technical discussion all the technology for industrial applications and the basic data for fundamental science.

The military applications of atomic energy remain classified and these will continue to be closely guarded.

The Commission is undertaking a second program for accelerated review under the new rules of declassification to determine what documents presently classified as secret or confidential may be made public. After the first program of accelerated review, early this year, based on the July 1955 Declassification Guide, only some 20,000 documents remained classified. Approximately 2,000 new technical papers classified since that time also will be reviewed.

The United States undertook, in consultation with the United Kingdom, the study of a declassification guide on research dealing with controlled thermonuclear reactions. The United States established a principle that it was desirable to declassify all basic technical information in this field unless the information was deemed of critical importance in solving the problems of developing a controlled thermonuclear reactor.

Distributing Information

Applications from individuals and private organizations for permits to have access to classified technical information continued to be received at a rate of about 40 a month, and as of the end of the year a total of 1,145 permits was in effect. The Commission issued 74 permits which include access to information about controlled thermonuclear research.

On September 12, the Commission amended its access regulations to provide that information about thermonuclear research could be made available under present conditions to limited categories of applicants.

To speed distribution of information and technical reports, the Commission further broadened its program, by holding meetings on selected technical subjects with interested industrial groups and publishing the proceedings, by planning a number of technical progress reviews on 10 categories of Government-sponsored research, by preparing to publish a monthly bulletin on Commission policies and programs for the information of management of industrial and scientific organizations, by adding 17 more depository libraries, offering 15 libraries to universities and colleges, and directing that 6 classified libraries be established in areas reasonably accessible to the majority of access permit holders.

A total of 21 new volumes or revisions of existing volumes was under preparation (9 contracted for in this reporting period), and 6 more were planned, to summarize present knowledge in fields of most interest to developers of civilian applications. A writing program to comprise more than 75 additional volumes was organized.

The Commission has contracted for a survey among access permit holders to evaluate industrial information services to them.

Operations and Other Major Activities

Raw Materials

Supporting the expanding peaceful uses of atomic energy as well as military applications, production of uranium ores and concentrates from all free world sources continued to increase during the second half of 1956. Increases in this country maintained the United States as one of the world's leading producers of uranium.

Uranium production in the United States totaled some 1.66 million dry tons of ore, and 3,400 tons of uranium oxide (U_3O_8) concentrate during the last half of 1956, nearly double the 840,000 dry tons of ore and more than double the 1,600 tons of concentrate produced during the last half of 1955. The 12 mills presently in operation—including 3 new mills and a mill which has been greatly enlarged—have a total daily capacity of 8,960 tons of ore, and additional mills to be built will add a total of 4,775 tons a day. These figures were announced by the Commission after the December 5 promulgation of its new Declassification Guide.

Additional large ore bodies were found. Typical of the expanding provision of uranium in the United States is the reserves status. In 1956, there were 33 ore deposits with known reserves of more than 100,000 tons each, and at least 8 deposits in the million-ton class. Two years ago, there were only 15 deposits with known reserves over 100,000 tons, and one reserve of over 1 million tons.

The Commission modified its rules for development of allowances to permit payments to producers of uranium ore whose development expenditures under present conditions usually are incurred before production starts.

Production in other areas of the free world continued at a normal rate, with Canadian and South African uranium output increasing, and more mills under construction.

The Commission in September announced a broadened program of international cooperation in exploration under which the United States offers to assist friendly nations by providing scientific and technical information on uranium geology and exploring, by offering training opportunities for geologists and technicians, and by sending Commission experts on request to other countries.

Production

New Commission facilities for production of special nuclear materials resulted in the production of a greater quantity during the second half of 1956 than in any previous 6 months.

Most new plants turning out feed materials for these new facilities were in operation, and various units were expected to be ready in time to meet capacity requirements.

Total Capital Investment

The Nation's capital investment in atomic energy facilities of all types, as of December 31, reached a total of about $6.8 billion, before depreciation reserves, with costs incurred during the reporting period estimated at $125 million.

Weapons

In its work with atomic weapons, Commission research and development activities continued to emphasize increasing and improving the arsenal of weapons, with additional stress on defensive weapons.

Construction continued to provide for research, engineering and production activities, and new experimental areas were under development. Test firings in Operation *Redwing* were completed in July.

Military Reactors

In the field of military reactors, construction of the Army's Package Power Reactor neared completion, and construction of another Army reactor began.

A contractor was selected for design and construction of a food-irradiation reactor.

Contract negotiations began on an Army experimental gas-cooled reactor.

For the first time, a turbojet engine in a test was powered exclusively with heat from an experimental reactor.

Design and construction of reactors to propel naval ships went forward at various sites. Erection of a section of a ship hull to house the reactor plant of the large ship reactor prototype (AlW) was completed. The USS *Nautilus* nuclear propulsion plant continued to operate satisfactorily. The *Nautilus* has steamed over 50,000 miles, over half the distance while fully submerged. Leaks in the steam superheating system delayed completion of the sodium-cooled reactor powerplant for the submarine *Seawolf*.

The Commission signed a contract for sale of byproduct electrical power produced experimentally by the land-based prototype of the *Seawolf* plant and, as of the end of the year, had sold 765,160 kilowatt hours at 3 mills an hour for a total of $2,295.45. The power went to Niagara Mohawk Power Corp. after two public bodies, which previously had expressed interest, notified the Commission they could not make arrangements for delivery.

Research

The Commission's programs of research in the physical and life sciences continued to make significant contributions to the fundamental knowledge of atomic energy and related sciences.

Research in high energy physics confirmed the existence of a nuclear particle called the "antineutron."

A new nuclear phenomenon termed a catalyzed fusion was discovered.

Conclusions on the effects of fast neutron bombardment on a wide variety of metals were issued.

Results of biological and medical research on effects of radiation upon man and of treatments of the effects are summarized in the special section of this semiannual report dealing with radiation protection in atomic energy activities.

Research during the last 6 months summarized in the progress section of the report includes fundamental work on the mechanisms of division in plant cell nuclei, mouse genetics, mercury toxicity, and other fields important in atomic energy activities.

A new irradiation center for plant breeders was opened at Oak Ridge, Tenn.

Exhibits

Besides its program for making technical information available, the Commission undertook to provide additional public information by placing two types of exhibits on Atoms for Peace on tour in the United States during this reporting period.

Three units of a large type which occupies a floor space of about 5,000 square feet were displayed in the District of Columbia and 13 States.

Five smaller units, set up in truck trailers, ready in November, are scheduled for showing through the next reporting period in 11 States.

Education and Training

Expanding its participation in the Government-wide effort to increase education and training for students seeking to develop scientific and technical skills, the Commission initiated a program of making direct financial grants to colleges and universities for purchase of equipment and training aids needed to establish and conduct studies in nuclear energy technology.

The Commission broadened its program of lending uranium and neutron sources to include other materials particularly related to nuclear energy technology.

The Commission launched four studies to calculate the needs of private industry, Commission contractors, universities, and Government agencies for technically and scientifically trained personnel.

Communities

Under the Atomic Energy Community Act of 1955, the first lots and homes were sold in Oak Ridge, Tenn., 82 vacant lots, 119 leased lots, and 723 houses.

At Richland, Wash., a community hospital was transferred to a local group, and a zoning ordinance was approved.

At Los Alamos, the Commission obtained complete administrative authority over some 67,000 acres of land formerly under control of two departments of the Federal Government.

Personnel

The Commission held its first Annual Honor Awards Ceremony on November 14, presenting 4 Distinguished Service Awards and 18 Outstanding Service Awards, and 35 awards of length of service.

The President appointed three new members of the General Advisory Committee of the Commission for 6-year terms ending August 1, 1962. The new members are T. Keith Glennan, former Atomic Energy Commissioner, president of Case Institute, Cleveland; Edward Teller, an associate director of University of California Radiation Laboratory, Berkeley; and Robert E. Wilson, president, Standard Oil of Indiana, Chicago. They replace Dr. I. I. Rabi, Eger V. Murphree and Dr. Walter G. Whitman, whose terms expired. Dr. Warren C. Johnson replaces Dr. Rabi as committee chairman.

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Representative Hinshaw

The Commission grieves with the associates in the Congress and the Joint Committee on Atomic Energy at the death of Representative Carl Hinshaw in August. His mastery of technical subject matter and sense of public policy had greatly helped to guide the development of the national atomic energy program from the time of his appointment to the original Joint Committee in the 79th Congress 10 years ago, and through all succeeding Congresses.

Special Report on Radiation Safety

In addition to its report on major activities during the last 6 months of 1956, this Twenty-first Semiannual Report of the Commission includes a special six-chapter section entitled "Radiation Safety in Atomic Energy Activities." The special section reports on the record in all activities in which the Commission and its contractors are responsible for protection of workers and the public, and summarizes the methods and administration of radiation safety, the provisions for protection of health and safety through regulation and licensing, the problems of controlling radiation hazards and the solutions found, and the results of biological and medical research, the effects of radiation upon man, and the treatments of those effects. The special section, printed as Part Two of the report, begins on page 109.

The success of the Commission's efforts to protect people against radiation originating in its programs is best evidenced by its record. The Commission has set very rigid standards and established radiation exposure levels which experienced scientists in the field believe to be conservative. Very few workers have received even this minimal amount. Exposure records of more than 9 years of routine operations by 32 principal Commission contractors of the Atomic Energy Commission show that 99.4 percent of nearly 200,000 workers monitored received less than one-third of the amount of radiation exposure deemed acceptable. Accident records, going back to 1945 show that in 11 years, there have been only 16 radiation accidents involving overexposure of contractors' employees. They caused 2 deaths in 1945 and 1946 and there have been overexposures of 67 others. Of the total, 28 were exposed at one time when service men, after a 1954 weapons test at Eniwetok, were exposed to an unexpected concentration of radioactive fall-out following a detonation.

This was the same test in which 239 Marshall Islanders were exposed to unexpected fall-out concentrations. After 2 years, the group exposed generally were in good health and nutritional condition, and none of the clinical findings of a check-up in March 1956, with the exception of four cases showing various amounts of skin damage, could be attributed to the effects of radiation. Fall-out from the same detonation also exposed 23 members of the crew of a Japanese fishing boat. This is the only case in which any member of the public is known to have received an overexposure to radiation as a result of atomic energy operations.

Program for Supplying Enriched Uranium for Peaceful Development

The President and Chairman Strauss announced on November 18, 1956, new steps taken by the United States to advance the development of nuclear reactors to produce electric power in countries which have agreements for cooperation with the United States under its Atoms for Peace program.

In a statement issued on that day from the White House, the President announced his approval of new charges which the Atomic Energy Commission recommended for uranium 235 supplied to friendly countries under agreements for cooperation in developing the peaceful uses of atomic energy. The charges are the same as those which the Commission makes to industrial users in the United States.

The President also approved prices which the Commission will offer to pay for plutonium or uranium 233 produced in reactors abroad that are fueled with materials supplied to cooperating countries by the United States. The President said that fissionable materials so purchased would be used only for peaceful purposes.

The schedule of charges to be made for uranium 235 varies according to the degree of enrichment of uranium 235 in the fuel material supplied. The value for uranium with 20 percent enrichment in uranium 235—the upper limit for most exports—will be about $16 a gram for contained uranium 235 at the stage of the gaseous diffusion plant product, uranium hexafluoride (UF_6), and charges for processing into the desired fuel will be added. The unit process charge will vary with the form in which the uranium 235 will be used (price schedule in Appendix 11).

The former value, announced August 8, 1955, was $25 a gram for uranium metal enriched to 20 percent in uranium 235. The prices charged for normal uranium metal, $40 a kilogram, and heavy water, $28 a pound, also announced August 1955, remained unchanged.[1]

The purchase price offered by the United States for plutonium metal or uranium 233 nitrate are based on the fuel value of the materials: for plutonium metal, $12 a gram, and for uranium 233 nitrate, $15 a gram of contained uranium 233.

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[1] See p. 89, Nineteenth Semiannual Report (July–December 1955).

The President's statement declared, "This Nation attaches the highest importance to development of nuclear power both at home and abroad. We are determined that this product of man's inventiveness shall be made available to serve the people of the world."

His statement recalled that on February 22, 1956, he had approved making available 20,000 kilograms of uranium 235 for distribution abroad;[2] observed that agreements for cooperation had been signed with 37 countries to promote the peaceful uses of atomic energy; and cited the Nation's role in promoting and organizing the International Atomic Energy Agency under whose statute signatory participating nations of the United Nations and its specialized agencies would work together to use atoms for peace.

The President said that these actions and the new steps he had just approved " . . . are designed to enable other nations or groups of nations to have firm assurance of the fuel supplies necessary to the continued operation of nuclear power installations, and thus to facilitate arrangements for financing. Today's actions . . . will permit closer estimates of net nuclear fuel costs, and will add firmness to the planning now under way in friendly nations for nuclear power, thereby accelerating their atomic power development.

"It will be our policy, of course, to seek to conduct our operations in support of nuclear power development abroad in consonance with the policy of the International Atomic Energy Agency, in whose endeavors we shall take our full part.

"We shall strive ceaselessly," the President concluded, "to attain the day when the uses of the energy of the atom fulfill mankind's peaceful purposes."

The statement issued by the White House on behalf of Chairman Lewis L. Strauss of the Commission declared, "The policies and undertakings . . . should substantially promote the advance of the free world toward abundant nuclear power. The Commission will continue to explore additional means to encourage the development of atomic power.

"There are obstacles to be overcome," the Chairman said. "Skilled manpower is presently in serious shortage. Large capital resources are required. The best technology remains to be worked out area by area.

"But I am confident that steps being taken in the United States and the progress being made by our friends abroad, are speeding the day when electrical energy from the atom will help lighten man's burden of work and lift the standards of living of peoples everywhere."

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[2] 20,000 kilograms of uranium 235 were simultaneously made available for domestic use, see pp. viii–x, and Appendix 8, Twentieth Semiannual Report (Jan.–June 1956).

The six steps taken with the approval of the President to accelerate the development of nuclear power abroad under the Atoms for Peace program, as described in the Chairman's statement, are:

a) Establishment of a schedule of charges for uranium 235 furnished by the Commission to other nations or groups of nations for use in power or research reactors under agreements for cooperation. The schedule sets charges for various degrees of enrichment; for example about $16 per gram of uranium 235 at 20 percent enrichment. The charges are the same as those made by the Commission to domestic users.

b) Adoption of a policy under which assurances can be made to nations with agreements for cooperation that the Commission—within the limits of the amounts of material made available from time to time by the President—is prepared to furnish uranium 235 in specified quantities based on estimated fuel requirements of a given power installation over a fixed period, beyond the present term of 10 years. Such commitments would, of course, be subject to observance of all terms and conditions of the covering agreement for cooperation. In carrying out this policy, it is recognized, the present term of agreements for cooperation would require extension.

c) Establishment of prices to be offered by the Commission for plutonium and uranium 233 produced in reactors abroad which are fueled under agreements for cooperation. These prices are the estimated fuel value of these special nuclear materials when a practicable method of using them for fuel develops from the research now being carried on. For plutonium metal, it is $12 per gram; for uranium 233 nitrate, it is $15 per gram of uranium 233. Material so acquired by the Commission will be used only for peaceful purposes.

d) Decision by the Commission that it stands ready to purchase during the period ending June 30, 1963, at the above mentioned prices, all plutonium and uranium 233 produced in reactors abroad which are fueled with material obtained from the United States. Under existing authority in the Atomic Energy Act of 1954, such purchases will, of course, be made on annual basis and subject to the availability of appropriations.

e) The Commission expects to recommend at the forthcoming session of the Congress legislation to provide authority to the Commission, with the approval of the President, to establish guaranteed prices for periods not in excess of 7 years for plutonium and uranium 233 which is delivered to the Commission and which has been produced in reactors abroad fueled with material supplied by the United States. Such authority will enable the Commission to provide the same assurance to foreign nuclear power programs that the 7-year guarantee period for prices under existing law provides to the domestic nuclear power program.

f) Decision to consider exchange of United States uranium 235 for source material (for example uranium ore or concentrates) from nations with agreements for cooperation.

Text of the statements issued at the White House for the President and the Chairman are printed in Appendix 11. Also in the Appendix are a summary of the general terms and conditions for governing international transactions in special nuclear materials under agreements for cooperation, the schedule of prices, and general background information of the new actions.

The Commission also announced on November 18 the unclassified guaranteed fair prices, identical with the prices offered to foreign countries, to be paid for a period of 1 year after June 30, 1962, for plutonium or uranium 233 produced in licensed reactors in the United States. The Commission stated it intended to extend year by year the period for which guarantee prices have been established so that the guarantee period would always extend at least 6 years in advance at any one time. Classified guaranteed prices already were operative in the United States, effective for 7 years after July 1, 1955, and extending to June 30, 1962, under authority of the Atomic Energy Act of 1954 to make guarantees for periods of 7 years.

Financial Summary

The report of the Comptroller to the Commission (Appendix 15) sets forth the financial position of the Commission. In form and content, it is similar to an industrial financial statement. It might be noted here that administrative expenses, compared to the total cost of operations, continued to decrease. They amounted to 2.4 percent of operating costs during fiscal year 1956, as compared to 2.6 percent in fiscal year 1955, and 3.4 percent in fiscal year 1954.

Part One

Major Activities in the Atomic Energy Programs, July–December 1956

Raw Materials

Uranium ore and concentrate production from all free world sources continued to increase during the second half of 1956. New facilities under construction or planned in the Union of South Africa, Canada, and the United States will result in further increases.

In September the Atomic Energy Commission announced a program for international cooperation in uranium exploration.

Domestic Production

The increase in domestic production of uranium ore and concentrates maintained the United States position as one of the world's leading uranium producers. Completion of new mills under construction, and construction of other mills under contracts now being negotiated will further increase production.

Ore Production

Although the number of uranium mines in production has remained about the same and no new uranium producing areas were discovered in the last 6 months, production from existing mines has increased and additional large ore bodies were found in known areas. Uranium ore production in the United States totaled 1.66 million dry tons during the last 6 months of 1956 as compared to 840,000 dry tons for the second half of 1955. These figures, and the later figures on reserves and production of concentrates, were publicly reported after promulgation on December 5 of the Commission's new Declassification Guide removed from classified categories of information data on reserves and production subsequent to June 30, 1955.

Domestic Uranium Program Circular 5, Revised, was modified on August 22, 1956, with regard to the payment of development allowances to producers of uranium ore. Circular 5, Revised, which remains in effect until March 31, 1962, established guaranteed prices for uranium-bearing carnotite and roscoelite ores of the Colorado Plateau area. It also provided for a development allowance of 50 cents per pound of contained uranium oxide, to be spent by ore producers for the development or exploration of their properties. The modification eliminates the provision that producers delivering more than 1,000 short tons of ore per calendar year must, under the terms of their contracts, submit proof that funds received as development allowances have been spent for development or exploration during the period of their contracts or within 6 months afterwards.

The modification was made necessary by changed conditions in domestic exploration and development. In early small-scale uranium mining activities, development expenditures were generally incurred while mining progressed and could be partly financed from receipts from ore sales. Today, most ore deposits are explored and largely developed before ore production starts, and consequently before contracts are entered into with the Commission, and sales of ore consummated.

Ore Processing

During the last half of 1956, the production of uranium oxide (U_3O_8) concentrate totaled 3,400 tons, more than double the 1,600 tons produced during the last half of 1955.

Three new mills started production during the last half of 1956: at Tuba City, Ariz.; Edgemont, S. Dak.; and Moab, Utah. In addition, a new unit to the Union Carbide Nuclear Co. mill at Uravan, Colo., was completed and put into operation. This new unit will double the production of the mill.

There are 12 mills in operation, all privately owned and financed except for that at Monticello, Utah, owned by the Commission. The mills are:

	Location	*Capacity, Tons Ore per Day*
The Anaconda Co	Bluewater, N. Mex	3, 000
Atomic Energy Commission	Monticello, Utah	600
Climax Uranium Co	Grand Junction, Colo	350
Kerr-McGee Oil Industries, Inc	Shiprock, N. Mex	500
Mines Development, Inc	Edgemont, S. Dak	300
Rare Metals Corp	Tuba City, Ariz	250
Union Carbide Nuclear Co	Uravan, Colo	850
Union Carbide Nuclear Co	Rifle, Colo	280
Uranium Reduction Co	Moab, Utah	1, 500
Vanadium Corp. of America	Durango, Colo	430
Vanadium Corp. of America	Naturita, Colo	350
Vitro Uranium Co	Salt Lake City, Utah	550
Total		8, 960

The Commission negotiated concentrate purchase contracts for production from the following mills to be built:

	Location	*Capacity, Tons Ore per Day*
Atomic Fuel Extraction Corp	Bedrock, Colo	200
Dawn Mining Co	Ford, Wash	400
Gunnison Mining Co	Gunnison, Colo	200
Homestake—New Mexico Partners	Grants, N. Mex	750
Lost Creek Oil & Uranium Corp	Split Rock, Wyo	400
Lucky Mc Uranium Corp	Fremont County, Wyo	750
Texas Zinc Minerals Corp	Mexican Hat, Utah	775
Trace Elements Corp	Maybell, Colo	300

Contracts were signed which provide for increased production from Salt Lake City mill of Vitro Uranium Corp. and a new mill of larger capacity at Rifle, Colo., to be constructed by Union Carbide Nuclear Co. Union Carbide Nuclear Co. will also install upgrading plants at Slick Rock, Colo., and Green River, Utah which will ship concentrates to the Rifle Mill. The estimated investment in the privately owned mills now in operation aggregates $50 million, with an additional private investment of about $35 million in mills under construction or for which purchase contracts were signed.

New ore-buying station. The new Grants, N. Mex., ore-buying station was officially opened on July 5, 1956.

Uranium in lignites. Pilot plant studies progressed in the attempt to develop an economic process for recovering uranium from lignites.

Uranium from phosphates. Production of small tonnages of byproduct uranium concentrates from Florida phosphate rock continued during the reporting period.

Foreign Procurement

The Commission announced on September 8, 1956, a program for international cooperation in exploration for uranium deposits under which the United States offers assistance to friendly nations along the following lines:

a) Access to information on uranium geology and exploration techniques. The United States has made substantial contributions to world knowledge in this field and has included several hundred reports on various aspects of uranium exploration and ore recovery in the technical libraries that the Commission has presented to many countries.

b) Geologists and technicians in interested countries will be encouraged to study uranium deposits and Commission exploration and laboratory projects in the United States. The Commission conducted an 18-day tour in September-October 1956 of uranium deposits and ore processing facilities in the western United States for 31 geologists and engineers of other nations. The group, representing 18 nations, visited major producing mines and various types of uranium deposits found in the United States and observed exploration techniques, milling procedures, and laboratory methods.

c) Commission geologists upon request may visit other nations to discuss uranium geology and exploration techniques and make preliminary investigations of known uranium occurrences and favorable areas.

These activities may result in cooperative exploration projects in other countries similar to those approved by the Commission over the past several years. Since 1951, projects lasting from a month to several years have been or are being carried out with Australia, Bolivia, Peru, Venezuela, Colombia, the Philippines and Turkey. Brief preliminary appraisals have been made in a number of other countries.

Belgian Congo

Production from the Shinkolobwe mine in the Belgian Congo continued at a normal rate during the period.

South Africa

Production from South Africa increased with the completion of two new processing plants. Sixteen of the authorized 17 uranium processing plants now are in operation. It is expected that the full production will be reached by the end of 1957.

Australia

The Port Pirie chemical plant continued to treat at a normal rate low-grade mechanical concentrates produced at Radium Hill in South Australia. Production of uranium concentrates from the Rum Jungle operations in the Northern Territory was also as expected.

Portugal

Portuguese operations continued at a normal rate during the last 6 months.

Canada

Important developments continued in the three principal producing areas. In the Blind River district of Ontario, Rio Tinto Mining Co. of Canada (a subsidiary of the British owned Rio Tinto Co.), through a merger with the Joseph Hirschorn interests, acquired control of six major mining properties, including Pronto and Algom, which are in production. Five other companies in the district are constructing ore treatment plants of large capacity.

Production of concentrates from the Bicroft mill in the Bancroft area of eastern Ontario began in October. Mill construction in the area by Faraday Uranium Mines, Ltd., was well advanced.

In the Beaverlodge area of Saskatchewan the substantial mill expansion program undertaken by Eldorado Mining and Refining, Ltd. proceeded on schedule. Gunner Mines, Ltd. prepared for underground mining operations to supplement and ultimately supplant ore production from the open pit. It also completed installation of additional equipment to increase mill capacity. Lorado Mines, Ltd. began building a custom mill to treat ores from a number of small mines in the district.

Eldorado's Port Hope refinery was in steady operation producing metal grade uranium oxide for sale to the Commission.

Domestic Exploration

Private activity during the reporting period was concentrated in large part on development work within previously discovered mineralized areas rather than in the search for new areas. As a result there was a steady increase in ore reserves in older mining areas and rapid expansion of reserves in newer areas, many of which are now capable of sustaining increased milling capacities.

The major sources of ore supply have shifted from areas containing many small-to-medium-size ore bodies to new areas, such as Ambrosia Lake and Laguna, near Grants, N. Mex., which contain multimillion ton reserves. Large-scale integrated mining and milling enterprises in these areas give assurance of a long-term uranium supply.

Today, there are 33 ore deposits with known reserves of more than 100,000 tons each and at least 8 deposits with reserves in the million-ton class, in contrast to the end of 1954, when there were 15 deposits with reserves over 100,000 tons and one deposit with reserves of more than 1 million tons. Ten percent of presently known deposits now contain 93 percent of estimated reserves.

Domestic ore reserves, by areas, were estimated as of November 1 as follows:

Measured, Indicated, and Inferred Ores

Area	*Tons*	*Percent of Total Reserves*	*Grade of Ore, In Terms of Percent U_3O_8*
New Mexico	41, 000, 000	68. 4	. 24
Utah	7, 500, 000	12. 5	. 34
Colorado	4, 100, 000	6. 8	. 33
Arizona	2, 600, 000	4. 3	. 30
Wyoming	2, 300, 000	3. 8	. 22
Washington	1, 500, 000	2. 5	. 18
Others	1, 000, 000	1. 7	. 24
Total	60, 000, 000	100. 0	

Exploration activities conducted during the period by the Commission with the assistance of the U. S. Geological Survey and the U. S. Bureau of Mines included basic geologic studies of uranium ore deposits, the dissemination of information useful to private operators, and the evalution of ore reserves. Government drilling has ceased. Total private drilling for the last half of 1956 was estimated at 4.5 million feet.

Process Development

The development of uranium recovery processes continued in the Commission-owned laboratory at Winchester, Mass., operated under contract by the National Lead Co., Inc.; in the Bureau of Mines Experimental Station at Salt Lake City; at Oak Ridge National Laboratory, and in the laboratory of the Dow Chemical Co., Pittsburg, Calif. Physical beneficiation of ores was studied at the McKay School of Mines, University of Nevada, Reno, Nev.

Commission-owned facilities at Grand Junction, Colo., also operated under contract by National Lead, carried on pilot plant testing of process improvements and of ores for projected mills.

Studies on recovery of uranium from Chattanooga shales on a laboratory and bench scale continued at Columbia University.

Production of Special Nuclear Materials

The past 6 months saw the full effect on plant productivity of the new production facilities completed during the first half of 1956. With improved performance of other manufacturing facilities, output of new facilities resulted in producing more of the special nuclear materials required for the military and civilian application programs than in any earlier half year.

Most of the major additions to the feed materials facilities at Fernald, Ohio, St. Louis, Mo., and Paducah, Ky., construction of which started in 1955, were in operation during this reporting period. Other modifications which will provide additional capacity in the refineries and uranium hexafluoride facilities are scheduled to be completed early in 1958. Progress at the new Weldon Spring, Mo., feed materials center was satisfactory. The various production units are expected to be ready for initial operation in time to meet capacity requirements.

In response to the Commission's invitation of October 27, 1955, to private industry to supply up to 5,000 tons per year of uranium oxide (U_3O_8) equivalent as uranium trioxide (UO_3), uranium tetrafluoride (UF_4) or uranium hexafluoride (UF_6) over a 5-year period beginning April 1, 1959, seven proposals were received by the October 1 deadline.

The Commission on December 5 signed a letter contract with the General Chemical Division of the Allied Chemical and Dye Corp., New York, N. Y., whose proposal provided the lowest cost to the Government. Utilizing uranium concentrates furnished by the Commission, the company proposes to supply 5,000 tons uranium oxide (U_3O_8) equivalent of uranium hexafluoride a year. The company will employ a new process which permits bypassing a refining step presently used in Commission plants, and will accomplish purification by distilling the uranium hexafluoride. The company expects its new plant to be in operation by April 1, 1959.

Production of uranium salts now is limited to Government-owned plants operated for the Commission by contractors. Operation by a corporation of privately financed facilities is a step in the Commission's program to broaden industrial participation in the atomic energy program. This new contract will help meet Government requirements for increased capacity.

On November 5, the Commission invited industry to submit proposals for the purchase of uranium-magnesium-fluoride slag generated at feed materials plants. The invitation foresees a 5-year contract under which the uranium-magnesium-fluoride slag would be sold to the contractor at a price established through competitive proposals, and recovered uranium purchased by the Commission at preestablished prices. The magnesium and fluorine content of the slag would remain the property of the contractor. Since January 17, 1956, when the program was first announced, some 75 firms have indicated an interest in participating.

In connection with the invitation, the Commission conducted a classified technical information meeting in St. Louis, Mo., on December 6 and 7. This meeting was attended by 88 representatives of 34 companies.

Military Application

During the period of this report emphasis has continued on research and development activities designed to increase and improve the United States arsenal of weapons. Work continued on designs for defensive use and on methods of reducing the radioactive contamination resulting from weapons detonations.

The test firings of Operation *Redwing*, started during May of 1956, were completed during July. No radiological hazard to populated areas resulted from the Redwing test series.

Production on a wide variety of nuclear weapons continued, in accordance with a directive of the President.

Additions to the Weapons Complex

The accelerated research, development and production programs necessitated planning for certain expansions of the weapons research, engineering, and production complex. For the most part these expansions will be accomplished by modifying or adding to existing facilities.

At the University of California Radiation Laboratory, Livermore, Calif., architect-engineering began on facilities to be completed in the near future at an estimated cost of $12 million. These facilities will include additional laboratory, fabrication, and experimental structures. Also at Livermore, and adjacent to the University of California Radiation Laboratory, the Commission soon will construct facilities in which the Sandia Corp., a Subsidiary of Western Electric Co., will perform ordnance engineering in support of the Radiation Laboratory programs. Architect-engineering started and this construction is scheduled for completion in early 1958 at an estimated cost of $6 million.

Augmentation of the production plant at Rocky Flats near Denver, Colo., proceeded satisfactorily.

Adjacent to the Nevada Test Site in southern Nevada and within the U. S. Air Force Nevada Gunnery Range, new experimental areas are being developed for the Commission. Initial construction of a new technical area in the general vicinity of Jackass Flats was planned for early 1957.

Construction started in July on a ballistics range located to the northwest of the present test area. This range will be used by the Commission for determining the ballistic characteristics of inert weapons shapes dropped from aircraft.

Expansion of facilities during 1958 is programmed for the Iowa Ordnance Plant at Burlington, Iowa, and the Pantex Ordnance Plant near Amarillo, Tex. Cost of expanding the two facilities operated for the Commission by the Army Ordnance Corps, is estimated at $7.5 million.

Additional laboratory facilities were under construction or programmed for early initiation at the Los Alamos Scientific Laboratory, located at Los Alamos, N. Mex., and operated for the Commission by the University of California. Also planned are expansions of the Commission's Kansas City Plant in Missouri operated by the Bendix Aviation Corp.; of the Commission's Sandia Laboratory, at Albuquerque, N. Mex., operated by the Sandia Corp.; and of the Commission's South Albuquerque works at Albuquerque operated by ACF Industries, Inc.

Weapons Testing

Operation Redwing

The last test firing of Operation *Redwing* was announced on July 23, 1956. The radiation protection area surrounding the Eniwetok Proving Ground was terminated on August 11, 1956. As was planned and reported earlier, the largest test of this series was of a yield substantially below that of the maximum in the 1954 series.

Operation *Redwing* gave important information relating to developing means of reducing fall-out from weapons firing, weapons for defensive purposes, and new design principles which will lead to more efficient weapons that can be more effectively employed.

International Activities

Significant progress was made during this reporting period in carrying out the objectives of the President's Atoms for Peace Program. Working closely with the Department of State, the Commission participated in the 82-nation conference which adopted the statute for the International Atomic Energy Agency.

Four additional agreements for cooperation went into effect, and another three were negotiated, making a total of 41 with 39 nations; 22 other agreements were being discussed. Plans were made to provide financial assistance to other nations on research reactor projects. Broader interchange was accomplished through joint working committees, and exchange of information, personnel and skills, and through conferences, meetings, training programs and reciprocal visits. Included were exchanges between the United Kingdom and the United States on research on peaceful uses of controlled thermonuclear reactions. Training and education programs for students from friendly nations continued. The United States announced a three-part program of early assistance to American states, and a second Atoms for Peace Mission visited six of the countries. Two overseas offices were opened.

A summary is given of the plans for construction of 12 research reactors and 3 power reactors now being planned by 10 countries which have agreements for cooperation with the United States.

The Commission assisted in United Nations discussions on disarmament, and on radiation effects, accepted responsibility for preparing for United States participation, in a second international conference on the peaceful uses of atomic energy in 1958, was asked to assist United States preparations for a world scientific exhibition at Brussels, also in 1958.

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INTERNATIONAL ATOMIC ENERGY AGENCY

The conference which approved a statute for an International Atomic Energy Agency held at United Nations headquarters in New York from September 20 to October 26, 1956, with representatives of 82 nations, included the largest number of nations ever to take part in an international conference. Seventy-two nations, including the United States, signed the agency statute.

At the closing session, Commission Chairman Lewis L. Strauss delivered a message from the President [1] announcing that the United States would make available to the international agency, on terms to be settled with the agency 5,000 kilograms of uranium 235 from the 20,000 kilograms allocated February 22 for distribution as needed under agreements for cooperation.[2] The United States also offered to match on comparable terms the allocations of nuclear materials to the agency by all other member nations through June 30, 1960. These proposals were made contingent upon (a) ratification of the agency's statute by the United States Senate, and (b) appropriate authority from Congress to transfer special nuclear materials to the international agency.

The signing of the agency statute brought nearer the successful completion of negotiations begun after December 8, 1953, when the President proposed establishment of an international agency in an address before the General Assembly of the United Nations. The Atomic Energy Commission has worked closely with the Department of State on technical matters during all stages of the negotiations. Representatives of the Commission served on the U. S. Delegation to the 12-nation meeting which drafted the statute submitted to the Conference. The Commission also was represented on the U. S. Delegation to the Conference.

The agency will come into existence when the statute has been ratified by 18 nations, including at least 3 to 5 major atomic energy nations—Canada, France, the Soviet Union, United Kingdom and the United States. Meantime a Preparatory Commission is already planning the specific steps for its formal establishment. The United States is represented on the Preparatory Commission and the Commission is active in support of the U. S. Representative on technical aspects.

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[1] See text, Appendix 10.

[2] See p. viii and Appendix 8, Twentieth Semiannual Report (January–June 1956).

Agreements for Cooperation

During this reporting period, four additional Agreements for Cooperation became effective—that with France covering both research and power activities and research agreements with Austria, Dominican Republic, and New Zealand. Negotiations were completed on three additional agreements: a power agreement with Norway, and research agreements with Guatemala and Iran. These three agreements will not become effective until they lie before the Joint Committee on Atomic Energy for 30 days while the Congress is in session.

Six other agreements will become effective upon exchanges of notes. These comprise research agreements with Costa Rica, Cuba, and Ireland, and power agreements with Australia, the Netherlands, and Switzerland.

As of December 31, there was a total of 32 agreements in effect, of which 4 were concerned with atomic power activities.

Since negotiations of agreements for cooperation began early in 1955, discussions have been held with a total of 49 countries, and as of the end of this reporting period, negotiations were concluded for 41 agreements with 39 nations.

The 39 nations include: 15 in Europe, 11 in the Americas, 8 in Asia and the Far East, and 4 in the Middle East. Research agreements among this group total 33, itemized in the following tables. The 8 power agreements, besides those already mentioned, are with Belgium, Canada, and the United Kingdom.

In addition to effective and pending agreements preliminary discussions on research agreements were held with 8 countries, and on power agreements with 15 countries.

Reported previously were amendments to the research agreements with Denmark, the Federal Republic of Germany and Sweden, increasing from 6 to 12 kilograms the permitted quantity of uranium 235 which may be transferred to each, and authorizing small quantities of highly enriched special nuclear materials for specific research purposes. These amendments must lie before the Congress for 30 days. Other countries are expected to seek similar amendments.

Amendments to power agreements with Canada and the United Kingdom completed their 30-day waiting period before the Congress. An amendment to the Belgium agreement still lacked a number of days of fulfilling this requirement at the year's end.

The current status of agreements for cooperation and pending negotiations was as follows:

AGREEMENTS IN EFFECT

1. Argentina	July 29, 1955	14. Korea	Feb. 3, 1956
2. Austria	July 13, 1956	15. Lebanon	July 18, 1955
3. Brazil	Aug. 3, 1955	16. Netherlands	Dec. 30, 1955
4. Chile	Aug. 8, 1955	17. New Zealand	Aug. 29, 1956
5. China, Republic of	July 18, 1955	18. Pakistan	Aug. 11, 1955
6. Colombia	July 19, 1955	19. Peru	Jan. 25, 1956
7. Denmark	July 25, 1955	20. Philippines	July 27, 1955
8. Dominican Republic	Dec. 21, 1956	21. Portugal	July 21, 1955
9. Germany, Federal Republic of.	Apr. 23, 1956	22. Spain	July 19, 1955
10. Greece	Aug. 4, 1955	23. Sweden	Jan. 18, 1956
11. Israel	July 12, 1955	24. Switzerland	July 18, 1955
12. Italy	July 28, 1955	25. Thailand	Mar. 13, 1956
13. Japan	Dec. 27, 1955	26. Turkey	Jun. 10, 1955
		27. Uruguay	Jan. 13, 1956
		28. Venezuela	July 21, 1955

Negotiations Concluded

1. Costa Rica
2. Cuba
3. Guatemala
4. Iran
5. Ireland

Discussions in Progress

1. Ceylon
2. Ecuador
3. Haiti
4. Iraq
5. Liberia
6. Nicaragua
7. Tunisia
8. Yugoslavia

POWER AGREEMENTS

AGREEMENTS IN EFFECT

1. Belgium	July 21, 1955	3. United Kingdom	July 21, 1955
2. Canada	July 21, 1955	4. France	Nov. 20, 1956

Negotiations Concluded

1. Australia
2. Netherlands
3. Norway
4. Switzerland

Discussions in Progress

1. Argentina
2. Brazil
3. Cuba
4. Federal Republic of Germany
5. Israel
6. Italy
7. Japan
8. Pakistan
9. Philippines
10. South Africa
11. Spain
12. Sweden
13. Thailand
14. Tunisia
15. Uruguay

Financial Assistance Programs

Bank loans for reactors. In October, the Commission and the Export-Import Bank agreed to joint action to provide financial assistance in the construction of nuclear powerplants and additional help on research reactor projects in nations which enter into agreements for cooperation with the United States for development of peaceful uses of atomic energy.

The bank will consider loans to both governments and private industry. In order to qualify for bank assistance a nation would have to negotiate an agreement with the United States, and to submit a comprehensive engineering survey of the project. The Commission will then provide a technical report on the proposed reactor. A country requesting a loan also must have an arrangement for getting atomic fuels for the period of the loan, and to demonstrate the economic and financial soundness of the project, the availability of funds to defray local currency costs, and the ability of the country concerned, to service the dollar debt involved. Loans could be spent only for equipment, materials, and technical services purchased in the United States.

Grants for reactors. As previously reported [3] grants have been made by the United States to assist foreign nations in financing approved research reactor projects.

Procedures were established during this reporting period to carry out the President's offer of June 11, 1955, to contribute toward the cost of research reactors projects undertaken by "free nations who can use them effectively for the acquisition of the skills and understanding essential to peaceful atomic progress." [4] Contributions made pursuant to the President's offer from funds authorized under the Mutual Security Act of 1956 are available to nations only under agreements for cooperation. The contribution to each nation is limited to $350,000, or half the total cost, if that is less, for the total reactor project including experimental equipment and supporting facilities and activities necessary to make the reactor an efficient training and research tool.

Before funds may be obligated for a specific reactor project, the Commission reviews the project proposal, usually prepared by the applicant nation with the assistance of a contractor it has chosen. The principal purpose of the review is to confirm that the project qualifies for assistance, and that it conforms with the governing agreement for cooperation. Technical aspects are considered, but approval does not comprise indorsement of plans from the viewpoint of technical design.

Each applicant nation is asked to provide formal assurance that it has available and is prepared to expend sufficient funds for completion and operation of the reactor project. The United States financial

[3] See pp. 14–15, Twentieth Semiannual Report (January–June 1956).
[4] See pp. 12–13, Eighteenth Semiannual Report (January–June 1955).

contribution is made as a grant and paid in dollars to the cooperating nation upon appropriate certification of completion of the approved project.

Grants of $350,000 each have been approved for projects in Brazil, Denmark, the Netherlands, and Spain. Requests for grants are pending from Belgium, Israel, Japan, and the Federal Republic of Germany.

A summary of procedures entitled "Information for Nations Desiring U. S. Financial Assistance on Research Reactor Projects" is available on request from the Commission.

Exchanges With Other Nations

The Commission continued its extensive program of exchanging atomic energy information through conferences, visits, and documents and through interchange of personnel skills and related activities.

Second Atoms for Peace Mission.[5] To assist certain American countries in planning their atomic energy programs, a second Atoms for Peace Mission visited Chile, Colombia, Costa Rica, Ecuador, Panama, and Peru. The mission was comprised of U. S. Government representatives and scientific personnel from Columbia University, University of Illinois, Pennsylvania State University, and University of California.

The mission discussed the President's Atoms for Peace Program, disseminated technical information on use of radioisotopes and radiation in research, research reactors, and nuclear power, and appraised local needs for nuclear training and education.

Patents. The United States, the United Kingdom, and Canada signed an agreement on September 24 relating to inventions and discoveries in the atomic energy field that were the subject of a patent or patent application owned by one of the Governments as of November 15, 1955. (See Patents.)

Classified conferences. Belgium, Canada, and the United Kingdom advanced international cooperation in nuclear technology through classified conferences with the United States. Several joint working groups were established among these nations, and notable progress was made in studying the technical problems on selected nuclear subjects.

A total of 214 classified conferences was held, and arrangements were made for approximately 280 United States representatives to

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[5] The first mission was reported on p. 19, Twentieth Semiannual Report (January–June 1956).

make classified visits to facilities in Belgium, Canada, and the United Kingdom. Representatives from these countries visiting the United States under the same arrangements totaled 212.

Unclassified Visits were arranged for 550 foreign representatives from 47 other countries to visit Commission installations; and for 363 foreign nationals and embassy personnel from 32 countries to visit Washington headquarters.

A special visit was arranged for 137 delegates from 54 nations and 4 international agencies represented at the International Atomic Energy Agency Conference to see the nuclear powerplant under construction at Shippingport, Pa., the first full-scale project for central station nuclear power production in the United States. Officials of the Commission, the Westinghouse Electric Corp., and the Duquesne Light Co. conducted the visit.

Reciprocal exchanges made in many areas of atomic energy developments through joint efforts of cooperating countries are reported below:

Discussions have been held in the hot-loop experimental programs continuing in *Canada*, the *United Kingdom*, and the *United States*. Tripartite meetings were held in Canada in September and October on corrosion of aluminum alloys in water at high temperatures. These materials are of use in power reactor studies. In Washington on October 18-19, 1956, discussions were held on analytical and sampling procedures used in fall-out studies. The Fifth Instrumentation Conference was held at Brookhaven National Laboratory, Upton, Long Island, N. Y., late in 1956. The Tripartite Nuclear Cross Section Committee met at Oak Ridge National Laboratory, Oak Ridge, Tenn., November 5-7 for the third time since establishment of the committee.

Commission representatives participated with *Belgium* in a classified Power Reactor Symposium held November 29-30, 1956, at the new Belgian nuclear research center at Mol. Preceding the classified discussions, a 2-day unclassified meeting was held in Brussels by the Atomic Industrial Forum, Inc., and its Belgian counterpart.

Discussions were held between *Canada* and the United States representatives on preparation, fabrication, and special handling techniques of plutonium-base alloys; on the Chalk River program for the separation of uranium and plutonium; on the establishment of an exchange program on power reactor fuel development. A series of meetings is expected to be arranged on problems related to economic fueling of natural-uranium, heavy-water reactors.

Beginning the week of October 1, 1956, a conference was held with *United Kingdom* representatives at Harwell, England, on liquid bismuth studies and a reactor physics program; at Oak Ridge National Laboratory, on October 8, 1956, a conference was held on homogeneous reactors. Exchanges were made in October of chemistry staff members from Argonne National Laboratory, Lemont, Ill., and Harwell Laboratory for a period of 1 year or more. This development in cooperative efforts will assist research studies in both countries.

Controlled thermonuclear research. In the furtherance of cooperation between the United States and the United Kingdom to promote and accelerate the peaceful uses of atomic energy, an exchange of classified and unclassified information on research in the field of controlled thermonuclear reactions was initiated under provisions of the agreement for cooperation between the two countries.

Controlled thermonuclear research is directed toward the possibility of controlling the release of the great amounts of energy produced by reactions involving the fusion of nuclei of light elements. Difficult technical problems must be overcome, and long-range research programs have been instituted in both countries in an effort to achieve this objective.

Thirteen United States representatives participated November 16–20 in discussions on this subject at the British Atomic Eenergy Research Establishment at Harwell, England. In October Commission officials visited British scientists in this field and British scientists visited controlled thermonuclear research facilities in the United States for discussions.

All classified technical discussions in this area are limited to United States and United Kingdom programs on peaceful uses of atomic energy (see also section in Declassification and Classification).

Training and Education

Assistance to American States

The Commission participated in the work of the Interdepartmental Policy Group on the Inter-American Committee of Presidential Representatives, established as an outgrowth of the President's address July 22 at the Panama Conference. The Chairman of the Committee, Dr. Milton S. Eisenhower, announced on September 17, the steps which the Commission would take to accelerate the application of the peaceful uses of atomic energy in the American Republics through existing components of the organization of American States.

These projects are, first, inauguration of a program of special assistance to the University of Puerto Rico to enable that university to offer training and education in nuclear energy in the Spanish language; second, the institution of a program of cooperation with the Inter-American Institute for Agricultural Sciences at Turrialba, Costa Rica, in use of radioisotopes in agricultural research; and third, planning for an Inter-American Symposium on Nuclear Energy to be held next year at the Commission's Brookhaven National Laboratory, Upton, Long Island, N. Y. The Brookhaven Symposium will discuss both scientific and economic aspects of atomic energy.

Puerto Rico Center. The program in support of the University of Puerto Rico is expected by the opening of the 1957–58 academic year to provide facilities for training programs in reactor physics and in the use of radioisotopes in various fields of research. The facilities will serve as a nucleus of a comprehensive educational and research program in pure and applied nuclear sciences at the university.

In his press statement of September 17, Dr. Eisenhower declared that because the facilities to be provided over the next few years would be outstanding and instruction would be in Spanish, "the University of Puerto Rico might well become a nuclear research and training center of interest to many countries of this hemisphere." He noted that about 300 students from Central and South America were attending the university. Dr. Eisenhower said that if more students wished to enter nuclear training and research courses, the United States would assist.

Institute at Turrialba. A four-fold program to assist the Inter-American Institute of Agricultural Sciences is being organized by the Commission: (a) Offering training at the Oak Ridge Institute of Nuclear Studies and Brookhaven National Laboratory for staff members selected by the Director of the Institute at Turrialba; (b) providing equipment for a radioisotope laboratory; (c) supplying a radiation source (cobalt 60) for plant irradiation in the field, radioisotopes, if desired, and help in the technique of using these tools; and (d) providing irradiation of plants and seeds for experiments as requested. The U. S. Department of Agriculture was consulted in connection with these Commission plans.

Brookhaven Symposium. The purpose of the Brookhaven Symposium is to clarify the present and future possible uses of atomic energy in American countries, and to call attention to the practical efforts necessary to support and accelerate the development of atomic energy in those areas if it is to be of value to their economic and industrial development. Emphasis would be placed on those branches of nuclear science which already are, or may soon be, providing benefits to the peoples of the Americas. Thus, the discussions would center around (1) the uses of radioisotopes in industry, agriculture, and medicine, (2) reactors, including types, uses and costs, with collateral discussion on the realistic prospects of nuclear energy as a source of power, and (3) safety standards and health aspects in the use of atomic energy. There also would be general discussions on raw materials, such a geology, exploration, and processing. Training would be stressed in discussions and by demonstration using the laboratory's equipment.

Five days of meeting at Brookhaven, during May 1957, would be followed by tours to atomic energy facilities, hospitals, universities and industrial establishments where the peaceful atom can be observed at work.

Invitations would be extended to approximately 100 American scientists and individuals prominently identified with the country's nuclear energy program.

Asian Nuclear Center

During a meeting in December at Wellington, New Zealand, of the Colombo Plan nations, the United States indicated a continuing interest in support of a cooperative effort to establish an Asian Nuclear Training and Research Center as proposed to the consultative assembly of the Colombo powers at Singapore in October 1955.[6] The Colombo powers at the Wellington meeting were informed that the United States is now prepared to contribute approximately $20 million for capital expenditures and initial operating costs for establishment of the Center, if mutually satisfactory arrangements can be worked out with other participating countries. The financing would be provided through the International Cooperation Administration from the President's Fund for Asian Economic Development, established under the Mutual Security Act.

Copies of a technical report on preliminary plans for the Center prepared by the Brookhaven National Laboratory, acting under contract with the International Cooperation Administration, were distributed to each delegation attending the meeting at Wellington. The Commission has provided technical assistance on this project, and will continue such guidance.

International School at Argonne

The fourth course of the International School of Nuclear Science and Engineering at Argonne National Laboratory began September 10 for foreign and domestic students. Students who on April 16 started their work at the associated schools, North Carolina State College and Pennsylvania State University, made a tour August 12–September 5 of Commission installations and other research establishments. They began the final phase of their training at Argonne September 10.

[6] See p. 20, Twentieth Semiannual Report (January–June 1956).

Fifty students from 24 other countries and 13 from the United States were selected for courses starting at the universities this fall. Fifty-nine students from 27 countries, and 11 United States students were selected on November 21 to attend the fifth course, beginning February 6, 1957. Since inception of the ISNSE in March 1955, a total of 166 foreign nationals representing 40 countries has attended the school.

ORINS Courses

Since October, 1948, the Oak Ridge Institute of Nuclear Studies has been conducting courses in radioisotope tracer techniques in research, to which a limited number of foreign scientists has been admitted. In 1954, the Commission approved establishment of special courses for them and authorized admittance to future regularly scheduled courses.

The first special course of foreign students was held in May 1955, a second course in October 1955. In September and October of 1956, courses were held for equal numbers of foreign and United States students.

The Radioisotope Tracer Techniques Course lasts four weeks and is divided among laboratory work, lectures on laboratory experiments, general background lectures, special topic seminars and laboratory work.

Technical Libraries

With the approval for presentations of technical libraries on atomic energy to the Governments of Cuba and Yugoslavia during this period, the Commission had authorized libraries for 44 foreign nations. Libraries have been presented also to three international organizations.

To increase the value of these libraries, the Commission has added 20 microcard reading machines to assist use of the technical information supplied to each library on microcards.

Atomic Energy Activities in Other Nations

Reactor Programs

Developments in atomic energy programs in which United States industry will participate in countries which have agreements for cooperation with the United States are listed in the following items.

Argentina. Plans are under way for construction of a 3-megawatt pool reactor for research at Buenos Aires.

Belgium. The Syndicat d'Etude de L'Energie Nucleaire (SEEN), a private Belgian organization, has under study the construction of a powerplant which will include a pressurized water reactor. The reactor was originally proposed for demonstration at the Brussels World's Fair in 1958.

Brazil. The Brazilian Government is interested in construction and operation of a boiling water power reactor of 10,000 to 20,000 kilowatts of electrical capacity.

Denmark. Construction is well under way for Denmark's Atomic Energy Research Center on an 130-acre tract on Roskilde Fjord, about 30 miles west of Copenhagen. A 5-megawatt, pool research reactor, being constructed in the United States is expected to be installed and in operation by December 1957.

Denmark has selected a United States contractor to build a solution-type reactor to be completed by May 1957.

Germany, Federal Republic of. The construction of three reactors is planned in Western Germany. The Technological Institute in Munich (Technische Hochschule Muenchen) plans to construct a 1-megawatt pool reactor. A second reactor a1-megawatt will be located at Hamburg and a third, a 50-kilowatt boiling water reactor will be located in Frankfurt.

Italy. Italy is building a research center about 40 miles from Milan. A contract has been awarded for construction of a 5-megawatt research reactor.

One Italian company has announced plans to purchase in the United States a power reactor of 100,000 to 120,000 kilowatts electrical capacity.

Japan. Representatives of the Japanese Government and leading Japanese industries visited United States Commission and industrial installations from August through November. Their prime interest was in nuclear power developments.

In addition, government representatives of Japan concluded a lease agreement with the Commission on November 23 under which fuel containing 2 kilograms of uranium 235 at 20 percent enrichment would be provided for a 50-kilowatt solution-type research reactor under an agreement for cooperation.

The reactor, to be installed at the new nuclear research center under construction 75 miles northeast of Tokyo for the Japan Atomic Energy Research Institute, is being built in the United States. On November 2, an export license was issued for export of the first components of the reactor to Japan.

A second research reactor of CP–5 type will be constructed at the Institute.

Netherlands. The Netherlands awarded a contract for construction of a pool research reactor to be used at an International Atomic Exhibition in 1957 at Amsterdam. During the Amsterdam Exhibition the reactor will be operated at about 10 kilowatts. When relocated at a permanent experimental facility for training and research in the Netherlands, it will operate at 100 kilowatts.

Sweden. Sweden has indicated an interest in a materials testing reactor of the Oak Ridge Reactor (ORR) type for operation by the end of 1958 at Sweden's new Studesvik nuclear research center.

Venezuela. The Instituto Venezolano De Neurologia E Investigaciones Cerebrales announced in October that two United States firms will assist the Institute in its atomic energy programs, to include a 3 to 5 megawatt pool reactor.

Establishment of Commission Overseas Offices

To assist the program of cooperation with other governments, including distribution of nuclear materials and exchange of information, the Commission established two offices overseas. During this reporting period, offices were opened in Paris, France and in London, England. The duties of the Commission representatives at the offices relate primarily to operations under the agreements for cooperation and are technical.

The Commission representatives will advise the United States Ambassadors and coordinate their own work with that of the Department of State. They will maintain contact with the atomic energy establishments of the countries to which they are accredited and will report on the technical aspects of atomic energy developments.

Other International Activities

Disarmament

Commission representatives acted as advisers on the U. S. Delegation at meetings of the United Nations Disarmament Commission, held in New York July 3–16.

United Nations Scientific Committee on Radiation

The United States presented 7 major reports at the October 19–November 2 meeting of the 15-nation Scientific Committee on the Effects of Atomic Radiation established by the Tenth General Assembly of the United Nations. United States representative was Dr. Shields Warren, New England Deaconess Hospital, Boston, Mass., with Dr. Austin Brues, Argonne National Laboratory, and Merril Eisenbud, of the Commission's New York Operations Office, as alternates.

Including the United States and its contribution, 23 Governments and one specialized agency of the United Nations submitted 44 reports. In the United States contribution was the report of the National Academy of Sciences-National Research Council "Biological Effects of Atomic Radiation," and data on levels of radiation by time and location collected by the United States through its world-wide fall-out collection system. In addition, the United States provided assistance to nine countries (Brazil, Egypt, Sweden, Argentina, Pakistan, Thailand, Union of South Africa, Burma, and Greece) in establishment of their own collection stations, and agreed to train a selected number of foreign scientists in analytical techniques and instrumentation relating to radioactive fall-out. Brazil, India, Thailand, and the Union of South Africa have requested this assistance.

The Committee (a) reviewed reports received in response to its previous request on levels of radiation and radioactivity from natural and artificial sources, (b) surveyed methods for measuring radiation and endorsed programs of the World Health Organization and the United Nations, Educational, Scientific and Cultural Organization for supplying calibration standards and instruments, (c) discussed problems associated with the disposal of radioactive wastes in the oceans, and (d) prepared a release of the Medical Press entitled "The Responsibilities of the Medical Profession in the Use of X-rays and Other Ionizing Radiations." Because so few countries had submitted material on the subject of genetics, it was decided to postpone detailed consideration of genetic effects of radiation until the next session in April 1957.

Second United Nations Scientific Conference

The Commission, at request of the Department of State, accepted responsibility for planning and coordinating the technical participation of the United States in the second United Nations scientific conference on the peaceful uses of atomic energy. The Commission performed this same function in the International Conference on the

Peaceful Uses of Atomic Energy held August 1955 in Geneva, Switzerland, which the Commission initiated. The Commission also will assume complete responsibility for organizing and coordinating whatever United States Government exhibit is planned in conjunction with the conference. The Commission will finance the preparation and the exhibit. The Department of State will bear the expenses of the official delegation.

Plans for the second conference began to take shape with the meeting in New York on September 28 of the Advisory Committee on Atomic Energy affairs to the Secretary General of the United Nations. The United States was represented by Dr. I. I. Rabi to whom the Commission supplied staff assistance.

At the meeting of the Advisory Committee, the following major decisions were reached:

a) The approximate date of the second Scientific Conference will be September 1, 1958.
b) The conference will be of two weeks duration with an agenda wide in scope but with priority being given to atomic power.
c) The Secretary General will conduct a survey of suitable sites for the conference.
d) Representatives of the specialized United Nations agencies will be asked to make brief presentations at the conference, possibly at night sessions, on atomic energy activities in which their agencies have participated.
e) The next meeting of the advisory committee will be held in May, probably in Europe, to determine the location of the conference, and the agenda.

Conference history. In connection with the first International Conference on the Peaceful Uses of Atomic Energy, Mrs. Laura Fermi, as historian for the United States delegation, prepared a book entitled "Atoms for the World." The book is an intimate and informative account of hopes and plans of the participants, the problems encountered, the people involved, and the successful culmination of the months of planning and work entailed by United States participation in the Conference.

The book is being published by the University of Chicago Press and will be released early in 1957. Mrs. Fermi is the widow of the Nobel laureate, Enrico Fermi, who designed and built the first successful nuclear reactor. She is the author also of "Atoms in the Family."

Brussels International Exhibition of 1958

The Commission was requested to assist in planning United States exhibits dealing with atomic energy for the three main types of exhibits which will be displayed at the International Scientific Exhibition, Brussels, Belgium, April to Ocotober 1958. The exhibits will comprise an international science section on nuclear physics, chemistry, solid state physics, and biology; national pavilions featuring nations' resources, production and roles in science, and contributions to world progress; and "The Atomium," a symbolic structure in which individual countries will have exhibits on peaceful uses of atomic energy.

Civilian Application of Atomic Energy

Continued activity and interest in developing private and public entities for a civilian atomic energy industry were evidenced during this reporting period by new applications for access to restricted data and for licenses to construct reactors and to obtain and use nuclear materials.

Under the program for granting access to restricted data for civilian use, 262 applications for access permits were received from private individuals and organizations representative of a variety of industries and professions. There were 1,145 such permits in effect at December 31, 1956.

During the period, 6 applications were received for licenses to construct nuclear reactors. A permit authorizing construction of a nuclear power reactor, the fourth such permit under the Atomic Energy Act of 1954, was issued on a provisional basis to Power Reactor Development Corp., Detroit, Mich. One construction permit was issued for a research reactor.

The use of isotopes in medicine, industry, and agriculture continued to expand. At November 30, 1956, there were 3,624 licensed users of these important materials in the United States representing an increase of almost 100 percent in the last 3 years.

In the regulatory field, the Commission issued regulations prescribing standards for protection against radiation hazards (10 CFR Part 20), and established rules applicable to the Commission's public records relating to proceedings under 10 CFR Part 2 (Rules of Practice). The regulation on licensing of byproduct material (10 CFR Part 30) was amended to place under general license spark gap and electronic tubes, lightmeters and ion-generating devices containing limited quantities of specified byproduct material, and Part 50 and Part 55 also were amended.

Access to classified information on controlled thermonuclear processes was authorized under certain criteria by amendment of the regulation dealing with access to restricted data (10 CFR Part 25).

Licenses Requested and Issued

During the reporting period, the Commission received:
18 applications for production and utilization facility licenses;
53 applications for operators licenses;
33 applications for special nuclear material licenses;
2,194 applications for byproduct material licenses; and
909 applications for source material licenses.
During the same period the Commission issued:
2 construction permits authorizing the construction of nuclear reactors;
3 licenses authorizing the operation of nuclear reactors;
1 license authorizing the export of a nuclear reactor;
8 operators licenses;
36 special nuclear material licenses;
2,209 byproduct material licenses including amendments; and
813 source material licenses.

Production and Utilization Facilities

Licenses applied for and issued during this period are listed in Appendix 8. Thus far, under the Atomic Energy Act of 1954, the Commission has issued 16 facility construction permits or facility operating licenses, including 4 for power reactors, 8 for research reactors, and 4 for critical experiment facilities.

In connection with the issuance on a provisional basis of a construction permit to the Power Reactor Development Co., Detroit, Mich., authorizing construction of a nuclear power reactor at Lagoona Beach, Monroe County, Mich., petitions for leave to intervene and further relief were filed on August 31, 1956, on behalf of the International Union, United Automobile, Aircraft and Agricultural Implement Workers of America, the International Union of Electrical, Radio and Machine Workers, the International Union, United Paperworkers of America, AFL–CIO.

The Commission on October 9, 1956, granted the petitions for leave to intervene. A hearing was ordered for January 8 in Washington, D. C., on the application upon a designated specification of issues. Jay A. Kyle, Assistant Chief Hearing Examiner, Federal Communications Commission, was designated as presiding officer.

Naval Research Reactor Licensed

The Naval Research Laboratory in Washington, D. C., was licensed to operate a 100-kilowatt atomic reactor for use in research, following

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a preoperational inspection of the facility by the Commission. It is similar in design to one which was in operation for several years at Oak Ridge National Laboratory. A simplified version was exhibited by the United States at the International Conference on the Peaceful Uses of Atomic Energy held in Geneva, Switzerland, in August 1955.

Operators' Licenses

Reactor operators' licenses had been issued to 27 persons as of December 31, 1956. Eight of these were issued during the period covered by this report.

Special Nuclear Material

As of December 31, 1956, a total of 60 licenses for possession of special nuclear material had been issued under the 1954 Act, 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 813 licensees during the 6-month period ended December 31, 1956. These included 308 to producers, 19 to processors, 22 to distributors, 143 to consumers, and 321 to exporters.

Byproduct Material

The number of byproduct (radioisotope) material licensees continued to grow during the past 6 months. By November 30, 1956, there were 3,624 licensed users in the United States representing an increase of 345 since May 31, 1956.

In the early days of radioisotope distribution, medical users far exceeded other types of users. At the end of 1951, industrial users outnumbered medical users. More recently, the medical users again surpassed industrial users.

Total shipments from the Commission's primary radioisotope supplier, Oak Ridge National Laboratory, during the June–November period amounted to 6,721 (see Physical Research). Under the revised byproduct material licensing procedures, all shipments for export must be reported to the Commission within 90 days. During this period 730 export shipments were reported.

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

The Advisory Committee on Isotope Distribution and its Subcommittee on Human Applications held their annual meeting in Washington on August 25–28. This committee was established in 1946 to furnish advice and recommendations on the distribution of radioisotopes. At its recent meeting, the full committee reviewed, in particular, radiation safety problems incident to the operation of high-level radiation facilities, introduction of byproduct material into the general environment, high school use of byproduct material and allocation of cyclotron produced radioisotopes distributed by the Commission.

The Commission approved on September 12 the addition of three items to those which may be possessed and used under a general license in Section 30: 21, 10 CFR 30, when manufactured, tested, and labeled in accordance with a specific license. General licensing now applies to the following devices: (a) Static eliminators containing not more than 500 microcuries of polonium 210 each as sealed sources; (b) spark gap and electronic tubes each containing not more than 5 microcuries of cesium 137, or nickel 63, or krypton 85, or more than 1 microcurie of cobalt 60; (c) light meters which contain not more than 200 microcuries of strontium 90 each as sealed sources; (d) ion generating tubes for ionization of air containing not more than 500 microcuries of polonium 210 each as sealed sources.

During more than 10 years of the Commission's radioisotopes distribution activities, byproduct materials have been used in practically all phases of basic research and industrial development. Some of the more recently developed uses are: (a) carbon 14 to trace fat absorption during frying; and (b) phosphorus 32 to produce labeled bacteriophage for testing the efficiency of gas masks.

Program for Access to Restricted Data

An average of 40 permits was granted each month during the period to private individuals and concerns interested in obtaining access to restricted data on the civilian applications of atomic energy. As of December 31, 1956, 1,156 permits had been issued. Eleven permits were terminated at the request of the permittees, leaving a balance of 1,145 in effect as of December 31.

Of the permits in effect, 579 were for access to Confidential material under L-type clearances, and 566 for access to Secret material under Q-type clearances. During the reporting period, 60 permits were converted to allow access to Secret material.

The Commission announced on February 4, 1956, that it had issued access permits for certain information on controlled thermonuclear reactions. The regulation covering access permits has been amended, as reported in the later section on regulations. As of the year's end, the Commission had issued 74 permits which include access to information on controlled thermonuclear research. The Commission advised, or is advising, 126 applicants that their applications failed to meet the special requirements for eligibility as provided in the amendment to regulations. In each instance, the applicant may submit additional factual data. Eight companies have withdrawn their requests, stating that their applications did not at this time meet the special criteria.

The increasing use made of the permits was evidenced by the growing number of reports purchased by permittees, which totaled 6,292 confidential reports during the last six months, and 1,704 secret reports.

CUMULATIVE CLASSIFIED REPORTS PURCHASED

	Confidential reports	*Secret reports*
Total, June 30, 1956	11, 329	1, 984
Total, December 31, 1956	17, 621	3, 68[illegible]

Requests for amendments to access permits, principally to enlarge the scope of access provided, stood at about 25 per month compared with 35 per month during the first half of this year.

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 June 30, 1956:

DATA ON ACCESS PERMITS

GEOGRAPHIC DISTRIBUTION

	June 30, 1956	*Dec. 31 1956*
New England	82	10[illegible]
Middle Atlantic	336	41[illegible]
East North Central	186	23[illegible]
West North Central	56	7[illegible]
South Atlantic	82	11[illegible]
East South Central	27	2[illegible]
West South Central	31	4[illegible]
Mountain	33	3[illegible]
Pacific	76	10[illegible]
Hawaii, Alaska, and Puerto Rico	3	[illegible]
Total	912	1, 14[illegible]

BUSINESS OR OCCUPATION

	June 30, 1956	Dec. 31, 1956
Aircraft companies	----------	11
Auto manufacturers	----------	3
Chemical processing	[a] 82	97
Consultants	[b] 128	175
Educational institutions	15	20
Engineering and construction	77	70
Federal, State and city governments and departments	----------	43
Financial organizations	21	20
Food companies	----------	3
Information services	----------	13
Instrument manufacturing	60	70
Insurance companies	48	64
Lawyers and accountants	----------	25
Metal mining and refining	44	60
Metal products manufacturing	151	189
Paper and pulp companies	----------	4
Petroleum companies	----------	20
Printing and publishers	----------	9
Railroad companies	----------	5
Research organizations	44	50
Rubber companies	----------	5
Shipbuilders	----------	9
Union, trade associations, and manufacturers' representatives	----------	12
Utilities	160	151
All others not elsewhere classified	82	17
Total	912	1, 145

FIELD OF INTEREST

OPERATING ATOMIC FACILITIES	June 30, 1956	Dec. 31, 1956
Reactors for production of electric power	158	168
Reactors for other purposes, such as research, propulsion of ships, etc	35	47
Plants to refine uranium and thorium ore and process feed materials	62	76
Chemical plants for reprocessing spent fuel elements	31	46
MANUFACTURE OF ATOMIC ENERGY PRODUCTS		
Entire reactors	72	100
Components, such as fuel elements, instruments, and pumps for reactors and related facilities	193	241
Materials for atomic energy applications such as zirconium, carbon, and special alloys	94	121

[a] Including petroleum.
[b] Including lawyers and accountants.

FIELD OF INTEREST—Continued

RELATED ACTIVITIES	*June 30, 1956*	*Dec. 31, 1956*
Utilizing radioactive isotopes for sterilization of food, radiochemistry research, etc	49	57
Design and construction of atomic energy facilities	71	79
General nuclear research	41	50
Consulting on atomic energy problems	132	172
Investing and lending capital	19	20
Evaluating insurance risks	47	59
Others not elsewhere classified	102	136

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

FOREIGN ACTIVITIES OF UNITED STATES COMPANIES

Under bilateral agreements for cooperation, the United States companies listed below were granted authorization to furnish to foreign governments or persons, services or materials involving the communication of restricted data.

U. S. Firm	*Country*	*Scope of Approved Exchange*
AMF Atomics, Inc., New York, N. Y.	Canada	Design, development, and fabrication of fuel elements for specified reactors.
Sylvania Electric Products Co., Bayside, Long Island, N. Y.	Canada	Design, development, and fabrication of fuel elements and reactor components for specified reactors.
AMF Atomics, Inc	United Kingdom	Engineering and design services for an evaluation of AMF Boiling Water Reactor in power program.
Norton Co., Worcester, Mass.	Canada	Technology of fabricating control rods, shielding materials, and fuel elements and crucibles for specified reactors.
Koppers Co., Pittsburgh, Pa.	Canada	Refining and processing source materials and reprocessing of spent reactor fuel.
Giffels & Vallet, Inc., Detroit, Mich.	Canada	Alloyed fuel fabrication and technology, separation facilities, waste disposal systems for evaluation of power reactor.

REGULATIONS

Two new regulations, in addition to the eight described in the January–June 1956 Report, were put into effect. The scope of these regulations (for text see Appendix 6) is as follows:

"*Standards for Protection Against Radiation*," 10 CFR Part 20, effective February 28, 1952, establishes standards for protection of workers and the public against radiation hazards arising from activities carried out under licenses issued by the Commission.

"*Public Records*," 10 CFR Part 9, was effective December 8 as a notice of proposed rule making. It sets forth the rules governing the Commission's public records relating to any proceedings subject to Part 2 (Rules of Practice) and Part 25 (Access to Restricted Data) of the Commission regulations.

Five existing regulations were amended as described below (see Appendix 6 for the text of these amendments):

"*Rules of Practice*", 10 CFR, Part 2: An amendment was published December 8, 1956, as a notice of proposed rule-making to establish procedures for handling restricted data introduced in hearings under Part 2, or otherwise required to prepare for hearings. This amendment is based on Section 181 of the Atomic Energy Act of 1954 requiring that "parallel procedures" be established by regulation to safeguard restricted data or defense information in such cases.

"*Access to Restricted Data*," 10 CFR Part 25, was amended in August 1956 to permit access to information on controlled thermonuclear processes under two special criteria. These are (a) that the applicant be engaged in a substantial effort to develop, design, build, or operate a fission power reactor that is planned for construction, or (b) that he possesses qualifications demonstrating that he is capable of making a significant contribution to research and development in the controlled thermonuclear field.

"*Licensing of Production and Utilization Facilities*," 10 CFR Part 50, was amended December 1956 to state that the Commission will not consider making a finding of practical value under Section 102 of the Act as requiring conversion of a previously issued Class 104 construction permit or license.

"*Operators' Licenses*," 10 CFR Part 55, was amended September 1956 to eliminate the requirement that applications for licenses be signed under oath or affirmation.

"*Licensing of Byproduct Material*," 10 CFR Part 30, was amended in October 1956 to place under general license certain consumer items containing limited quantities of radioactive materials.

State cooperation. Further steps were taken in the Commission's program for cooperation with the States. Meetings were held to discuss matters of mutual interest and to exchange information in the regulatory field with State officials. Means of providing additional assistance to the States were explored.

A second meeting of the Advisory Committee of State Officials, which was organized following a July 1955 conference with State representatives, was held November 26. The Committee discussed the Commission's "Standards for Protection Against Radiation" (10 CFR 20) and means of further cooperation between the States and the Atomic Energy Commission. These activities supplement the Commission's practices of providing technical advice to the States, informing them of licenses issued, and inviting them to participate with Commission representatives in making visits to licensees.

Materials and Services

Plutonium 239 and Uranium 233

The Commission established guaranteed fair prices, for the fiscal year July 1, 1962, to June 30, 1963, to be paid licensees for the production of special nuclear materials. (See Foreword.)

Spent Reactor Fuel Elements

The Commission made available a limited supply of spent fuel elements for rental to licensees as sources of gamma radiation. These elements are from the Materials Testing Reactor at the National Reactor Testing Station near Idaho Falls, Idaho. They are available primarily for research and development purposes and generally no one user may possess more than four elements at any one time. They are among the most powerful sources of gamma radiation distributed by the Commission.

Reactor Development

The program of developing reactors for industrial power and for military uses made progress during the last 6 months of 1956. Two more industrial groups, Carolina-Virginia Nuclear Power Associates, Inc., and the New England Electric System proposed to build atomic power plants without direct financial participation by the Government, making seven such proposals in all. Under the Commission's Power Demonstration Reactor Program in which the Government does contribute, contract negotiations were in process wtih three groups. One was concluded in June 1956, three proposals were rejected; on several contracts negotiations have encountered delays.

Increased industrial participation in the atomic energy program was further evidenced by the fact that private industry for the first time supplied fuel elements for a Commission-owned facility; and that industry contracted to supply the Commission's needs for the reactor material, beryllium. Further, a contractor was selected to help design, develop, and build a food irradiation reactor for the Army Ionizing Radiation Center; while another company contracted with the Commission to design, fabricate and operate a gas-cooled reactor experiment.

Satisfactory progress was made in the Commision's experimental power reactor program during this reporting period. The Nation's first large scale civilian nuclear powerplant, the Pressurized Water Reactor at Shippingport, Pa., neared completion and was scheduled to begin operation the latter part of 1957; the Experimental Boiling Water Reactor at Argonne National Laboratory, Lemont, Ill., was scheduled to begin generating power early in 1957. The Commission began contract negotiations for the design, construction and test operation of a nuclear propulsion plant for the first atomic-powered merchant ship. Fabrication difficulties set back time schedules on Homogeneous Reactor Experiment No. 2, and on the Sodium Reactor Experiment.

In the field of military reactor development, construction commenced on a land-based prototype of a reactor plant to propel a small submarine. The naval reactor test facility at National Reastor Testing Station made a record full-power continuous run of 66 days—believed to be the longest ever completed by any propulsion plant. Completion of the sodium-cooled reactor for the powerplant of the Submarine *Seawolf* was delayed during the reporting period due to leaks in the steam superheating system.

The Army Package Power Reactor neared completion at Fort Belvoir, Va., with operation scheduled for early 1957.

A notable advance was made in the program to develop aircraft nuclear propulsion.

The Commission, in October, made public a comprehensive listing of nuclear reactors built, building, or planned in the United States. This tabulation was revised as of December 31, 1956, and is reproduced as Appendix 14 to this report.

The tabulation shows that, as of December 31, a total of 90 reactors had been built in the United States, of which 17 had served their purposes and had been dismantled. Of the 73 nuclear reactors now operating or licensed, 27 were either testing or research reactors, 24 were critical experiments and zero power reactors, 13 were production reactors, 5 were military power reactors, and 4 were civilian power reactor experiments. Of 45 reactors being built as of that date in the United States, 21 were in the research and testing category (including 10 critical experiments and zero power), 15 were military power reactors, and 9 were civilian power reactors. Thirty-three research and testing reactors were planned in the United States as of December

31 (including 7 critical and zero experiments), and, in the field of power, the Government planned to build 23 military power reactors and 5 civilian power reactors, and United States companies had announced plans for 12 civilian power reactors.

Civilian Power Reactor Program

The objective of the Commission's Civilian Power Program is to achieve economic nuclear power production as early as possible, both in the United States and for other cooperating nations. However, the Commission recognizes that progress toward achievement of this objective is in its early stages, and that large amounts of manpower and money will be required to attain it.

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

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

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

Reactor concepts which still looked promising after passing this second developmental phase were proposed as subjects of reactor experiments. Several are under way, as reported elsewhere in this section. In this stage, design and construction of one or more operating reactors of a concept are undertaken to provide the most definitive answers possible to remaining technological questions, including, for example, performance of fuel elements, behavior of control systems, safety of the reactor, and its general physics and engineering characteristics. As indicated in the table, Appendix 14, nine such reactor experiments have been completed at Commission laboratories. Five were dismantled after they had served their experimental purposes.

Four additional reactor experiments are under construction and five more are planned. Progress on these is reported later.

Generally speaking, the fundamental scientific and many of the engineering problems of a reactor concept have been solved after a reactor experiment. Operation of these relatively small experiments generally cannot demonstrate everything it is desirable to know about a similar full-scale reactor operation. This is true particularly of construction and operation costs. Concepts which still seem promising after a reactor experiment, therefore, are carried through a further phase in which a full-scale prototype, or demonstration powerplant is built.

As shown in the Appendix 14 table, 18 prototype plants have been proposed and are in varying stages of advancement. Ground has been broken for 3 plants, 4 others have received construction permits, 1 has received a Commission contract, and 6 others have been approved as bases for contract negotiations. Progress on individual prototype proposals is reported in succeeding sections.

Privately Financed Power Reactors

In addition to the new proposals, the industrial and utility organizations or groups which, according to statements of the organizations concerned, were building or propose to build nuclear powerplants without any direct financial participation by the Government were: Commonwealth Edison Co., Consolidated Edison Co., General Electric Co.—Pacific Gas & Electric Co., Pennsylvania Power & Light Co. and a group of Florida companies, including Florida Power & Light Co., the Tampa Electric Co. and the Florida Power Corp. Their plans were reported in the Twentieth Semiannual Report.[7] In addition to these facilities proposed by domestic utilities, American and Foreign Power Co. has proposed to construct 10,000-kilowatt plants by its subsidiaries in Brazil, Cuba, and Mexico.

Outstanding developments on various individual proposals during the last 6 months are given below. Operating dates where given, represent estimates of the organizations concerned.

Carolina-Virginia Nuclear Power Associates, Inc. The Carolina-Virginia Nuclear Power Associates, Inc., formed as a nonprofit corporation for developing atomic power in the area served by the companies, includes: Virginia Electric and Power Co., Richmond, Va.; Carolina Power and Light Co., Raleigh, N. C.; Duke Power Co., Charlotte, N. C.; and the South Carolina Electric and Gas Co.

The new company plans to construct a multimillion dollar nuclear power facility to produce electricity for commercial distribution.

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[7] See pp. 35–38, January–June 1956 report.

Details such as plant location, capacity in installed kilowatts, type of reactor, etc., were yet to be determined.

New England Electric System. The New England Electric System informed the Commission that it plans to construct a nuclear power reactor with a capacity of 200,000 kilowatts of electricity. The site and the type of reactor remain to be determined, but plans call for completion by 1964. The company would expect to finance the reactor without Government assistance.

The New England Electric System is one of the participating companies of the Yankee Atomic Electric Co. which in June signed a contract with the Commission under its Power Reactor Development Program, in which the Government does make financial contributions.

Pennsylvania Advanced Reactor Project. Some 50 representatives from the Pennsylvania Power and Light Co., Westinghouse Electric Corp., Union Carbide Nuclear Corp., Westinghouse Commercial Atomic Power Activity, and the Commission attended the first annual progress report meeting of the Pennsylvania Advanced Reactor Project held on October 2 at the Westinghouse Engineering Center, Pittsburgh, Pa.

A report was presented on various phases of the project, including the slurry-fuel development program, mechanical engineering program, plant study, chemical reprocessing and plant layout and maintenance. Program plans and problems were also discussed.

The Pennsylvania Advanced Reactor Project—a joint program of Westinghouse Electric Corp. and Pennsylvania Power and Light Co.—was initiated in July 1955 to build a nuclear powerplant of at least 150,000 kilowatts using an aqueous homogeneous reactor. If research and development are successful, construction would be planned to start about 1958, operation by about 1962.

Commonwealth Edison Reactor. The Commonwealth Edison Co. received authorization in September from the Illinois Commerce Commission to build its 180,000 electrical-kilowatt boiling water nuclear powerplant at Dresden, Ill., near Chicago. The company was granted a construction permit on a provisional basis by the Commission in May 1956, and is planning to begin construction in 1957. Authority from the Commission and the Illinois Commission will be sought to operate the plant. Completion is expected in 1960.

Power Demonstration Reactor Program

Contract with Yankee. A contract was signed in June 1956[8] with the Yankee Atomic Electric Co., of Boston—the first signed under the Commission's Power Demonstration Reactor Program. Westinghouse Electric Corp. was selected by the company as subcontractor to develop and design a 134,000-electric-kilowatt pressurized water nuclear powerplant to be operated at Rowe, Mass., by 1960 according to company announcements. Government representatives and officials of Yankee and Westinghouse met in Boston on September 5–6 to work out additional details of subcontract administration and of research and development programs.

On December 6 representatives of Yankee Atomic Electric Co. and their principal contractors, Westinghouse Electric Corp., and Stone and Webster Engineering Corp., met in Washington with top Commission management to review progress.

The companies reported that research and development and procurement programs were on schedule and that the reactor was expected to be completed early in 1960 as planned.

The Yankee contract grew out of one of three proposals received by the Commission in response to its first invitation, issued in January 1955, under the Power Demonstration Reactor Program. This program enlists private resources in a cooperative effort with Government to demonstrate the technical and economic feasibility of power reactors in a wide range of capacities and design concepts.

Contracts being negotiated. As a result of other responses to this first invitation under the Power Demonstration Reactor Program, two further contracts were being negotiated at year-end—with the Consumers Public Power District of Columbus, Nebr., and with the Power Reactor Development Co., Inc. (Detroit Edison and others) of Detroit, Mich. A twice-postponed hearing in the matter of the Power Reactor Development Co. construction permit was to be held in Washington, D. C., starting January 8, 1957 (see Civilian Application).

Consumers Public Power District proposes to build a thermal sodium-graphite reactor plant of 75,000 kilowatts electrical capacity, to be located at Hallam, Nebr., and scheduled for completion in 1960; the Power Reactor Development Co., a sodium-cooled fast breeder plant of 100,000 electrical kilowatts at Monroe, Mich., to be completed in 1960. The Consumers Public Power District proposal was altered, after discussion, to a new basis involving Commission ownership of a part of the plant.

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

Small powerplants under the second invitation. Further contract negotiations resulted from seven proposals submitted in response to the Commission's second invitation under the Power Demonstration Reactor Program. This invitation specified that proposals be for reactors with capacities between 5,000 and 40,000 kilowatts of electricity.[9]

On August 2, the Commission authorized negotiation of a contract with Chugach Electric Association of Anchorage, Alaska, and Nuclear Development Corp. of America of White Plains, N. Y., based on a proposal for a 10,000-kilowatt electricity plant to be located at Anchorage. This plant would be liquid sodium-cooled, heavy water-moderated, and would use slightly enriched uranium as fuel.

The Commission authorized negotiation of a contract providing a ceiling on Federal costs for preliminary research and development work, and further providing that the project will be continued through design, construction, and operation stages if the contracting parties agree, after preliminary work, that the concept continues to hold promise for economic power.

Three other contracts were being negotiated as a result of the second group of proposals. These were with Rural Cooperative Power Association of Elk River, Minn., the Wolverine Electric Cooperative of Big Rapids, Mich., and the City of Piqua (Ohio). The Rural Cooperative Power Association proposed a 22,000 electrical kilowatt boiling water reactor; Wolverine Electric Cooperative a 10,000 electrical kilowatt aqueous homogeneous reactor; and the City of Piqua a 12,500 electrical kilowat organic moderated reactor. Contract negotiations have been delayed in some cases because of difficulties in reconciling proposals with criteria of the power demonstration program.

The Commission in January rejected the remaining proposals—those from the University of Florida, the City of Orlando, Fla., and the City of Holyoke (Mass.). The proposals of Holyoke for a 15,000-electrical kilowatt gas-cooled reactor with a closed-cycle gas turbine, and of Orlando for a 25,000 to 40,000 electrical kilowatt station using a liquid-metal reactor were rejected on the basis that the technical feasibility of the proposed reactor concepts had not yet been established. The proposal of the University of Florida for a 500-kilowatt pressurized water reactor was rejected on the basis that it would not demonstrate its practical value as a power producer and thus did not constitute an acceptable basis for contract negotiation under the Power Demonstration Reactor Program.

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[9] See p. 4, Twentieth Semiannual Report (January–June 1956).

Experimental Power Reactor Program

With the exception of the Pressurized Water Reactor, which is a prototype plant, the major projects in the Commission's Experimental Power Reactor Program reported here, are all reactor experiments.

Pressurized Water Reactor. During the last 6 months of 1956 substantial progress was made in the construction of the Nation's first large-scale (at least 60,000 kilowatts) civilian nuclear powerplant—the Pressurized Water Reactor at Shippingport, scheduled to be completed in the latter part of 1957. The Duquesne Light Co. of Pittsburgh, Pa., is building the non-nuclear portion of the plant and will operate the entire plant when it is complete.

The steel containers which will house the reactor portions of the plant were accepted after pneumatic testing. The four heat exchangers and the pressure vessel were installed.

Design of the reactor's second core is proceeding at the Commission's Bettis Plant which is operated by the Westinghouse Electric Corp., Pittsburgh. Emphasis is being placed on obtaining a nominal power rating of 100,000 kilowatts of electricity. Details of this and other reactor systems were summarized in the last report.[10] Safety characteristics of reactors are summarized in the section on radiation protection, Chapter III.

Experimental Boiling Water Reactor. The Experimental Boiling Water Reactor (EBWR) at Argonne National Laboratory will begin producing power early in 1957. It went critical on November 30.

The EBWR powerplant is designed to produce 20 megawatts of heat and 5,000 kilowatts of electricity. This is considered to be the minimum capacity necessary to provide the experimental data desired. Power produced by EBWR will be used to meet the needs of the laboratory.

Architect-engineer for the EBWR was Sargent & Lundy Co. of Chicago, Ill. The Sumner Sollitt Co., Chicago, constructed the reactor building under a lump-sum contract. The turbine-generator, condenser, circulating water pumps, and associated equipment were fabricated by the Allis-Chalmers Co., Milwaukee, Wis.

Current work by Argonne National Laboratory in the boiling water reactor program will be supplemented by the construction and operation of an experimental reactor facility at the National Reactor Testing Station in Idaho. The new facility, to be operated by ANL, will be known as the Argonne Boiling Reactor Facility (ARBOR). Argonne will be responsible for the conceptual design of the reactor and the detailed design of the reactor core, controls, and instrumenta-

[10] See p. 43 et seq. Twentieth Semiannual Report (January–June 1956).

tion. An architect-engineer, to be selected later, will design the reactor building and other features of the reactor system.

The facility will consist of a reactor core and pressure vessel, steam condensers, heat exchangers, pumps and the necessary valves, controls and auxiliary equipment. It will have sufficient flexibility in size, power removal equipment, and design pressure to simulate experimentally a wide range of operating conditions pertinent to the performance of boiling water reactors. Experiments conducted at the new facility are expected to contribute materially to the progress of design studies now under way of several large central station powerplants using boiling water reactors.

Cost of the facility is estimated to be $8.5 million and it is expected to be in operation in late 1959.

Sodium Reactor Experiment. Preoperational design, development and fabrication of reactor components for the Sodium Reactor Experiment (SRE) at Santa Susana, Calif., were completed in November by Atomics International, a division of North American Aviation, Inc. Installation of components neared completion. Startup was expected during the first half of 1957. Construction difficulties occurred during this reporting period, leading to schedule delays and increases in costs.

In a central station powerplant direct contact of radioactive sodium with water can be avoided by use of separate intermediate heat exchangers. In such a case the radioactive sodium exchanges heat with nonradioactive sodium (or a mixture of sodium and potassium having a much lower melting point), which in turn generates and superheats the steam. This technique does not eliminate the possibility of liquid metal-water reactions, but limits such reactions to non-radioactive substances.

Fast Breeder Reactors. The Commission planned at Argonne National Laboratory, a new core for the Experimental Breeder Reactor No. 1 (EBR-1) to replace the second one, damaged at the National Reactor Testing Station in the November 29, 1955 incident.[11] In the new core possible thermal warping of fuel elements will be better controlled by mechanical design. Because it is believed that bowing inward of fuel elements was largely responsible for nuclear instabilities noted in the EBR-1, the new core is being designed to minimize the possibility of such bowing.

Conceptual design of the Experimental Breeder Reactor No. 2 (EBR-2) was completed at Argonne National Laboratory. H. K. Ferguson Co. of Cleveland was awarded a contract for the architec-

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

tural-engineering phase of the project. Construction was scheduled to start in June 1957.

Molten Plutonium Reactors. Los Alamos Scientific Laboratory is exploring the possibilities of developing reactors using molten plutonium as fuel. Los Alamos Molten Plutonium Reactor Experiment No. 1 (LAMPRE–1) is under development and may possibly be tested for operational characteristics by about January 1958. If this experiment is successful, LAMPRE–2 will be developed on a larger scale. Should LAMPRE–2 proceed as planned, the reactor experiment will have a thermal output of about 10 megawatts as compared to 1 megawatt for LAMPRE–1.

Neither of these reactor experiments is designed to be power producing but will serve as engineering guides in designing a larger reactor (LAMPRE–3) which will be an electric power producing plant. At this early stage it is hoped that LAMPRE–3 might be capable of producing about 15,000 kilowatts of electricity.

Because of the health precautions required in experimenting with molten plutonium, progress in this program is not expected to be rapid. Problems of containing molten plutonium are being investigated at Los Alamos and samples have been prepared for irradiation in the Materials Testing Reactor in Idaho.

Homogeneous Reactors. The program of preoperational testing of various components and associated equipment for the Homogeneous Reactor Experiment No. 2 at Oak Ridge National Laboratory was interrupted for a period of 6 weeks during this reporting period because of chloride contamination in the small diameter steel tubing used in the leak-detector system.

Attempts were made to remove this contamination. Preoperational testing was resumed but was halted because of leaks in the flanges to which the contaminated tubing had been attached. These flanges are being examined to evaluate the nature and extent of the problem and to determine what effect it will have on the startup date of the HRE–2.

In addition to HRE–2 at Oak Ridge, homogeneous reactor experiments are being conducted at Los Alamos Scientific Laboratory. Los Alamos Power Reactor Experiment No. 1 (LAPRE–1) went critical for very short periods the last of October. Heat-exchanger leaks forced a shutdown. After considerable study and evaluation, it was decided to abandon the experiment.

Organic Moderated Reactor Experiment. Construction of reactor buildings and utilities for the Organic Moderated Reactor Experiment (OMRE) by Atomics International at the National Reactor

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Testing Station, Idaho, proceeded on schedule. Critical loading was expected to be completed in the next reporting period.

The OMRE, which carries forward research previously done by North American Aviation, Inc. for the Commission will simulate conditions of heat transfer, temperature, and coolant flow, which would exist in a practical power reactor. It will be designed to generate 5 to 15 megawatts of heat.

Liquid Metal Fuel Reactor Experiment. During this reporting period The Babcock & Wilcox Co., New York, N. Y. undertook a review with Brookhaven National Laboratory, Upton, Long Island, N. Y., of recent technological developments by the laboratory in the liquid metal fuel reactor program.

The Commission signed a contract with the company November 14 for development, design, fabrication, and operation of a Liquid Metal Fuel Reactor Experiment (LMFRE). The Union Carbide Nuclear Co. of Union Carbide & Carbon Corp. (New York, N. Y.), will be subcontractor primarily in chemical processing of fuel.

Plutonium recycle program. A research and development program aimed at demonstrating the feasibility of recycling plutonium in thermal power reactors has been initiated by the Hanford Works, Richland, Wash. Future plans include the construction of a heavy water moderated reactor which will be used to test the feasibility of plutonium recycling.

Advanced design studies. The Studebaker-Packard Corp., Detroit, Mich., and Ford Instruments Co., a division of the Sperry-Rand Corp., Long Island City, Long Island, N.Y., submitted to the Commission for review a final study of gas-cooled reactors, designed to provide a better understanding of the potential economics of this reactor concept, and to delineate the research and development remaining to be accomplished. (Additional developments in the gas-cooled reactor program are reported in the section on the Army Reactors Program.)

E. I. du Pont de Nemours & Co., Inc., Wilmington, Del., undertook a design study of a heavy water power reactor, and prepared a proposal indicating the scope of the program, the required development, and the economic feasibility of this system. The work, which will pay particular attention to natural uranium as a fuel, will be performed under the Commission contract with du Pont to operate the Savannah River Plant in South Carolina.

Maritime Propulsion Reactors

First Atomic-Powered Merchant Ship

In October the Commission accepted as a basis for contract negotiations a proposal by The Babcock & Wilcox Co. to design and construct a nuclear propulsion plant for the first nuclear-powered merchant ship.

Public Law 848 passed in July 1956, authorized the construction of this ship for foreign trade. Approximately $42.5 million is available for the purpose. The President, on October 15, directed the Commission and the Maritime Administration to proceed as rapidly as possible with its construction, stating that, "The reactor itself will be a definite step forward in nuclear propulsion." The Law made the Commission responsible for providing the powerplant, the Maritime Administration for providing the ship and all equipment other than that provided by the Commission, for training crews, for providing shore handling facilities, and for future operation of the ship. The contract for the ship was not yet placed at the end of the year.

Under the proposed contract The Babcock & Wilcox Co. will design and construct a 20,000 shaft-horsepower pressurized water reactor system of advanced design. Project completion is scheduled for 39 months from the contract date.

The merchant ship will be powered by a pressurized water reactor, the same general type of system used in the first nuclear-powered submarine, USS *Nautilus*. The system was selected because experience with it has proved it to have excellent performance qualities and to be inherently safe. Choice of a system which has already proved satisfactory permits construction of the ship and demonstration of its operating characteristics to proceed without any delay due to using a previously untried reactor concept. Information about the reactor will not be classified so that, in this country and in cooperating nations, there will be opportunity to become familiar with nuclear-powered ships.

The Babcock & Wilcox proposal was among four made to the Maritime Administration in response to its invitation.

Economically Competitive Nuclear-Powered Merchant Ships

The application of nuclear power to merchant ships is one of the more economically promising applications of atomic energy. It also would make a contribution to national defense by providing a ship with independence from the need for frequent refueling. It would contribute to world-wide economic development by conserving the dwindling world supply of fossil fuels.

Contracts were signed by the Commission and the Maritime Administration for design feasibility studies on advanced reactor concepts which show promise of producing commercially competitive nuclear propulsion for merchant ships.

The contractors and the concepts to be studied are: Atomics International Inc., organic-moderated and -cooled reactor; Ford Instrument Co., gas-cooled reactor (nitrogen-graphite moderated) closed-cycle turbine; American Machine & Foundry Co., New York, N. Y., boiling water reactor; General Motors Corps., Detroit, Mich., gas-cooled (helium-graphite moderated), closed-cycle turbine; General Atomic, San Diego, Calif., gas-cooled reactor (hydride moderated), closed-cycle turbine.

General Engineering and Development

Engineering Test Reactor

It was found that a delay of several months in completing the Engineering Test Reactor (ETR) at the National Reactor Testing Station may be caused because of late delivery of an 8-inch stainless steel grid, holding up installation of mechanisms in the reactor tank. Effects on estimated costs were under investigation.

The proposal of The Babcock & Wilcox Co. to fabricate a year's supply of fuel and control elements for the reactor on a fixed-price basis was the most favorable received, with a proposal of $357.91 per fuel element and $408.16 per control element.

Architect-engineering and construction of the reactor were performed by the Kaiser Engineers Division of the Henry J. Kaiser Co., Oakland, Calif. Nuclear design of the reactor core and facilities within the tank was being performed by the Atomic Power Equipment Department of General Electric under contract to Kaiser. Fuel elements were being designed by the Oak Ridge National Laboratory. Phillips Petroleum Co., Bartlesville, Okla., will operate the facility for the Commission.

First Fuel Elements from Industry

During July, reactor fuel elements were supplied commercially by private industry for the first time when The Babcock & Wilcox Co. supplied the elements for the Materials Testing Reactor at the National Reactor Testing Station, Idaho.

Enriched Fuel Elements for Reactors Abroad

Consistent with its policy of procuring fuel elements from private sources, the Commission has asked industry to manufacture fuel elements enriched to 20 percent with uranium 235 for use in research reactors under agreements for cooperation with other countries. The Phillips Petroleum Co. as been requested to procure from commercial suppliers a core loading with 20 percent enrichment for the Materials Testing Reactor so as to provide performance data.

A program undertaken by Oak Ridge National Laboratory will study several approaches to the fabrication problem. The laboratory is studying the use of uranium carbide and uranium-aluminum alloys as well as uranium oxides.

Industry to Meet Beryllium Needs

The Commission contracted to buy 1 million pounds of reactor-grade beryllium from the Beryllium Corp. of America, Reading, Pa., and Brush Beryllium Co., Cleveland, Ohio, with each company supplying 500,000 pounds on a unit-price basis. Procurement contracts were negotiated on the basis of proposals submitted by companies responding to a general invitation issued by the Commission in January 1956.[12] Deliveries will be made over a 5-year period at an average cost of about $47 a pound.

Conference on Experimental Reactors

The Commission held a classified conference on the Sodium Reactor Experiment (SRE) and the Organic Moderated Reactor Experiment (OMRE), at which Atomics International was host for access permit holders and Commission contractors at the Institute of Aeronautical Sciences auditorium at Los Angeles, Calif., on November 8–9. The 2-day meeting was one of a series designed to keep industry informed of progress in the Commission's civilian power programs.

Sanitary Engineering

Representatives of the Commission met in San Francisco on August 22 with officials of California's Department of Public Health and Division of Industrial Safety to discuss the use of radioisotopes and disposal of radioactive wastes. Better understanding and closer liaison were gained and the way paved for future meetings on specific

[12] See p. 56, Twentieth Semiannual Report (January–June 1956.)

problems. Disposal and treatment of radioactive wastes are reported in detail in Chapter IV of the special section, Radiation Safety in Atomic Energy Activities.

Reactor Safety

During this reporting period transient tests continued with the Special Power Excursion Reactor Test (SPERT–1), a heterogeneous reactor facility, located at the National Reactor Testing station and operated for the Commission by the Phillips Petroleum Co. Of considerable significance in recent tests was a preliminary finding of instability [13] which occurred under conditions of boiling when reactivity was gradually increased. The causes of this instability are being investigated. Design work on SPERT–2, another heterogeneous reactor, progressed satisfactorily. Design of reactor internals and control drives for SPERT–3 (which is to be a pressurized water reactor) was completed by Phillips and fabrication of components begun.

Experimental tests have started on the Kinetic Experiment on Water Boilers facility (KEWB), a homogeneous reactor for transient testing operated by Atomics International, a division of North American Aviation, Inc., at Santa Susana, Calif. Initial data on operating characteristics were obtained and transient tests conducted. Preliminary planning started for a second test facility, KEWB–2.

Chemical Engineering

Volatility separation. As reported previously [14] Argonne National Laboratory and Oak Ridge National Laboratory are developing new separation processes based on fluorination of spent reactor fuel elements.

Preliminary results of research at Argonne on applying the fluoride volatility process to fuel elements appear promising. The process involves dissolving uranium in molten fluorides and then generating uranium hexafluoride which volatilizes readily. Fewer steps are required than in conventional solvent extraction methods and for certain fuels the economies of the fluoride volatility process appeared more attractive than aqueous methods.

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[13] *Instability in the SPERT–1 Reactor (Preliminary Report)*, by S. C. Forbes, F. Schroeder, and W. E. Nyer, AEC Research and Development Report TID–4500, Ed. 12, October 10, 1956. For sale by the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., price 20 cents.

[14] See p. 59, Twentieth Semiannual Report (January–June 1956).

High Temperature Chemical Separation

Under a Commission contract Atomics International will experiment with pyrometallurgical processing of spent fuel elements in order to attain sufficient purification of fuel to permit its reuse in sodium graphite reactors.[15] This processing method will be tested on a pilot-plant scale.

Military Reactors Program

Naval Reactors Program

Submarine Thermal Reactor (S1W/S2W). The Naval Reactor Facility (S1W) plant continued during the reporting period to operate at the National Reactor Testing Station, Idaho, for testing and training of naval personnel. This reactor, prototype of the propulsion plant in submarine USS *Nautilus*, was routinely shut down on August 8, 1956, at the end of what is believed to have been the longest full-power run ever completed by any type of propulsion plant. On a single charge of uranium fuel (and using only part of that charge), the reactor operated at an average power of 100 percent for 1600 hours, the equivalent of 66 days.

In this test, designed to prove the reliability and stamina of pressurized water reactors for ship propulsion, the S1W met the most exacting requirements that could be placed upon it. If the *Nautilus* itself had made a cruise for this length of time—1,600 hours—she could have steamed at top speed, submerged, around the world and many thousands of miles more, without refueling. A similar cruise by a diesel-powered submarine would require about 1,600,000 gallons of fuel—enough to fill 160 railroad tank-cars, a freight train over one mile long.

The USS *Nautilus* itself, powered by the S2W nuclear propulsion plant, now has operated satisfactorily for nearly two years. *Nautilus* has steamed over 50,000 miles and was fully submerged for more than half the distance.

Submarine Intermediate Reactors (S1G/S2G). Operation of the S1G, land-based prototype of the nuclear propulsion plant for the submarine *Seawolf*, continued at West Milton, N. Y., for testing and training of naval personnel. Since leaks developed in the superheaters, the prototype operated at 40 percent of rated power with the leaking superheaters by-passed. Cause of the leaks remained to be determined.

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[15] See pp. 59–60, Twentieth Semiannual Report (January–June 1956).

The *Seawolf* reactor is cooled by liquid sodium—the only plant of this type installed or planned for installation in a naval vessel.

Completion of the sodium-cooled reactor for the *Seawolf's* plant (S2G) was delayed also because of leaks in the steam superheating system. The exact cause of this failure has not yet been determined. No difficulty has been experienced with the nuclear reactor itself and the safety of the plant has not been impaired.

The molten sodium coolant comes out of this propulsion reactor at a high temperature and is highly radioactive. The problem is to transfer this heat to water in order to produce steam to drive the propulsion turbines. Since sodium may react violently with water, the exchange of heat directly between radioactive sodium and water is undesirable until considerably more experience has been gained.

For this reason, the *Seawolf* uses a double tube heat exchanger. Radioactive sodium is pumped through the inner tube, nonradioactive sodium-potassium is maintained (not flowing) between the central tube and the second tube, and steam is generated outside of the double tube. The tubes are bent into a "U" to provide freedom for linear expansion and rolled and welded into tube sheets. Pressures are maintained so that flow due to a leak would always be from the nonradioactive sodium-potassium into the radioactive sodium system or into the water side.

Such heat exchangers are subject to mechanical stresses from fabrication, from the pressures and expansions caused by the operating temperature, and from transient temperatures which may be large and rapid with liquid metal cooled reactors. Corrosion effects may occur in the sodium sides if impurities, particularly oxygen, cannot be maintained at extremely low levels. The water side is subject to corrosion from water as well as from impurities such as chloride ion which is particularly difficult to keep out in a naval plant. Both the water and sodium sides also are subject to corrosion if there is any leakage, and subject to formation of reaction products between the sodium or sodium-potassium and water. Choice of suitable materials and fabrication methods under these circumstances is obviously difficult.

In the development of a sodium-cooled reactor to propel a submarine a whole new technology has been explored. Fabrication techniques and components to handle high temperature sodium have already been substantially developed.

Submarine Advanced Reactor (S3G/S4G)

Construction of test site facilities for the land prototype of the Submarine Advanced Reactor continued at West Milton, N. Y.

Submarine Reactor Small (S1C)

Combustion Engineering Inc., New York, N. Y., under Commission contract, continued design and development work on a nuclear propulsion plant for a small submarine. The land-base prototype will be built at Windsor, Conn., the site of Combustion Engineering's Nuclear Engineering and Development Laboratory. A small critical assembly installed at the laboratory for experimental work went critical in December.

Large Ship Reactor (A1W). Design and development of the Large Ship Reactor prototype propulsion plant by Westinghouse Electric Corp. continued at the Bettis Plant, Pittsburgh, Pa. Construction of conventional site facilities continued at the National Reactor Testing Station. The erection of a section of ship hull to house the reactor plant was completed.

Sale of West Milton Power. In July the Commission signed a contract with the Niagara Mohawk Power Corp. for sale of byproduct electrical power produced experimentally by the land prototype (S1G) of the nuclear propulsion plant for the *Seawolf* at West Milton, N. Y. The sale price was set at 3 mills per kilowatt-hour at the West Milton bus bar, and, as of December 31, the Commission had sold 765,160 kilowatt-hours for a total of $2,295.45. The contract extends through December 31, 1957, subject to termination for the Government's convenience on 15 days' notice. Because of the experimental nature of the West Milton nuclear powerplant operations are intermittent and assurance as to the amount and timing of available power cannot be given to the purchaser.

In January 1955 the power at West Milton was offered to preference groups—public bodies or cooperatives—as required under the Atomic Energy Act of 1954. The City of Holyoke, Mass., and the village of Ilion, N. Y., each contracted in February 1956 to take half the power, subject to their ability to work out before May 1, 1956 arrangements for transmitting the power from the West Milton site to their own systems. The two communities stated in May that they were unable to make transmission arrangements.

Under the termination article of the contract with Niagara Mohawk, the Commission may enter appropriate agreements with preference customers if at any time they can arrange to take the power at the West Milton bus bar.

Army Reactors

Army Package Power Reactor. Construction of the Army Package Power Reactor (APPR–1) neared completion at Ft. Belvoir, Va., during this reporting period. The building to house the reactor was completed and essentially all the primary loop, except the core, was installed and tested under the supervision of the prime contractor, Alco Products, Inc., Schenectady, N. Y. The plant, scheduled for operation early in 1957, is expected to produce 1,825 kilowatts of electricity.

The Engineering Research Development Laboratories, Department of the Army, contracted with the Glenn L. Martin Co. of Baltimore, Md., to conduct theoretical and experimental investigations of systems of the APPR type to improve their design and operating characteristics.

Argonne Low Power Reactor. Construction of the Argonne Low Power Reactor (ALPR) began at the National Reactor Testing Station. The ALPR is one of several prototype reactors being developed as power sources for remote military installations. The plant, which will generate both electric power and space heat, is expected to cost about $1,225,000. The Argonne National Laboratory is in charge of overall development of the reactor. Pioneer Service and Engineering Co., Chicago, is providing architect-engineer services for the non-reactor components of the plant.

Food Irradiation Reactor. The Commission has selected Kaiser Engineers, Oakland, Calif., to design and construct a Food Irradiation Reactor (FIR) for the Army's Ionizing Radiation Center. The Department of the Army selected Sharpe General Depot, Stockton, Calif., as the site after a joint Commission-Department of the Defense survey of possible locations.

Eleven concerns, including Kaiser, made proposals in response to a general invitation issued by the Commission on July 23, 1956.

The Food Irradiation Reactor will provide an intense source of gamma radiation to test preservation of food by irradiation for the Army Quartermaster Corps and for experiments with other materials. It will be water-moderated and have solid fuel elements. Its design will be based on a conceptual study made by the Internuclear Co.

Gas-Cooled Reactor Experiment. During this reporting period the Commission began contract negotiations with the Aerojet-General Corp. of Azusa, Calif. for the design, fabrication, and initial operation of a Gas-Cooled Reactor Experiment (GCRE) at the National Reactor Testing Station. This experiment is intended to develop engineering data and provide experience for the design and construction of gas-cooled reactors to meet military needs and for possible civilian requirements for small central power stations.

Twenty proposals to undertake the design, fabrication and operation of the reactor were received in response to the Commission's invitation of June 22, 1956.

Gas-cooled loops which will serve to screen and test components considered for use in the GCRE are being designed. These loops will be in reactors operated by Battelle Memorial Institute, Columbus, Ohio, Oak Ridge National Laboratory, and at the Engineering Test Reactor at the National Reactor Testing Station.

The Sanderson and Porter Co., New York, N. Y., under contract to the Army's Engineering Research and Development Laboratory, completed the design of a closed-cycle gas-turbine test facility to provide experimental data for adaptation of closed-cycle, gas-turbine, power-generating equipment to nuclear reactors.

Advanced reactor systems. During the latter part of 1956, the General Motors Corp., Detroit, Mich., under Commission contract, neared completion of an engineering analysis of a nuclear propulsion system for use in a cargo ~~carrying ship~~ CARRIER. Gilbert Associates, Inc., Washington, D. C., continued work on the design of a 20,000 kilowatt powerplant for construction overseas. The study of Raytheon Corp., Waltham, Mass., on a conceptual design of a liquid-metal-fuel package reactor proceeded satisfactorily with completion scheduled early in 1957.

Aircraft Reactors Program

Atomic power in turbojet engine. For the first time, a turbojet engine was powered exclusively by heat from an experimental reactor. This occurred in the Heat Transfer Reactor Experiment No. 1 operating on the ground at the National Reactor Testing Station.

Although this reactor-turbojet engine combination was a laboratory model, the fact that it operated solely on nuclear power marked a significant advance toward the ultimate goal of achieving atomic-powered flight.

Additional test facilities. During this reporting period, Burns and Roe, Inc., New York, N. Y., was awarded a contract for architect-engineering work on additional aircraft reactor test facilities at the National Reactor Testing Station.

Construction of laboratory. Construction of facilities by the Air Force for the Connecticut Aircraft Nuclear Engine Laboratory

(CANEL) at Middletown, Conn., to be operated by the Pratt and Whitney Aircraft Division, United Aircraft Corp., East Hartford, Conn., progressed satisfactorily during the last 6 months of 1956. The laboratory will be used as a research and development center for work being sponsored by the Air Force and the Commission.

Declassification and Classification

The Commission put into effect on December 5, 1956, a new Declassification Guide for Responsible Reviewers which provides for maintaining security of information by safeguarding selected technical information. This revision of the Guide, based on the recommendations of the Eighth International Declassification Conference held in Washington in April with the United Kingdom and Canada, will permit declassification from confidential and secret categories of a large body of documents which will be available to the public and will facilitate the development of the peaceful uses of atomic energy.

Under this Guide, it will be possible to declassify documents containing sufficient information to enable industry to design, construct, and operate civilian power reactors and their associated processing plants. This action will strengthen the Atoms for Peace program of cooperation with friendly foreign nations. Much more can be accomplished through unclassified agreements for cooperation when the new policies are applied. At the same time, the Guide recognizes the protection of information which is significant to the military security of the United States, and also retains classification on applications of atomic energy in the reactor field which are primarily of military interest.

In addition, under the new Guide it will be possible to declassify data on the effects of radiation on various reactor materials; the technology of heavy water manufacture; liquid thermal diffusion methods of concentrating uranium 235, the fissionable isotope of uranium; metallurgical data on production of fuel elements including some using plutonium alloys; considerable material on chemical reprocessing of spent fuel elements; information on current and future reserves of uranium ores, and on current and future production of ore concentrates; information on final stages of separating zirconium and hafnium, two metals used in reactors; and all data on mass spectrographs.

Consistent with the Commission's policy of declassifying as quickly as possible all information which, as defined in the new Guide, will not adversely affect the common defense and security, arrangements were made to launch early in 1957 a second program for accelerated review and declassification of accumulated technical information. The objective was to put into the open literature all technical information that may be declassified under the provision of the revised Guide so that it may be employed by the public, United States industry, and cooperating foreign nations. After the first program of accelerated review, based on the Declassification Guide put into effect July 1, 1955, nearly 20,000 documents remained classified as confidential or secret.[16] These documents will be reviewed again to see if the new Guide permits declassification as will some 2,000 additional documents classified under the previous guide, and issued during the past year. The routine functioning of the Commission's classification program keeps abreast of current material as it is produced, and makes it available to the public and to industry in accordance with the existing Guide; hence the material produced in the coming year will be classified under the new Guide's provisions, and most of the technical information contained in the peaceful applications field will never bear a classification mark.

In a statement issued with the announcement of the new Declassification Guide, Chairman Strauss pointed out, "The information will provide a practical basis for enlarging and improving high school, college, and university curricula on nuclear science and engineering, and text book publishers will be enabled to produce new, updated texts and general study aids on nuclear energy applications.

"A like opportunity is opened up for the general, technical, and business press to provide a wider scope of information to those readers who need to know more about nuclear energy and its uses.

"We are confident that the benefits of the actions announced today will have equal application in the United Kingdom and Canada. For the United States, the new large volume of information to be declassified should speed the development of civilian nuclear power here at home and at the same time enable us to be of greater assistance to other nations in fulfilling the broad aims of President Eisenhower's Atoms for Peace Program."

Supplementary Guides Issued

On August 23, 1956, the Commission and the Department of Defense put into effect a new Classification Guide for their joint use to provide a common basis for protection of information pertaining to the military application of atomic energy.

In recognition of the Commission policy to conduct basic research efforts with a minimum of classification, a revised Guide to Unclassified Fields of Research was prepared.

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[16] See p. 13, Nineteenth Semiannual Report (July–Dec. 1955), and p. 64, Twentieth Semiannual Report (Jan.–June 1956).

Controlled Thermonuclear Research

In November, United States representatives met with United Kingdom representatives at Harwell, England, to discuss a joint guide to the classification of research on controlled thermonuclear reactions.

The Commission also permitted exchange of classified information on controlled thermonuclear reactions with the United Kingdom, subject to the terms of an agreement for cooperation that now exists between the two countries. (See International Activities.)

Information

Exhibit Program

The Commission's program to provide several traveling exhibits on the peaceful uses of atomic energy for showing in the United States made considerable progress during this reporting period.[17] Two types of Atoms for Peace exhibits were prepared for the Commission and are operated by the Oak Ridge Institute of Nuclear Studies. They comprise: (1) a large exhibit requiring about 5,000 square feet of floor space for display, and (2) a smaller mobile exhibit set up in truck trailers. The exhibits are available to qualified exhibitors free of rental and transportation charges.

Three large exhibits were put on tour and are scheduled well into 1957. During the reporting period, they were shown in the District of Columbia and in 13 States.

In the fall of 1956, five smaller mobile units, designed for ease of presentation in rural and small urban areas, were made available. Four of these units, sponsored by the National University Extension Association, an organization with membership of the extension divisions of 76 colleges and universities, and the United States Junior Chamber of Commerce, were scheduled for showing through June 30, 1957, in 11 States. The fifth mobile unit will be scheduled directly from Washington headquarters of the Atomic Energy Commission.

The sponsoring organizations make advance arrangements to assure widest possible participation of adults and of junior and senior high school students during the showings. Students and teachers are assisted in following up their viewing of the exhibit by devoting further classroom attention to the subject of the peaceful uses of atomic energy.

Tours of high school demonstration units are reported in the section on Education and Training.

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[17] See pp. 67–68, Twentieth Semiannual Report (January–June 1956).

Between January and December of 1956, the Commission's 12 film libraries loaned films on 60 atomic energy subjects for a total of over 9,913 showings viewed by some 400,000 persons.

New Technical Information Services

Throughout the latter half of 1956 technical information activities continued to reflect the progressively broadening interest of industry and science in atomic energy and its applications. As demands for information grew, the Commission responded with practical steps to aid access permit holders and industry generally in getting technical information more easily and quickly.

The provision of more technical reports and more and better reference tools to aid their use by industry generally, by science, and by the holders of access permits has been reported earlier.[18] This widening and improvement of the system of publishing reports and providing reference services continued during this reporting period.

Summary Volumes Under Preparation

At the same time, the program to consolidate the knowledge in reports, journal articles and monographs for more rapid and more effective use by industry and science gained speed. By year's end, the Commission had under preparation, mostly by contract, 21 new volumes or revisions of existing volumes, 12 of which were reported previously.[19] It was planning to contract for six more volumes covering in summary fashion the present knowledge in the fields of most interest to developers of civilian applications.

Technical Progress Reviews

New knowledge is continually emerging from the work of laboratories and contractors in the atomic energy projects. Keeping up with the literature reporting technical developments and advances in atomic energy is essential to the vigorous growth of industrial applications of atomic energy. This task is a major one. The Commission initiated a program to prepare and publish a number of quarterly Technical Progress Reviews, some classified and some unclassified, covering government-sponsored research and development in the atomic energy field.

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[18] See pp. 96–98, Nineteenth Semiannual Report (July–December 1955), and pp. 68–73, Twentieth Semiannual Report (January–June 1956).

[19] See p. 68, Twentieth Semiannual Report (January–June 1956).

For the purpose of organizing the Technical Progress Reviews, atomic energy information was divided into 10 general categories: reactors, radiation applications, instrumentation, spent fuel processing, raw materials, feed materials, fuel element fabrication technology, materials, radiation safety, and nuclear physics (includes thermonuclear). Within each category scientists and engineers of recognized competence will, under contract, prepare reviews covering and evaluating significant developments in technology and science. The first of the Technical Progress Reviews to appear will be in the category of Radiation Applications and will be published early in 1957.

Monthly Publications for Management

Commission policy and program information is as important to management of industry and science organizations as technical information is to the scientist and engineer. To meet the needs of management for this type of information, the Commission will publish a monthly bulletin, the first issue to appear early in 1957.

The monthly bulletin will carry the title, *AEC—This Month. Policy and Program Developments*, and will print, as regular features, departments reporting month-by-month the actions of the Commission on policies affecting industry and science, new Commission programs of interest and benefit to management, new contracts, briefs on developments in basic and applied science performed by Commission contractors, developments in education and training programs, and progress in the Atoms for Peace program. In addition to these and other regular departments, the publication will have reports on special subjects of broad interest to management of industry and science organizations, as for example, a survey of industry opportunities to supply materials now manufactured by the Government.

Publications

Nine additional unclassified publications, printed or released during the last 6 months and available from the Office of Technical Services, Department of Commerce, Washington 25, D. C. comprise: "Polonium" (TID–5521) July 1956, edited by Harvey V. Moyer; "Rare Earths in Biochemical and Medical Research: a Conference Sponsored by the Medical Division, Oak Ridge Institute of Nuclear Studies, October 1955," (ORINS–12), September 1956, edited by Gravil C. Kyker and Elizabeth B. Anderson; "Fourth Atomic Energy Commission Air Cleaning Conference Held at Argonne National Laboratory," November 1955 (TID 07513, Pt. 1) June 1956; "Papers Prepared for Radiation Effects Review Meeting, Congress Hotel, Chicago, July 31–August 1, 1956," (TID–7515–Pt. 1), August 1956; "Feasibility Study of Pressure Vessels for Nuclear Power Generating Reactors," (AECU–3062), December 1955, compiled by Frank W. Davis; "AEC Materials Management-Contractor Representatives Meeting, Washington, D. C., May 7–9, 1956" (TID–7516–Pt. 1) September 1956; "Aqueous Homogeneous Reactors," (PNG–7), February 1956; "Army Package Power Reactor," (AECD–3731) October 14, 1955; and "Papers Presented at The Technical Briefing Session Held at Idaho Falls, Idaho, November 1–2, 1955" (TID–7506–Pt. 1) July 1956.

Depository Libraries

The Commission added 17 new depository libraries in the United States to bring to 66 the number of official reference centers housing complete collections of the Commission's nonclassified reports and reference tools. The 17 libraries will be located at Baltimore, Md., Birmingham, Ala., Charlotte, N. C., Dallas, Tex., Houston, Tex., Indianapolis, Ind., Louisville, Ky. Memphis, Tenn., Miami, Fla., Milwaukee, Wis., New Orleans, La., Portland, Oreg., Providence, R. I., Rochester, N. Y., San Antonio, Tex., San Diego, Calif., and Youngstown, Ohio.

In addition, as part of its program of educational assistance, the Commission is providing 15 depository collections to universities and colleges which are offering training courses in nuclear technology.

The Commission also authorized establishment of six classified depositories, to be located in areas reasonably accessible to a majority of access permit holders.

A complete reference center on Government-developed information on atomic energy, both classified and unclassified, was established in the Technical Information Service quarters in Oak Ridge. The services of this center are available to any citizen. Classified information, of course, is restricted to authorized access permittees.

Literature Search Service

To assist access permit holders and industry to obtain desired and useful information from the large number of documents on atomic energy currently available, the Commission has established a new literature search service. For a charge of $6 an hour, the Technical Information Service searches its collection of reports and supplies specific data, or lists of reports pertinent to a specified subject area. This service is particularly useful to individuals and small concerns lacking large files and resources.

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Survey of Access Permit Holders

The Commission awarded a contract in October to McKinsey & Co., Washington, D. C., for a survey of access permit holders to evaluate the effectiveness of present technical information services, and to obtain suggestions for improving them. The survey is intended to: (1) Determine what access permittees believe they need in the way of technical information services; (2) determine how useful they find the existing services and what deficiencies they have noted; (3) find the facts about the character and extent of technical information service provided to permittees by Commission contractors; (4) ascertain what needs to be done to assure maximum information assistance to permittees consistent with the overall objective of the Civilian Application Program and the general policies of the Commission; and (5) ascertain the investment of industry in plant and talent devoted to atomic energy purposes.

Industrial Exhibits

The Commission assisted in designing and preparing the National Science Foundation display for the Fourth International Measurement Instrument Exhibition, Stockholm, Sweden, September 15 to 23. A Commission booth at the Trade Fair of the Atomic Industry, Chicago, Ill., September 24–28, drew more than 9,000 visitors.

Education and Training

The Commission, its contractors, and private industry continued to face problems in the recruitment, retention, and compensation of scientists and engineers.

The Commission continued and expanded its program efforts to solve these problems by assisting educational institutions and industries in training engineers, scientists, and medical personnel with specialized knowledge and skills in the field of atomic energy. These efforts included the start of a program of making direct financial grants to colleges and universities for securing equipment and teaching aids needed to establish and conduct curricula in nuclear energy technology. In addition the Commission's existing program of loaning uranium and neutron sources was broadened to include other materials peculiarly related to nuclear energy technology.

The Commission is continuing to cooperate in Government-wide efforts to develop solutions for the problems. During this reporting period, the White House established its Steering Committee on Engineers and Scientists for Federal Government Programs, upon which the Commission is represented and for which a Commission employee is staff director. This committee is expected to make recommendations concerning the Government's use of engineers and scientists, both as direct employees and as employees of Government contractors.

Assisting Educational Institutions

Provision of materials, facilities, equipment, and services. The Commission began a program of making direct financial grants to colleges and universities for furnishing teaching aids, demonstration apparatus, and laboratory equipment needed for laboratory course work in nuclear energy technology. Evaluation of requests received was under way and initial grants were to be announced during the next reporting period.

Three institutions have received loans of natural uranium and neutron sources for subcritical assemblies, and 12 others have been approved for similar loans. The institutions that have received loans are New York University, the University of Florida, and Virginia Polytechnic Institute. Those approved are: Alabama Polytechnic Institute, City College of New York, Cornell University, Georgia Institute of Technology, Iowa State University, Massachusetts Institute of Technology, North Carolina State College, Ohio State University, Reed College, Stanford University, University of Maryland, and Yale University.

The Argonne National Laboratory designed and built a reactor, the Argonaut,[20] designed primarily for educational and training purposes. Further progress in the development of such reactors and in the use of subcritical assemblies for educational purposes was planned.

The "Oracle" Applications Program of the Oak Ridge Institute of Nuclear Studies (ORINS) got under way in July 1956. Conducted by the University Relations Divisions, ORINS, and the Mathematics Panel of Oak Ridge National Laboratory, the program's purpose is to make available to universities throughout the region the services of the high-speed digital computer, Oak Ridge Automatic Computer and Logical Engine, "Oracle". University personnel will have not only computer time, but also the combined experience and knowledge of members of the Mathematics Panel to assist with computational problems arising in research activities.

College conference. A conference was held in September 1956, at Gatlinburg, Tenn., at which Commission personnel discussed with deans of the colleges of engineering and university and college presi-

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[20] See p. 78, Twentieth Semiannual Report (January–June 1956).

dents the need for scientists and engineers and the Commission's program of assistance. A total of 293 representatives from 151 institutions attended.

Teaching and libraries. Scientists from Commission facilities lectured, conducted seminars, took part in colloquia, and carried on related activities at universities.

The Commission is providing nonclassified depository libraries on nuclear technical information to a number of universities and colleges (see Information Services).

Faculty training. Two 2-month institutes in nuclear reactor technology were conducted in 1956 in cooperation with the National Science Foundation and the American Society for Engineering Education. Ninety college faculty members took part.

Because of the demand, this program is being expanded during the coming summer to include additional Commission facilities offering such institutes. Present estimates are that approximately 200 faculty members will participate.

Faculty members from universities also continued to participate in research at national laboratories. Last summer approximately 285 college faculty members took summer employment at Commission facilities. Plans to expand these programs are under way. The Commission during this period approved and issued a statement of policy and criteria governing on-the-job participation.

Research contracts. Through Commission support of research in the physical and biological sciences at colleges, universities, and other nonprofit institutions, more than 2,000 students received assistance and training. The schools gained in experience for faculty and often acquired additional facilities for postgraduate programs.

Fellowship Program

The Commission continued its already established special fellowship programs in radiological physics with 75 participants, in industrial hygiene with 9 participants, and in industrial medicine with 8 participants, all administered for the Commission by the Oak Ridge Institute of Nuclear Studies.

The University of Kansas, Lawrence, was added to the group of universities at which special fellowships in radiological physics are offered. The university, in cooperation with the Hanford plant, Richland, Wash., offers 9 months of formal graduate work; a succeeding 3 months of specialized study and field work is carried out at the Commission installation.

To help provide scientific and reactor engineering personnel for expanding activities, 150 special fellowships in nuclear energy technology may be awarded during the 1957–58 academic year. The fellowships will be administered for the Commission by the Oak Ridge Institute of Nuclear Studies. In addition to increasing the number of professionally trained personnel, this program will encourage colleges and universities to establish or enlarge their graduate courses of nuclear study.

Graduate School

The Commission proceeded with its previously announced plan to double the capacity of the International School of Nuclear Science and Engineering, Argonne National Laboratory, Lemont, Ill., and expects next year to double the capacity of the Oak Ridge School of Reactor Technology through a cooperative program of education carried on by both the Oak Ridge School and universities.

On September 10, the International School of Argonne, in cooperation with Pennsylvania State University, University Park, and North Carolina State College, Raleigh, began its fourth session. Details are reported in the section on International Activities.

The 53rd basic radioisotope-techniques course offered by the Special Training Division, Oak Ridge Institute of Nuclear Studies, opened on September 3 with an enrollment of 15 United States scientists from 12 States, and 15 scientists from 13 other countries. Participants were teamed so that each United States student had a foreign "partner" for the duration of the course. This is the method planned for future courses with a large complement of foreign participants; it is believed to offer more advantages to the noncitizen scientists than the two previous all-foreign courses presented by the Institute.

High School and Other Programs

In an effort to stimulate interest at the high school level in scientific careers in atomic energy, the Commission and the National Science Foundation this past summer jointly sponsored *radiobiology training courses* at Duke University, Harvard University, and the University of New Mexico. Fifty-nine high school science teachers participated. Because of the initial success of the program, plans were laid to expand the work next year when summer courses will be conducted at 5 universities. Participants who successfully completed the course were presented by the Commission 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 to high school students. Each kit includes a simplified scaler, 2 Geiger counter tubes, an ultra-violet source, a spinthariscope, and X-ray films and equipment for using and developing them.

The second annual 1-month *Summer Institute in Secondary-School Science Teaching*, sponsored by the National Science Foundation in cooperation with the Commission, ended on July 6, with a total attendance of 96. The first Summer Institute in College Science Teaching, also sponsored by the Foundation in cooperation with the Commission, was held at the Oak Ridge Institute of Nuclear Studies, July 9–August 3. It was attended by 48 teachers.

These institutes, which enlisted the services of outstanding scientists as lecturers, were designed to give a selected group of teachers in the physical sciences an up-to-date review of scientific developments, to stimulate interest and to increase subject matter competence. The ultimate purpose was to help teachers interest a greater number of qualified students in scientific careers.

Three *high school demonstration units*, operated for the Commission by the Oak Ridge Institute of Nuclear Studies, were sent on tour. Each unit includes a panel truck containing demonstration equipment consisting of such items as a power reactor model, a visual and auditory chain reaction device, a Van de Graaff generator, a Geiger counter, and other scientific demonstration equipment. For the fiscal year ended June 30, 1956, these units had conducted 222 high school demonstration programs for a total of 148,000 high school students. The three units are expected to be booked into 480 high schools and will reach approximately 300,000 students during the current fiscal year.

Under the *Oak Ridge Traveling Science Demonstration Lecture Program*, administered by ORINS under the sponsorship of the National Science Foundation with the cooperation of the Atomic Energy Commission, 7 high school science teachers started in September on visits to more than 200 high schools in 48 States and the District of Columbia. The program is designed to stimulate interest among high school students in science and science-teaching careers.

Each teacher spends a week in each selected high school in his assigned area, giving lecture demonstrations before science classes and consulting with faculty members on science-teaching techniques. The teachers travel in station wagons equipped with more than 800 pounds of demonstration equipment. At the conclusion of the school year, the teachers will return to Oak Ridge to help evaluate the program.

At the University of California Radiation Laboratory, Berkeley, 26 high school teachers from the surrounding area were given an 8-week *training program* during the summer, the second program of this sort at the laboratory. The teachers received lectures and served as junior members of experimental groups in physics, chemistry, and biology-chemistry.

There has been considerable acceleration in the number of requests received by the Commission for *kits of published material* on atomic energy from elementary and high school students and their teachers. Between July 1954 and June 1955, a total of 5,781 kits had been distributed; in the year ended June 1956, the Commission distributed 7,983 kits. The number distributed during the period covered by this report nearly doubled over a comparable period last year.

Other activities of assistance to elementary and secondary educational institutions included, during this reporting period, some 150 talks to high school audiences, and between January and December, over 9,000 screenings of films on atomic energy.

Simultaneously, the Commission started a detailed inventory of the training and education programs of Commission contractors, both for their own employees and for employees of private industry. Detailed information is being gathered on numbers of persons trained, the content and level of the instruction, and the financing of the training.

Completion of these studies will enable the Commission to reach more definitive judgments on requirements for scientific and engineering manpower as a guide to developing training activities.

Another study which began in this period covers the present employment, utilization, and compensation of graduates of the Oak Ridge School of Reactor Technology, Oak Ridge, Tenn. This study is being conducted by the Bureau of Labor Statistics, Department of Labor, costs being reimbursed by the Commission.

Staff Studies of Needs and Training Activities

As indicated in the previous report, the Commission embarked on a series of surveys to determine overall national needs for professional persons trained in nuclear science and engineering. This four-part manpower study is based on the principle that the rate of advancement of nuclear science and engineering in this country depends on the availability, now and in the future of an adequate number of persons trained in engineering and in the physical, mathematical, and natural sciences. The studies are:

a) A study of the needs of private industry by the Atomic Industrial Forum, Inc., New York, N. Y., under contract to the Commission.

b) A study of the needs of Commission contractors by Commission staff.

c) A study of the needs of universities and nonprofit research institutions.
d) A study by Commission staff of the needs of other Government agencies and their contractors.

Physical Research

During the past 6 months, the Commission's physical research program continued to make significant contributions to the fundamental knowledge of atomic energy and the related sciences. The importance of accelerators to the program was proved once again by the research accomplished on the cosmotron and bevatron during this period. A number of interesting particles were studied by university groups and a new neutral theta particle was discovered with the cosmotron at Brookhaven National Laboratory. Following an important basic experiment on the "collision cross section" of antiprotons in liquid hydrogen, the antineutron was discovered at the Bevatron at the University of California Radiation Laboratory, Berkeley. A new nuclear phenomenon interpreted as catalytic fusion by mu-mesons, was discovered.

In the field of isotopes, the amount of radioactive material shipped increased about 100 percent. Development work continued on processes for separating fission products from waste and another large cesium 137 teletherapy source was fabricated. The stable isotope inventory also was expanded.

Metallurgists continued their studies on the effect of irradiation on the mechanical and physical properties of a variety of materials.

In chemistry, research with californium 254 has provided some interesting information which has contributed to the understanding of the astrophysical processes while other developments include the development of a tantalum monoboride compound to retard uranium corrosion, and the discovery of a new analytical method with the X-ray spectrograph.

Physics

A gamma ray spectrometer was constructed at Argonne National Laboratory to study gamma radiation emitted by neutron-capturing materials that have been placed in a region of high neutron flux in the CP–5 reactor. This instrument, a bent-crystal, transmission type, is useful for measuring gamma rays in the energy range from 20,000 electron volts to 7,000,000 electron volts (20 kev to 7 Mev) and is especially suited to the low energy range below 2 Mev in which no other method known has comparable accuracy and convenience. It produces very sharp spectrum lines, so that the gamma ray energies can be determined to an accuracy of about 1 to 2 parts in 10,000.

The first results were obtained using gold 197 as the source of gamma rays resulting from neutron capture. More than 30 different gamma ray emissions have been found between 90 kev and 439 kev. From these, a tentative scheme of the energy levels of gold 197 was developed. Its predictions are being tested by a further search for gamma lines at energies above and below the region studied so far.

This was a beginning of a systematic study planned for all elements.

Accelerator design. The Midwestern University Research Association [21] (MURA) is continuing its research, design, and development program on some of the most advanced particle accelerators. The main effort was in design of accelerators using a fixed field and alternating gradient, a type invented by MURA scientists which gives promise of high intensities as well as high energies. High intensities have application to the ultra-high energy field of nuclear physics where it may be possible to construct the equivalent of an accelerator in the 1,000-billion-volt range. A major part of the effort has been theoretical and computational. Digital computors were employed in the study of the equations involved.

Equipment constructed as a part of a study program using models includes two accelerators of the fixed-field, alternating-gradient type; magnet models and measuring equipment; and model radio-frequency testing equipment. Within the limits of available funds, this equipment is being used to supplement theoretical work.

Cosmotron and Bevatron Research

Cosmotron research. In one experiment conducted at the cosmotron, at Brookhaven National Laboratory, a Columbia University group discovered a new particle as part of the summer's work of the Brookhaven high-energy physics research program. One of the heavy mesons first discovered in cosmic rays, a neutral particle now called the theta-one meson, decays into two pions with a mean life of about 10^{-10} seconds (one 10-billionth of a second). It was predicted that another form of this neutral particle should exist which would exhibit a considerably longer mean life and would decay into three particles.

This theoretical prediction followed from the rigid application of a concept closely related to that of the existence of antiparticles which has been confirmed by research at the bevatron at the University of Cal-

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[21] For a list of member universities to which the University of Kansas is added, see p. 81, Twentieth Semiannual Report (January–June 1956).

ifornia and elsewhere. A proof of the existence of the predicted neutral theta particle would constitute support for a theory of fundamental importance.

The group from Columbia University obtained 8,000 cloud chamber photographs which revealed 23 events in which particles were found that decayed into three other particles and for which the mean life was 50 to 1,000 times more than 10^{-10} seconds. It thus appears that the predicted neutral theta meson does exist with characteristics agreeing with those predicted. This new information has no known practical value at the present time, but adds to the fund of basic data underlying atomic energy development.

Two other interesting heavy mesons known as the tau and theta mesons have identical masses, within experimental error, according to investigations carried out by a group at the University of California Radiation Laboratory. These two particles are known to have different modes of decay. The tau meson decays into three pions, and the theta meson into two pions. It is nearly impossible theoretically to see how these two modes of decay can occur for the same particle.

Two experiments have been completed at Brookhaven in a search for possible differences between the particles other than the two modes of decay. A group from Princeton University determined that, within an uncertainty of 8 percent, the mean lives of the two mesons were identical. A second experiment, performed by a group from the Massachusetts Institute of Technology, scattered both tau and theta mesons, and then compared the ratio of the two when scattered to their ratio when not scattered. No differences in scattering cross section were found for the two particles. The results of these two experiments, therefore, support the hypothesis that the tau and theta mesons represent simply alternate modes of decay of the same particle.

Antineutron discovery. As a result of the discovery last year of the antiproton [22]—a particle with a proton's mass, but carrying a negative electrical charge instead of a positive charge—the University of California Radiation Laboratory, Berkeley, initiated an intensive program to discover a counterpart of the neutron, namely the antineutron. The discovery of the antineutron was made in this reporting period by a team of physicists composed of Drs. Bruce Cook, Glen Lambertson, Oreste Piccioni and William Wenzel. At the present time the bevatron is the only accelerator of sufficiently high energy to produce these two antiparticles. This is the third instance in recent

[22] See pp. 59–60, Nineteenth Semiannual Report (July–December 1955) and pp. 84–86, Twentieth Semiannual Report (January–June 1956).

months in which existence of an hypothecated particle has been confirmed, the third being the neutrino, reported previously.[23]

When the antiproton was discovered last year by a process actually producing a proton and antiproton pair by converting energy into mass, physicists assumed that by a similar process a neutron-antineutron pair could be produced in the bevatron. Since the antineutron, like the neutron, has no electrical charge, its detection would prove to be more difficult. A method of detection called the "charge-exchange process" was developed, however, and the discovery was made. This method required a much larger supply of antiprotons that had previously been attained. In the entire experiment last year only about 600 antiprotons had been identified. As a result of technical improvements the yield of antiprotons has been increased to a maximum of 6,000 per day. Six months were required to set up the equipment and perfect the procedures before the actual experiment was started on July 4, 1956.

The discovery was preceded by a basic experiment considered by some physicists to be even more important than the discovery of the new particle. That basic experiment was the determination of what is called the "collision cross section" of antiprotons in liquid hydrogen. This cross section is a measure of the forces acting between the fundamental particles of ordinary matter and the antiproton. It was shown that antiprotons interacted in the hydrogen 2 to 4 times as often as positive protons; a fact that present theories do not as yet explain satisfactorily.

To permit observations of the antineutrons, a high intensity beam of antiprotons was made to pass through an absorber. Some negative or antiprotons lost their negative charges to positive protons in the absorber, making them neutral, converting the proton and antiproton into neutral particles, a neutron and an antineutron. The antineutrons, which annihilate when colliding with ordinary matter, just as do antiprotons, continued on through the experimental apparatus which discriminated against antiprotons and occasionally gave a large annihilation star which could be detected in a lead-glass Cerenkov counter. Only a relatively small number of such events have been found, and much more has yet to be done to learn about the basic properties of the antineutron.

The antineutron does not differ from a neutron in carrying a positive or negative charge since both neutrons and antineutrons are neutral electrically. But these nuclear particles, like the parent protons and antiprotons have a magnetic moment, that is they behave like tiny magnets. An antineutron has a magnetic moment opposite to that of a neutron.

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[23] See p. 82, Twentieth Semiannual Report (January–June 1956).

Catalyzed Nuclear Reaction

The discovery of a heretofore unknown interaction which forms a mesic molecule with a subsequent release of energy similar to that which occurs in thermonuclear reactions was made during this report period by a team of University of California Radiation Laboratory scientists: Drs. Luis W. Alvarez, Hugh Bradner, Frank S. Crawford, Jr., John A. Crawford, Paul Falk-Vairant, Myron L. Good, J. Don Gow, Arthur H. Rosenfeld, Frank Solmitz, M. Lynn Stevenson, Harold K. Ticho and Robert D. Tripp. The observations were made in studies of photographs of tracks in a 10-inch hydrogen bubble chamber used with the bevatron.

It had been expected that all mu-mesons that came to rest in hydrogen would simply decay by electron emission. It was noticed at the laboratory, however, that occasionally a particle that appeared to be a mu-meson came to rest, but instead of decaying, flung out another particle that also appeared to be a mu-meson which went a short distance, came to rest and decayed. In some of the photographs there was a gap between the two tracks of particles in the bubble chamber.

The phenomenon now is understood as follows: When the negative mu-meson comes to rest it becomes attached to a proton forming a "mu-mesic atom" similar to an ordinary "electronic" atom, but scaled down two-hundred-fold in total size. In natural hydrogen, one atomic nucleus in 5000 has a neutron attached to its proton, and is called a deuteron. It can be shown that a mu-meson prefers to form an atom with a heavy particle at its center; so the mu-meson will form an atom selectively with a deuteron, even though the protons are much more abundant. Any mu-mesic atom will eventually attach itself to another hydrogen atom to form a molecule.

The gaps are explained as a drift of the tiny neutral mu-mesic deuteron atom as it dashes away from the proton from which it stole its mu-meson. Any complete atom, regardless of its size, is a neutral system, and does not make a track. Being neutral, the mesic atom makes no track.

The result of all these processes is that shortly after a mu-meson comes to rest in hydrogen it finds itself holding a deuteron and proton together in the form of a tiny molecule. The deuteron and the proton are bound so closely that soon they fuse to form helium 3. The mass of helium 3 is less than the combined mass of a proton and a deuteron, and the difference is available as energy—5.4 million electron volts. This energy release is of the same type that occurs during thermonuclear reactions.

In order to test this hypothesis of their observations, the physicists added deuterium to the naturally occurring deuterium already in the bubble chamber. As expected, there was an increase in the fraction of photographs in which there was an ejected mu-meson or a gap at the end of a mu-meson track. Two pictures out of 10,000 showed a "chain" reaction two links long—where a single mu-meson catalyzed two nuclear reactions before decaying.

The new phenomenon is described as a catalyzed nuclear reaction. This term was selected because of the comparison with a chemical catalyst which is used to speed up a reaction but is not consumed in the reaction itself.

A catalyzed nuclear reaction is similar to a thermonuclear reaction in that the same nuclear fusion reactions are common to both, but the conditions of the surroundings are quite different. Thermonuclear reactions take place only at extremely high temperature—in stars or thermonuclear weapons—between nuclei propelled together by the great heat; a mu-meson can pull nuclei together and catalyze a nuclear reaction at any temperature.

At the present time, the energy-producing reaction is only a laboratory phenomenon. The chain of catalyzed reactions cannot continue long enough to generate commercially useful amounts of power because mu-mesons decay into other particles after only two-millionths of a second. Unfortunately from the point of view of thermonuclear power, mu-mesons can be generated only in high-energy nuclear collisions of particles accelerated by cyclotrons and other expensive machines. However the scientists described as "interesting" the possibilities if a much longer lived particle, with properties similar to that of the mu-meson, was ever found. The Russian physicist Alikhanian has reported evidence for such a particle.

Radioisotope Production

Radioisotope production at Oak Ridge showed a steady increase. The amount of radioactive material shipped increased about 100 percent during 1956 over 1955 totals, but the number of shipments remained at the level of 1,100 per year, indicating a trend to larger shipments. The increased volume was mainly a result of demand for large cobalt 60 and cesium 137 radiation sources and recently introduced materials with short half-lives.

Development work continued on processes for separating fission products from waste, and another large cesium 137 teletherapy source (2,000 curies) was fabricated for use at the University of Michigan. This source was fabricated by pressing cesium chloride into pellets and double-sealing them in stainless steel, making a source similar to the first one now undergoing tests by the Medical Division of the Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tenn.

The Multicurie Fission Products Pilot Plant, now under construction, was scheduled for completion in July 1957. This plant will be used to separate large quantities of cesium 137 and other fission products from reactor wastes and to fabricate kilocurie sources for use in research and development work in medical teletherapy, food sterilization, and catalysis of chemical reactions.

Stable Isotope Separation

The stable isotope inventory at Oak Ridge National Laboratory was expanded to include separated isotopes of europium and dysprosium, bringing the total number of elements in the electromagnetic separators to 53. All but four elements that can be processed by this method now are made available. There are not yet sufficient quantities of lutecium, ytterbium, and erbium for starting material, and osmium is so toxic in vapor form that separation has not been attempted.

Silicon 28 with a purity of 99.9 percent and calcium 40 with a purity greater than 99.9 percent have been made with a single cycle in the separators. Very high purity boron 10 and boron 11 are being collected, using enriched charge materials. Rare gases such as neon and krypton, enriched oxygen 17, and oxygen 18, are now being separated by thermal diffusion. The oxygen isotopes are of particular interest as tracers in biological studies.

METALLURGY

Irradiation can affect materials by changing their mechanical and physical properties; by altering the kinetics of solid state reactions such as precipitation from solid solution, diffusion, etc.; by increasing the chemical reactivity of solids with liquids or gases, and so on. Only a few of the many interesting projects carried on during the last half year in the research program in metallurgy, solid state physics, and ceramics, can be reported in this summary.

At the Knolls Atomic Power Laboratory, Schenectady, N. Y., a study has been in progress for some time to determine the effect of neutron bombardment on the properties of a wide variety of metals. The experiments are designed to show the changes in tensile properties, hardness, metallurgical structure, and electrical resistivity as affected by temperature, irradiation time, and flux of neutrons. Thus far, work has been completed (partly in this period) for exposures up to 7×10^{19} fast neutrons per square centimeter at a temperature of 70 degrees to 90 degrees centigrade in the Materials Testing Reactor, National Reactor Testing Station, Idaho. From metal tests under these conditions of radiation the following conclusions can be made:

a) With the exception of titanium, all metals which, prior to irradiation, show continuous yielding in a tension test (that is, the strain in the sample increases continuously with the increase in applied stress), will after irradiation develop a discontinuous yielding (that is, they give way abruptly when a certain point in strain is reached).

b) The temperature at which molybdenum makes the transition from ductility to brittleness is increased 100 degrees centigrade by irradiation.

c) Yield strength of the various metals increased by 63 to 453 percent under tension tests after irradiation. The increases in electrical resistivity ranged from 3.1 to 23.8 percent.

d) Neutron bombardment caused no changes in the microstructure of the metals.

e) Annealing treatment sufficient to reduce the hardness of metals to preirradiation levels does not cause recrystallization or grain growth.

These conclusions supply engineers with information as to what performance they can expect from metals under neutron bombardment, and assist reactor designers who may wish to use the metals as structural or other components in reactors.

Effect of Irradiation on Elastic Properties

The distribution of defects in the lattice of atoms making up a solid, around the point of collision between an energetic particle and a lattice atom, is a very important question in the theory of radiation damage and one which as yet has not been satisfactorily answered. Recent studies at Oak Ridge National Laboratory, Oak Ridge, Tenn., of the effects of fast neutron bombardment at 20 degrees Kelvin (253 degrees below zero, centigrade) on the elastic properties of single crystals of copper have thrown much light on this problem.

It has been shown that, in single crystals of copper, the internal friction, i. e. the dissipation of vibrational energy as heat by the movement of linear lattice defects, or dislocations, is markedly decreased by fast-neutron bombardment. It is believed that lattice defects produced by irradiation impede the movement of the dislocations through the crystals, therefore, after exposure, most of the vibrational energy can be dissipated as sound. This effect has been dramatically illustrated by use of a copper tuning fork which, after exposure, rings with a fine tone, but will not ring beforehand.

Because of the distribution of linear dislocations in the crystal expected after bombardment, and the small amount of bombardment required to produce a large change in elastic behavior, the point defects produced in the metal by bombardment and which are capable of stopping the movement of dislocations, apparently move appreciable distances in pinning down the dislocations. At 20 degrees Kelvin thermal migration of the point defects should be almost entirely stopped. Since an effect, though not so large as that at room temperature, still was observed at 20 degrees Kelvin, it must be concluded that some point defects caused by reactor irradiation do move a considerable distance before coming to rest.

Calculations show that dislocations are rendered motionless as far as 150 atomic distances from a neutron hit creating a point defect. This conclusion was confirmed by the disordering rate of a copper-gold sample (Cu_3Au) during exposure at 20 degrees Kelvin. This concept has important consequences in developing a theory to explain the effect of irradiation on metals.

Gamma Rays Damage in Germanium and Copper

Until recently, studies of radiation damage in solids have been confined almost entirely to lattice damage resulting from fast neutrons, electrons, and cyclotron particles. It now has been shown at Oak Ridge National Laboratory that energetic gamma rays also may produce lattice defects, presumably interstitials and vacancies in the normal structure of atoms through the agency of Compton electrons and photoelectrons released from atoms when they absorb gamma rays. The results of gamma ray irradiation thus are the same as for electron bombardment and gamma rays penetrate more deeply. Studies of the electrical properties of germanium, and the internal friction in single crystals of copper, show that the gamma ray effect is only one-thousandth as great as that observed for a similar flux of fast neutrons. However, since the distribution of gamma ray lattice defects throughout the specimens is quite uniform, in marked contrast to the highly heterogeneous distribution of defects produced by neutrons, the results of exposure are considerably sharper. They are also less complicated by interactions between closely spaced defects and with effects associated with thermal resonances.

Techniques of this kind for fundamental studies of lattice defects are of great importance; for example, important energy levels associated with defects in germanium have been located with high precision in gamma-irradiated specimens.

Chemistry

Astrophysical Processes

A very interesting scientific aspect of a thermonuclear test held at the Eniwetok Proving Ground in November 1952 was the discovery in the resulting debris of many new heavy isotopes, including isotopes of elements 99 and 100.[24] One new isotope of element 98, californium 254, produced in this thermonuclear explosion was of particular interest in that it was the first reported example of a radioactive nuclide which decayed primarily by spontaneous fission.

Scientists at the Mount Wilson and Palomar observatories and at the California Institute of Technology made the suggestion that the spontaneous fission of californium 254, with a half-life of 55 days, was responsible for much of the tremendous output of light from type I supernovae, or extra large "new stars"—actually suns which flare to brilliance, or explode, and afterwards fade. In these fast-fading suns, the rate at which their light output decays, after an initial period, has an exponential form with a half-life of 55 days. These scientists evaluated various alternatives and showed that the buildup of californium 254 by very rapid successive neutron captures, starting with iron, provided a reasonable explanation for production of this type of supernova. It is particularly striking that scientific work in conjunction with a program as nonbasic in its objectives as weapons development, can provide information which contributes to the understanding of astrophysical processes. Experiments were in progress to measure the half-life of this isotope more accurately.

Pyrometallurgical Research

The development of a pyrometallurgical separations process, a molten-metal method of removing some fission products from irradiated uranium, requires considerable fundamental research effort. One principal problem studied was the reaction of molten uranium with materials used to contain it.

For some operations it would be desirable to use a metal container for the molten uranium, but uranium attacks metals too rapidly for this to be feasible. Thermodynamic data indicated that some metal borides would stand up, and work at Argonne National Laboratory led to developing a promising and practical boride film.

Tantalum, a metal which is attacked by molten uranium, can be protected by forming a surface layer of tantalum monoboride (TaB).

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[24] See p. 41, Sixteenth Semiannual Report (January–June 1954) for the description of laboratory method of production.

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The layer is formed by painting a film of boron on the tantalum and heating for a few minutes at 1400 degrees centigrade. This treatment forms tantalum diboride (TaB_2) which, by further heating at 1900 degrees centigrade, is converted into the desired TaB film.

Crucibles of borided tantalum contained molten uranium for several days with only negligible corrosion.

Analytical Chemistry

In connection with evaluation and control of separations processes, the use of the X-ray spectograph was extended to provide rapid analyses of a variety of systems. A method was developed for determining the ruthenium and molybdenum content of uranium alloys without destroying the alloy by using an X-ray emission spectrograph with a topaz analyzing crystal.

This method made it possible to analyze a sample in about 10 minutes, compared with about 8 hours for the wet chemical method previously used.

An X-ray spectrophotometric method was devised for rapid analysis of uranium or plutonium solutions in very low concentrations.

Spectrometry of Vapor Polymerization

Thermochemical studies at University of California Radiation Laboratory, Berkeley, have shown that the vapor state of many compounds is complex and that considerable quantities of polymers of the simple species may be present. Mass spectrometric techniques are doubly useful in sorting the various species and measuring them quantitatively.

Simple metal strip ovens made of platinum, tantalum, or iridium strips about 1 mil thick, and 30 mils wide by ¼ inch long, served as electrical resistance heaters to produce the temperature necessary to vaporize almost any compound. The vapor was ionized by a stream of electrons and the positive ions were analyzed in the mass spectrometer.

It was found that the trimer—that is, a molecule consisting of three atoms of the metal plus three atoms of the halogen (bromine, iodine, or chlorine) is the most abundant species in a vapor of the halides of both copper and silver. The similarity in the mass spectra of the silver and copper halides, together with the magnitude of the heat of trimerization of silver chloride (which has been determined to be 110,000 calories per mole), suggests that the molecular structure of the trimers of both metals is the same, and that this structure might be a molecule with the six atoms formed in a ring-like configuration.

Heats of activation for vaporization also were measured for species such as lithium bromide, lithium iodide, sodium chloride, and potassium chloride, and found to be in good agreement with values determined by equilibrium thermochemical methods.

The results of these experiments emphasize the complexity in the vapor phase at high temperatures and indicate that a reevaluation of earlier vapor pressure data is needed.

Biology and Medicine

During the last half of 1956, research related to the effects of radiation upon living systems, the treatment of effects, and upon the application of radiation and radiation techniques to increasinng knowledge in the life sciences, continued to make constructive contributions to progress in the biomedical and biochemical fields. Many of the previous results of the portions of these broad programs of research applicable to health problems in atomic energy activities are summarized in the special section later in this report dealing with radiation protection. Here, the Commission summarizes work during the last 6 months of radiation effect, cancer, agriculture, and toxicity in production operations, and reports on contributions to civil defense, and on the progress of the new medical research center being built at Brookhaven National Laboratory, Upton, Long Island, N. Y.

Brookhaven Medical Research Center

Construction of the Medical Research Center at Brookhaven National Laboratory was about 11 percent complete at the end of the reporting period.

Preliminary designs for the center were developed by the laboratory and an architect-engineering contract for design and construction supervision was awarded by the Atomic Energy Commission to the firm of Eggers and Higgins, New York, N. Y., in April 1954. The one-story center will have 118,000 square feet, and will include laboratories for medical physics, pathology, microbiology, biochemistry, and physiology, a 48-bed research hospital, and an industrial medicine branch for the laboratory.

Heavy building excavation was finished. The entire Medical Research Center including the medical reactor is scheduled for completion in 1958. Malan Construction Co., Long Island City, N. Y., was awarded a contract to construct the buildings.[25]

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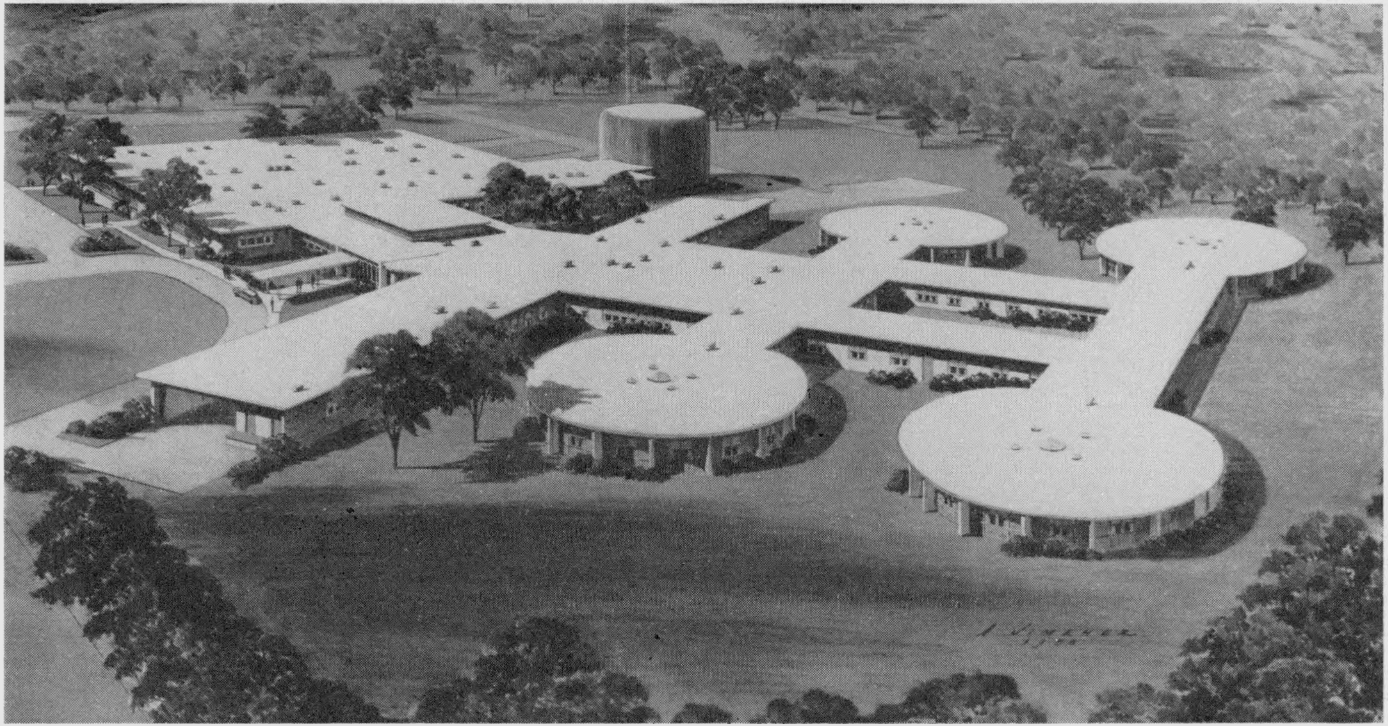
[25] See p. 100, Twentieth Semiannual Report (January–June 1956).



Medical Research Center. A drawing of the Brookhaven National Laboratory Medical Research Center, being constructed at the laboratory near Upton, Long Island, N. Y. The cylindrical building in the rear will house the special medical research reactor; the four circular structures at the ends of wings house groups of hospital rooms, each group opening on a central nursing station.

Work on the design of the medical reactor which will be housed separately has been under way for 3 years. In 1953 the Nuclear Development Corp. of America, White Plains, N. Y., conducted a survey for the Brookhaven Medical Department of radiation sources, including accelerators, radioactive isotopes and reactors, to determine which would best meet the specified needs. The Nuclear Development Corp. recommended and prepared a preliminary design of the general type of reactor required. Detailed design was executed by a design committee composed of representatives from the Laboratory. A contract with the Daystrom Nuclear Division, Daystrom, Inc., Elizabeth, N. J., for building the medical reactor was executed in September.

This first nuclear reactor designed specifically for medical therapy and research will be cooled and moderated by water and will use an alloy of enriched uranium and aluminum as fuel. Two ports, one on either side of the reactor, will permit beams of neutrons to pass out into treatment rooms. Each port will be controlled by a 43,000-pound shutter which can release or close off the neutron beam within a period of three seconds. Operators will be further protected by a 2-foot thick shielding wall. The shutters were fabricated and poured by Baldwin-Lima-Hamilton, Philadelphia, and were being tested.

A third face of the reactor will be equipped for the irradiation of large objects and the fourth face will have three injection holes to be used for production of special, short-lived radioisotopes. The availability of the short-lived radioisotopes at the hospital site will make possible a much wider range of medical investigation into fundamental body processes than can now be conducted.

The need for a medical reactor has developed over the last 6 years during which time Brookhaven scientists have used the available research reactor for neutron capture therapy in certain types of brain tumors. In this treatment, the patient receives into the blood stream an injection of a boron compound which tends to localize in the tumor and to capture neutron particles. A stream of neutrons from the reactor is directed at the brain tumor at a time when the tumor has concentrated the boron so that the radioactivity generated in the boron destroys the tumor cells with minimal effects on adjacent normal tissue. The technique is experimental at present.

This new medical reactor will produce a beam of thermal neutrons having an intensity 50 times greater than that available from the Brookhaven general research reactor for treatment purposes. It will thus permit both wider medical application of neutrons and greater flexibility of treatment.

In addition to research on neutron-capture therapy, a program of investigations was under way utilizing radioactive isotopes in the diagnosis and treatment of a wide variety of diseases. These problems ranged from laboratory studies of molecular structure to the care and management of patients receiving specialized diagnostic tests and treatments.

Research Results

Radiation Effects

Radiation and blood-clotting. Heparin, a recognized anticoagulant, is a member of a group of substances known as mucoproteins, some of which influence blood clotting. Recent work at the University of Rochester, Rochester, N. Y., showed that the level of mucoproteins in the blood of dogs is increased by a factor of two to four by radiation doses just under the lethal range. Work was under way in experimental animals to determine whether or not these substances, perhaps released from tissue damaged by radiation, are an important factor in the tendency toward hemorrhage resulting from radiation in man and other mammals.

Other research on radiation effects and treatments is reported in Chapter VI of the special section on radiation protection.

Agricultural Research

Plant biochemistry. An effect of ionizing radiation in inhibiting photosynthesis was investigated at Oak Ridge National Laboratory, Oak Ridge, Tenn. (Photosynthesis is a process by which plants build their substance from elements in earth, air, and water using the energy of sunlight—a complex process which thus directly and indirectly accounts for all food and chemical fuel sources.) It was found that dosages of greater than 100,000 roentgens of gamma radiation are necessary to reduce the rate of photosynthetic carbon dioxide fixation to 25 percent of normal in wheat leaves. This inhibition of photosynthesis by a single dose of 100,000 to 400,000 roentgens is temporary. Recovery is nearly complete 24 hours afterwards. During the period of inhibition there is no change in distribution among the products of the photosynthetic carbon cycle.

The photosynthetic process in green plants was thus found not radiation-sensitive in the sense of suffering permanent harm, and outside the area of blast and heat, the ability of plants to maintain this vital process would be undamaged by dosages of radiation from the detonation of nuclear weapons.

The effect of radiation on induction of the photosynthetic process was tested by growing plants from seed in total darkness and then exposing them to gamma radiation before placing them in the light to induce greening. This process of turning green in the light reflects the formation in the plant cells of chloroplasts and all the activity of many enzymes needed for photosynthesis. Inhibition of this greening process was found also to require 100,000 roentgen or more of radiation. Therefore, neither the photosynthetic process itself nor its initiation is radiation-sensitive at dosages high enough to stop all further cell division and plant growth.

Seed and plant irradiation. The University of Tennessee-Atomic Energy Commission Agricultural Research Project, Oak Ridge, Tenn., built a central irradiation facility for plant breeders of the Southern Agricultural Experiment Stations. The facility provides a cobalt 60 irradiation field to irradiate seed, and to investigate the use of ionizing radiations for plant improvement.

The first actively growing tissue (as distinct from dormant seeds), from species including peach trees, pine seedlings and grape cuttings, was irradiated with a range of doses. In addition, a field study of the radiation response of first generation material was started by giving 5 doses of gamma rays and 5 doses of neutrons to 19 different species or strains, as follows (one variety except where noted parenthetically) : crimson clover, button clover, birdsfoot trefoil, red clover (2), sweet clover, orchard grass, fescue, alfalfa (2), vetch, wheat (2), oats (2), barley (2), and rye (2). A control group of each was untreated.

Plantings were staggered according to optimum dates for each crop. Information is sought on germination, seedling vigor, survival to maturity, and fertility. Favorable dominant mutations also are looked for. The experiment was performed four times, using 10,000 treated seeds of each strain in each test.

Genetics Research

Genetics of mice. Extensive experiments at Oak Ridge National Laboratory on the genetic effects of radiation in mice have sought to obtain better estimates of the genetic hazard of radiation in man. Earlier estimates of this hazard were based mainly on mutations in the fruitfly. Results already obtained from the mouse work have necessitated a revision of estimates based on fruit fly data.

In contrast to the fruit fly work, most of which was done by irradiation of spermatozoa, or late germ cell stages, the mouse data were obtained from irradiation of spermatogonia, the cells from which new batches of germ cells are constantly being developed. The mouse experiments were made in this way because, in man, the conditions of radiation exposure are such that most of the total dose received by a germ cell prior to fertilization will usually have been accumulated in the spermatogonial stage, not in the spermatozoal stage. This point is important because it has been shown that mutations from irradiation at these different stages differ both quantitatively and qualitatively.

From the immediate practical point of view, the most important result of the mouse work was the estimate that mouse genes are about 15 times more mutable per roentgen of X-rays than are comparable genes in fruit flies.

A second important discovery was that offspring conceived a long time after exposure of the father to radiation were just as likely to inherit induced mutations as those conceived a few weeks after exposure. This point had not been investigated before for mutations induced in spermatogonia, or for an animal as long-lived as the mouse.

A third important finding was that more than half the induced mutations studied in the mouse have proved to be lethal when inherited from both parents.

A fourth finding was that there was measurable damage in the first generation offspring of an irradiated parent. The magnitude of this effect was higher than supposed by many geneticists and indicates that, even on genetic grounds, it was desirable to set a dose limit for individuals as well as a dose limit for the population.

Considerable expansion in studies of human and medical genetics was being undertaken at the University of Michigan Medical School. Determinations of spontaneous mutation rates of specific inherited traits continued. In addition, present accumulation of deleterious genes in human populations were investigated through analysis of the Japanese data on the outcome of consanguineous marriages; by direct estimates of the frequency of hereditary diseases; and by the use of biochemical methods to detect genetic carriers. The action of selection on human populations was being followed in genetically controlled serological systems.

Studies of the frequencies of deleterious genes in humans were also in progress at Argonne National Laboratory through analysis of the outcome of consanguineous marriages in American populations.

The recent development at the University of Colorado School of Medicine of methods whereby colonies of cells can be grown from suspensions of single cells with close to 100 percent efficiency opened up the possibility of direct experimental comparisons of effects of radiation on human and other mammalian material. Studies were initiated at the Johns Hopkins and Yale Universities and at the Long Island Biological Association to compare the effects of ionizing radiations on chromosome breakage and mutation rates in tissue cultures of human and other animal cells.

Mechanism of chromosomal replication. The mechanism of chromosome replication during cell division was investigated at Brookhaven National Laboratory in an autoradiographic study using a solution of thymidine labeled with tritium. Seedlings were grown for a limited time in a solution containing the thymidine, a precursor of desoxyribonucleic acid (DNA). Roots then were taken from the solution containing the radioactive tritium tracer and grown in a nonradioactive solution containing colchicine.

Colchicine treatment permits determination of the number of division cycles, or replications, the chromosome goes through after the tracer isotope is incorporated in the chromosome.

At intervals, roots were fixed, stained, smeared, and placed on autoradiographic film. The autoradiographs showed that the daughter chromosomes resulting from the first division after incorporation of the tracer were both labeled equally and uniformly. In an ensuing replication, after withdrawal from the tracer solution, the label appeared in only one of the two daughter chromosomes.

These findings indicate that (a) DNA is synthesized as a unit which extends throughout the length of the chromosomes and remains intact through subsequent cell divisions, (b) that a chromosome is composed of two such units, both identical to each other, and (c) that after each unit divides to form a chromosome with four units, the chromosome divides so that each of its daughter chromosomes regularly receives an "original" unit, and a "new" unit.

Cancer Research

Localizing treatment. Since cancer is rarely controlled once it has spread widely in the body from the place of origin, effective treatment of metastisized cancer with radiation from radioactive isotopes requires a means by which the body will transport them specifically to the cancer growths. At the University of Rochester, research is aimed at producing labeled antibodies that, after intravenous injection, will localize in cancer tissues, and so serve as carriers of radioactivity for therapy. Some success was achieved in using this method to localize radioactivity in various tissues of the bodies of experimental animals.

Tracer Research

Radioiron. At Argonne Cancer Research Hospital, the presence of a powerful stimulus for the formation of red blood cells has been demonstrated even in the blood of anemic individuals—those whose blood is deficient in red cells. The anemia apparently does not arise from the absence of this stimulus.

Radioiron was used successfully as a tracer in experiments bearing on this point. The presence of the stimulating substance in the blood of anemic individuals had been suspected for some time. In the studies on animals, uptake of radioiron in developing red cells was measured as an indicator of the rate of blood cell regeneration.

Thyroid physiology. A tracer study at University of Tennessee and the New England Center Hospital on the action of the thyroid gland, made possible by using radioiodine to label the thyroid hormone, demonstrated that in rats a diet of wheat and soy beans causes a rapid loss of the hormone from the body. To replace the lost hormone, the rats' thyroid gland attempted to increase the rate of production, a process that can result in goiter. Casein in milk products and fibrin, or plant fiber, were found to counteract this effect in rats.

Toxicity Studies

Mercury. Biological investigations of the toxicity of various metals used in the atomic energy field were under way at the University of Rochester and the Mound Laboratory, Miamisburg, Ohio. The Rochester studies include work on mercury and ionium, another name for thorium 230.

The use of mercury poses certain safety problems in protecting personnel against chronic toxicity from this metal. Studies were under way on the mechanisms of the effects of mercury and similar agents on cells and tissues. The binding of mercury to the surface of the cells, its penetration into the interior of cells, and accompanying physiological effects have been described. Among the several actions of mercury that may be of consequence in chronic mercury poisoning the most important seems to be an effect on mineral metabolism.

Living cells are normally rich in potassium and low in sodium whereas the reverse is true of the blood plasma and body water surrounding them. It is generally believed that the condition is maintained by so-called "sodium and potassium pumps" located in the surface membranes of the cell. Actually little is known about the specific mechanisms by which these "pumps" operate. Nevertheless, the maintenance of the proper mineral balance between the cells and the surrounding medium is of vital importance to all cells.

It was found that mercury in small amounts interferes with the ability of cells to retain potassium, presumably by modifying the action of the "potassium pump". It does so by combining with certain parts of protein molecules in the cell surface called sulfhydryl groups. It is of some interest that radiation can also influence these same sulfhydryl groups.

Studies of the action of mercury on potassium metabolism of cells may lead not only to important knowledge concerning the nature of chronic mercury poisoning, but at the same time to a greater understanding of cellular metabolism.

Ionium. In general, since predictable fractions of most accidentally inhaled radioactive elements are excreted daily in the urine, estimates can be made of the amount present in the body—the "body burden"—from the amount excreted in the urine over a certain period of time. Studies were made to determine if this pattern holds true for ionium, an alpha-emitting thorium isotope of high radioactivity formed during the radioactive decay of uranium 238 which may be accidentally inhaled or ingested by workers during its production and separation.

At the University of Rochester, this problem was approached by injecting a solution of an ionium salt directly into the lungs of test animals and subsequently studying excretion over a period of months.

Some of the injected solution is coughed up, or is moved to the mouth by action of the hair-like ciliary projections in the lining of the air passages, is then swallowed and soon appears in the urine or feces. The object of this long-term experiment was to determine if there would be a detectable urinary or fecal excretion after coughing or ciliary action no longer was a factor; and further, to determine if over a prolonged period of time body processes might remove the element from the lung and deposit it in another organ.

Since it was very difficult to prevent cross-contamination between the feces and urine in these experiments, a short-term experiment was designed to obtain urine for analysis before ionium could appear in the feces. The results of the acute experiment showed that no detectable amounts of ionium were found in the urine. The long-term experiment showed that at no time was there ionium in the urine that could not be accounted for by contamination from the feces. During the first week after injection, the amount in the feces decreased rapidly with time, so that after the first week, little or none was found in the feces. In growing rats, 1 to 2 percent of the ionium dose was deposited in the bone.

These data indicate that examination of the urine would be of no value in determining the amount of ionium in the lungs, but that the amount appearing in the feces would give a very rough idea of the content of the lung within a week following an exposure.

Ciliary action. Another study at Rochester was on the effects of ciliary action in relation to inhaled dusts. Billions of these microscopic hair-like projections, the cilia, are attached to and blanket, like blades of grass in a thick lawn, the mucous membranes that line most of the inside of the nose, the trachea, and the small air ducts in the lungs of man and other mammals. Cellular processes cause the cilia to wave back and forth in a regular rhythm, with the result that there is a movement of the thin film of mucus overlying these cilia. As a result mucus is continuously carried upward to the back of the throat where it can be swallowed or expectorated. The mucus carries with it insoluble particles of dust which are entrapped when air is inhaled.

This entire process is a special type of excretion which serves to protect the lungs and, indirectly, other organs from toxic dusts (including radioactive particles) that may be breathed in.

Little is known about the factors which control the rate and force of ciliary action. In an attempt to learn more about this process, isolated strips of living mucous membranes have been illuminated with a flashing light. When the flash frequency is adjusted to equal that of the beating cilia, the cilia appear through a microscope to be standing still. This stroboscopic technique shows that cilia beat as rapidly as 25 times each second.

The influence of several drugs on this contractile rhythm is under current investigation.

Polonium and actinium. Biological investigations of the toxicity, metabolic fate, and the gross effects of polonium on rats have been performed at the Mound Laboratory. Between 35 and 45 microcuries of injected polonium were found to kill 50 percent of the rat population in 20 days. In less than lethal doses, polonium may produce lesions in the visceral organs. It will damage blood cells and blood-forming tissues, but this effect is not prominent at low dosage levels. Polonium also will cause loss of appetite, some diarrhea, and decrease in weight gain of animals. Although the effects of polonium on humans were not completely evaluated, a retention half-time of 36.6 days was determined from the routine analysis of urine samples.

Similar studies were conducted on actinium 227 and radium 223. Approximately 50 percent of the actinium administered to rats lodges in the skeleton where it may cause considerable damage to the blood-forming cells. This effect is caused by the ionizing effects of the high alpha-activity of its short lived daughter products. Other organs are not damaged to the same extent. Although they absorb much of the injected or ingested actinium, they also tend to excrete the daughter products quite readily. Orally administered actinium is almost wholly excreted.

An interesting product of this experiment has been the development of a strain of rats highly susceptible to chloro-leukemia. Such a strain may be useful in future experimental work. Results also indicate that radium 223 and thorium 227 may be transferred in the milk from an injected female to her offspring.

An analytical method for determining radium 226, actinium 227, and thorium 228 in urine was devised. The procedure involves coprecipitation of radium with barium nitrate in 80 percent nitric acid, and coprecipitation of actinium and thorium with cerium phosphate. Results are derived from differential analysis of alpha activity measurements.

The studies of polonium and actinium toxicity and metabolism required the design and construction of special counting apparatus and the use of special mathematical analysis of the counting results.

Instrumentation

Radiation dosimetry studies. At the Oak Ridge Institute of Nuclear Studies experiments with a dosimeter needle of silver phosphate glass developed by the Naval Research Laboratory, demonstrated that this instrument offers unique possibilities in studies of radiation dosage because it is small and inert.

Using the needles, an attempt was made to estimate experimentally the maximum permissible ingestion of yttrium 90, based on the dose rate to the gastrointestinal tract of the dog. Five needles were placed, by surgical procedure, 1 or 2 millimeters under the mucosa at specified points from the stomach to the lower large intestine of each dog.

Yttrium 90 then was administered either as a single dose, or as a daily dose for 7 days. Several days after the last treatment, the dosimeters were recovered, measured, and calculations were made of the radiation received by the intestinal mucosa. From this value and the dosage of radioactivity, the intake of yttrium 90 required to produce a dose rate of 0.3 roentgen per week was calculated.

Neutron exposure reinterpretation. New techniques of neutron dosimetry, applied by Oak Ridge National Laboratory in cooperation with the Los Alamos Scientific Laboratory and the School of Medicine, Randolph Air Force Base, during Operation *Teapot* weapons test series in the spring of 1955, indicated the need to revise some of the earlier concepts of the variation of neutron doses and spectral distribution as a function of distance from the point of detonation. The Los Alamos Laboratory combined dosimetry data with weapons information on the Hiroshima and Nagasaki-type bombs and preliminary results indicate that the average lethal dose of radiation to man is somewhat higher than the usually accepted figures.

Information collected by the Atomic Bomb Casualty Commission at Hiroshima and Nagasaki, Japan, where atomic weapons were exploded during the war, now can be combined with better estimates of dose, and will yield more accurate indications not only of the average lethal dose, but of the doses that produce loss of hair, temporary sterility, cataracts, and leukemia.

Civil Effects Program

Loans of Radiation Sources

During the reporting period cobalt 60 sources were lent, upon endorsement by the Federal Civil Defense Administration, to the following territorial, State and local civil defense and cooperating organizations for demonstration and training use: Territorial Civil Defense Agency, Honolulu, Hawaii; Division of Civil Defense, State of Kentucky, Louisville, Ky.; Office of Civil Defense, Park Forest, Ill.; University of Missouri, Columbia, Mo.; Eastern Illinois State College, Charleston, Ill.; St. Procopius College, Lisle, Ill.; and Chicago Teachers College, Chicago, Ill.

Radiation Survey of Test Site Environs

In connection with the continuing field research program on radioactive fall-out from continental tests, the Commission arranged with the Geological Survey, Department of the Interior, to supplement information gained through ground monitoring by an aerial radiological monitoring system, using techniques and instrumentation similar to those applied to aerial prospecting for radioactive materials. A survey was made October 22–November 5, 1956, in a radius of about 100 miles from the Nevada Test Site.

The Federal Civil Defense Administration participated in this pilot survey, which further demonstrated the feasibility of measuring ground radiation by aerial methods.

Action in Damage Claim Suits Against Government

After a trial lasting two weeks and two days before U. S. District Court in Nevada, Judge Sherman Christenson on October 27, 1956 found for the Government in the pilot case of seven suits alleging that death or injury of some 11,000 sheep [26] had been caused by fall-out after test activities at the Nevada Test Site during the spring of 1953. The decision in the case of Bulloch et al. vs. United States found that the plaintiffs had failed to establish their case by a fair preponderance of the evidence.

The court said, ". . . the maximum radioactive doses to which the Bulloch sheep could have been subjected, whether as a result of direct

[26] See pp. 50–51, Fifteenth Semiannual Report (July–December 1953).

fall-out, residuals therefrom, ingestion of plants or water, or through other means, was substantially less than would have caused damage; that the expected and actual fall-out . . . was well within the permissible maximums for human or animal body tolerance . . . no negligence on the part of the Government has been established . . ."

As a result of the decision, on November 16, the six other cases were dismissed with prejudice but without costs. The case was decided on its merits. The Court indicated that the fact that the Government had discretion to conduct the tests did not eliminate liability for possible negligence, and pointed to the Commission's duty to warn persons who might be damaged by impending fall-out.

A consolidated suit involving three persons filed for alleged personal damages from radioactive fall-out in the same 1953 weapons test was dismissed under a Stipulation and Order signed October 25 in the U. S. District Court of Southern California. Separate suits for $100,000 each were filed by Elma Mackelprang and Dewey A. Horrt in the Southern District of California, and for $75,000 by Aaron Leavitt, in the U. S. District Court in Nevada, and these suits were later consolidated.

The sites where the alleged exposure took place were from 60 to 105 miles from the Nevada Test Site.

The Stipulation and Order was entered into at the request of the plaintiffs after a pretrial conference disclosed deficiency in the proposed proof. At that time, plaintiffs stipulated they would feel disposed to withdraw unless certain anticipated testimony from an acknowledged expert in the field of radiological medicine could be obtained. The Stipulation further indicated that if such testimony could not be obtained, a motion to dismiss would be made by the plaintiffs.

Security

On September 12, 1956 the Atomic Energy Commission approved an amendment [27] to its Criteria and Procedures for Determining Eligibility for Security Clearance, 10 CFR Part 4, (See appendix 6). This revision provides for the appointment to each Personnel Security Board of a nonvoting member to serve as Counsel to the Board. As a nonvoting member, Counsel to the Board will not be permitted to take part in the deliberations of the Board nor advise it as to the merits of a case. Prior to this modification, the regulation required the appointment of an attorney to serve as Counsel to the Board but Counsel was not to be a member of the Board.

[27] See pp. 117–118, Twentieth Semiannual Report (January–June 1956).

The modified regulation will make eligible a greater number of attorneys in private practice for appointment to such Boards by affording limited exemptions as prescribed in Section 163 of the Atomic Energy Act of 1954. Section 163 allows members of Commission advisory boards, while serving as such, to receive compensation in certain instances from other activities directly or indirectly involving the Government except that they cannot receive compensation from any matter in which the Commission is directly interested.

Nuclear Materials Management

Standards Program

Reports were received from the Committee for Uranium Isotopic Standards which was established during the previous reporting period [28] to evaluate the suitability for reference of a series of uranium isotopic standards and the study group established at the same time to consider the broader question of an overall standards program for materials peculiar to the atomic energy industry. The committee recommended that certain additional work be performed before final acceptance of the materials as reference standards.

Both groups recommended that the National Bureau of Standards, Department of Commerce, be requested to assume the standards work and discussions with the Bureau were under way.

Materials Budgeting

Administrative arrangements were made to assure that nuclear materials are efficiently used by Commission installations and that enough materials are available for such nonweapon program needs as Commission research, distribution under domestic programs and to friendly foreign nations under research and power agreements for cooperation. The Commission assigned to the Division of Nuclear Materials Management the function of reviewing, controlling, and reporting on all requests for material, and providing mechanisms within production exigencies and the authorization of the President whereby requests for nuclear materials can be satisfied. To meet this responsibility, a Materials Budgeting Branch was organized.

Peaceful Uses of Nuclear Materials

Domestic. So that domestic private industry should have the benefit of Commission experience in handling and accounting for nuclear

[28] See Appendix 2.

materials and know first-hand the Commission's requirements, plans were formulated to hold a symposium during the spring of 1957 to which representatives of private industry licensed to handle nuclear materials were invited.

Another symposium on "Modern Approaches to Isotopic Analysis of Uranium", will be held at Chicago in February 1957. It will largely deal with methods which may result in reducing capital outlay while still providing satisfactory precision and accuracy of measurements. To the extent possible, the meeting will be opened to private industry.

Foreign. A control system was being worked out to provide adequate safeguards for special nuclear materials to be distributed abroad under the Atoms for Peace program. A manual was being prepared for use of foreign nations in handling and accounting for nuclear materials, describing the United States requirements for records, inventories, and reports on holdings.

Inspection

Inspection of Licensees

Nine inspections covering the pre-operational and startup activities of five reactors were made during the reporting period. The program for inspection of byproducts (radioisotope) and source material licensees was under way. Responsibility for inspection of material licensees was assigned to Commission operations offices, each office having responsibility for a specific geographical area. Organization of inspection groups was initiated in most field offices and they are now performing inspections.

A number of conferences was held with State officials to acquaint the States with the Commission's inspection program and to arrange cooperation.

Procedures for systematic investigation of any incidents which may involve unplanned release of radioactive substances, or unplanned exposure of personnel, are being formulated.

Inspection of Commission Offices and Contractors

Surveys of the systems of inspection employed by headquarters offices and divisions of the Commission were substantially completed and continuing test checks of their operation in the field were carried forward. Several operations offices initiated programs to combine

411053—57——8

the results of inspections of contractors into annual appraisals of contractor performance.

Construction and Supply

Construction

The Nation's capital investment in atomic energy facilities continued to rise steadily during the reporting period, and as of December 31, 1956, had reached about $6.8 billion, before depreciation reserves. During the 6-month period ended December 31, 1956, costs incurred by the Commission for new plant and equipment were estimated to be about $125 million. Activity during the second half of fiscal year 1957 was expected to continue at substantially the same level, and construction costs for the year should approximate the $300 million incurred during fiscal year 1956.

Construction continued to progress satisfactorily throughout the program. Work continued on major new facilities for the production, weapons, reactor development, and physical research programs.

Motor Vehicle Management

The Annual Motor Vehicle Report showed substantial improvement in cost of operation of the Commission fleet during fiscal year 1956 as compared with fiscal year 1955. The average operating and maintenance cost dropped 1 cent per mile to show $700,000 savings on the 71 million miles operated. Mileage was down approximately 12.9 million resulting in a reduction of expenditures of about $1 million. The net active fleet is 591 vehicles less than the fleet of a year ago, a 6 percent reduction.

Auction Sales

Gross returns from four auction sales of used equipment and other property held at Oak Ridge, Tenn., Richland, Wash., and two at Portsmouth, Ohio, during the past 6 months, averaged 23.7 percent of the original cost of the property. During the past 3 years, used property which originally cost approximately $41 million has been sold at 20 auctions held at 7 different locations. Total returns were approximately $10.4 million, or 25.2 percent of the original cost.

Bartering Farm Commodities for Strategic Materials

Procedures were developed for cooperation with the U. S. Department of Agriculture through the Commodity Credit Corp. in disposing of surplus agricultural commodities by bartering these commodities for strategic materials required in the Commission programs.

Under this system, offers received from commercial and industrial agents and principals to furnish foreign strategic materials are referred by the Commission to the Commodity Credit Corp. The Commission also referred to Commodity Credit Corp. any substantial requirement it had for foreign materials so that CCC could arrange for possible barter of agricultural commodities. For purposes of this program, "strategic materials" may include any material of foreign origin required in substantial quantities in the Commission programs, and materials produced in the United States from raw materials originating in other countries. Proposals were being considered for the exchange of sizable quantities of thorium nitrate and zirconium sponge for surplus agricultural commodities.

Small Business

During the past 6 months, the Commission participated in numerous Small Business Administration Small Business Conferences held throughout the country by providing speakers and contractor exhibits on subcontract opportunities. In furtherance of the Commission program to assist small business, its contract finance policies were amended, pursuant to a recommendation of the President's Cabinet Committee on Small Business, to assure that a small business concern's need for advance or progress payments shall not be treated as a handicap in the award of contracts.

The share of Commission subcontract dollars going to small business continues to be substantial and showed a further increase in fiscal year 1956 with 45.7 percent or $211.1 million out of a total of $461.8 million subcontract dollars being awarded to small business. From July 1, 1951 through July 1956, Commission cost-reimbursable contractors awarded 40.5 percent or $1.194 billion to small business out of a total of $2.993 billion. Direct contract awards to small business during the same period amounted to $230 million or 3.2 percent of $7.29 billion.

The Commission's policies and procedures for increasing small business's share in the Government dollar through efforts to have its prime contractors emphasize letting its subcontracts to small business concerns was reviewed during the first half of 1956 by the Select

Committee on Small Business of the Senate, as reported previously.[29]

In its report [30] on the results of its review, the Committee concluded:

"The Atomic Energy Commission is to be complimented on its subcontracting program. In operation since 1951, the program requires all AEC cost-type prime contractors to follow AEC requirements on subcontracting. As a result of aggressive and imaginative implementation of the program by AEC procurement officials and the prime contractors, the share of AEC subcontract dollars going to small business has risen from 26.7 percent in 1951 to 47.6 percent in the first half of 1956."

New Headquarters Office Building

The construction of the Commission's new headquarters at Germantown, Md., proceeded according to schedule and is expected to be completed by November 1957. It will be a modern brick-faced suburban office building, air-conditioned, and containing approximately 400,000 gross square feet. There will be a cafeteria, auditorium, garage, warehouse, and parking facilities for 700 cars. Provisions have been made for future expansion of the building if necessary.

The building is situated on a knoll of 109 acres of rolling farm land and is so designed as to take advantage of the vista across the countryside and to permit all offices to have outside exposure. Access to the building will be from Route 118 near the Germantown interchange of Route 240.

Arrangements have been made for the General Services Administration to operate and maintain the building and for the Government Services, Inc. (GSI) to operate the cafeteria.

Mobilization Planning

Active participation in the various mobilization readiness programs of the Office of Defense Mobilization (ODM) was continued.

The most comprehensive test so far of the Commission's Emergency, Disaster, and Mobilization Plans was held in connection with Operation Alert 1956 (July 20–25). More than 600 Commission and operating contractor personnel were engaged in the activities at the Headquarters and Field Emergency Relocation Centers. The exercise demonstrated the ability of the relocated personnel, under the assumed attack conditions, to effect the emergency transfer plan for nuclear weapons and components, to assess bomb damage in terms of its effect

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[29] See p. 136, Twentieth Semiannual Report (January–June 1956).

[30] See p. 39, "Government Procurement—1956," Report No. 2827, the Select Committee on Small Business, United States Senate, on Small Business Participation in Government Procurement, 84th Cong., 2d Sess.

on production capability, to reschedule production, and to take appropriate administrative actions including those growing out of the simulated Emergency Proclamations and Executive Orders.

Community Operations

Oak Ridge

On July 11, 1956, the Housing and Home Finance Agency made a finding that it was feasible under the Atomic Energy Community Act of 1955 to sell the real property in Oak Ridge. The sale of property began with the offering on July 31 of 680 residential lots to resident priority holders. Beginning September 7, four groups of houses, comprising 1,648 single and 735 duplex buildings, were offered for sale to occupants. As of the end of this reporting period 82 vacant residential lots and 723 houses had been sold as had 119 leased lots. The sale of commercial property will begin early in 1957.

The church sale program was completed with 38 groups purchasing building sites and, as of the year's end, 26 congregations had built. Three congregations occupied chapels bought from the Commission and two others were building churches.

A zoning ordinance developed by a private consultant for the Town Council was submitted to the Anderson County Court for enactment. Public discussions were held on a proposed municipal charter and on estimated municipal revenues and expenditures. The Town Council held public hearings on legislation for community incorporation, and established a legislative committee to work with the Tennessee General Assembly on a new incorporation statute.

Richland

The residents of Richland protested as too high the appraised valuations placed by the Federal Housing Administration (FHA) on Richland property. A private appraiser was retained by the FHA to review its appraisals of Richland property and was expected to report early in 1957. Pending publication of this review, the Housing and Home Finance Administrator withheld his finding regarding the feasibility of selling real property in Richland which must precede a sale.

The Kadlec Hospital was transferred to the Board of Hospitals and Homes of the Methodist Church on September 9, 1956, without interruption of service. A contract was executed to provide for assistance payments under the provisions of the Community Act.

This is the first transfer of a "municipal installation" to a local entity to be completed under the provisions of the statute.

Negotiations were begun with the General Telephone Co. of the Northwest for sale to the company of the Richland telephone system.

The Richland City Council agreed upon land-use regulations which it will recommend to county authorities for enactment. The Commission has prepared and will file with the County Recorder before the first sale of property a declaration relating to the use of land. The final report of a study on municipal personnel prepared by the Public Administration Service has been released through the City Council.

The Richland School District Board which has operated the schools under contract is studying the feasibility of accepting transfer of school facilities, and is planning to correlate takeover with the incorporation of the city. Due to the delay in initiating property sales, the probable date for incorporation is uncertain.

Los Alamos

The program for eliminating substandard housing at Los Alamos continued during this reporting period with the start of construction of 226 replacement housing units, expected to be completed by January 1958.

Amendment in June 1956 of the Atomic Energy Act of 1954 permitted Federal negotiation of commercial leases on Government property at Commission communities. Previously, the 35 Los Alamos concessionaires, whose leases on Government-owned commercial facilities originally were granted under open bidding, had no assurance of lease renewal.

With transfer to the Commission by act of the Eighty-fourth Congress of full administrative control over about 67,000 acres of land formerly under the Departments of Agriculture and of the Interior, the Commission administers the lands of all Los Alamos County. These lands include some 45,000 acres in the Santa Fe National Forest, and from the Ramon Vigil Grant administered under the Bankhead-Jones Farm Act by the Department of Agriculture plus about 22,000 acres of the public domain administered by the Department of the Interior. The Manhattan Engineer District, which established the Los Alamos laboratory and community, originally had purchased about 3,600 acres from private owners. Although the Manhattan District and the Commission had use of these lands, they did not previously have full administrative control.

The Commission now may grant long-term leases on, or sell, particular portions of the transferred lands, as homesites, store locations, and the like. This will further plans for sale of land to individuals for home construction.

Organization and Personnel

Personnel Activities

Incentive Awards Program

The Commission held its first Annual Honor Awards Ceremony on November 14, 1956. Distinguished Service Awards were presented to Richard W. Cook, Deputy General Manager; Jesse C. Johnson, Director, Division of Raw Materials; William Mitchell, General Counsel; and Charles Vanden Bulck, Assistant Manager for Administration, Oak Ridge Operations Office.

Eighteen employees received Outstanding Service Awards. Thirty-five employees were recognized for number of years of Federal service, three receiving 40-year Length-of-Service Awards and 32 receiving 30-year Awards. Previous recipients of the Distinguished Service and Outstanding Service Awards were presented the Atomic Energy Commission medal struck since the presentation of their awards, gold for distinguished and silver for outstanding awards.

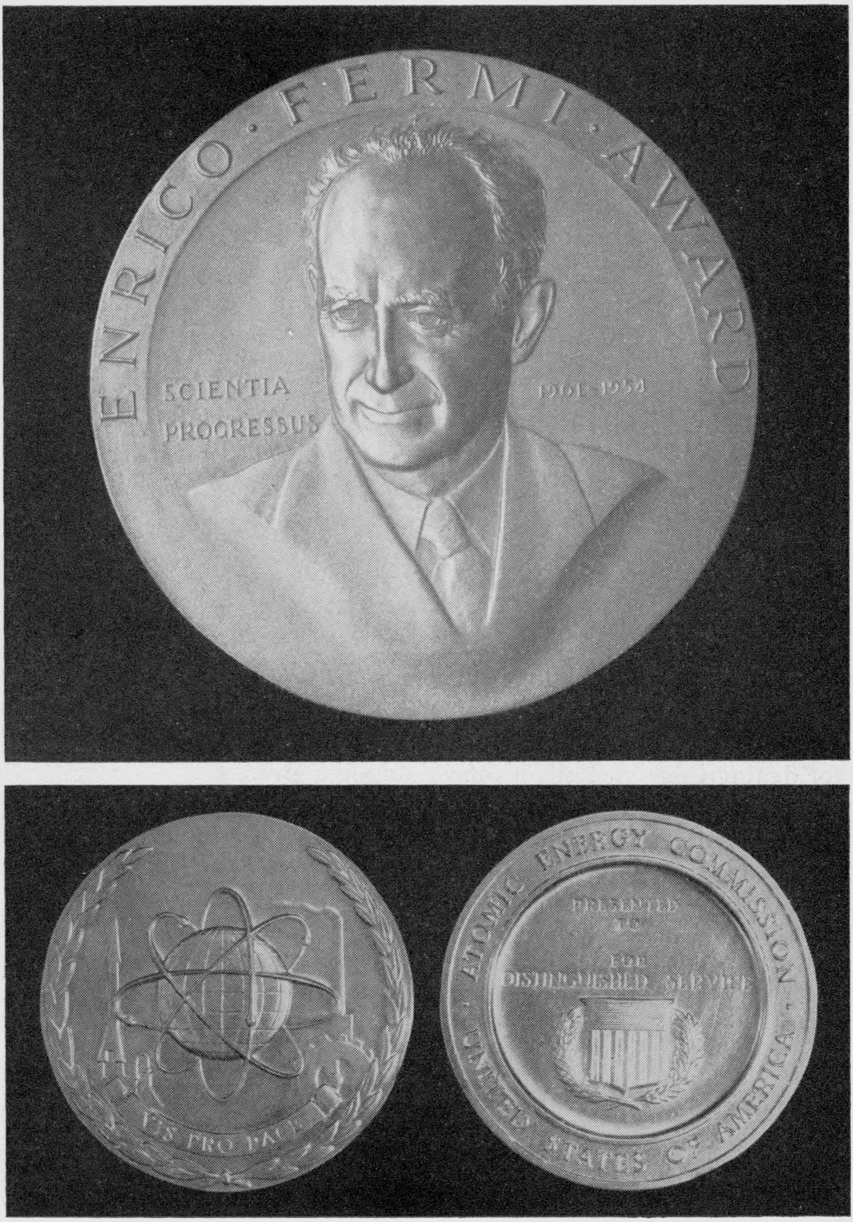
Increased activity took place in the suggestion and superior performance award program, as shown by the following figures for fiscal years ended June 30, 1955, and June 30, 1956:

	Suggestions Made	*Suggestions Adopted*	*Superior Performance Awards*	*Special Act or Service Awards*
1955	85	4	15	0
1956	342	45	77	2

Cash Awards

	FY 1955	*FY 1956*
Suggestions	$665	$2, 305
Superior Performance	1, 825	23, 260
Special Act or Service	----------	900
Total	$2, 490	$26, 465

Net first-year dollar benefits from suggestions were $49,824.46 for 1955, and $234,703.44 for 1956.



Awards. Medals presented by the Atomic Energy Commission: Above is the Enrico Fermi Medal, presented with the annual Enrico Fermi $50,000 award for an especially meritorious contribution to the development, control, and use of atomic energy. Below is the gold Commission's Distinguished Service Medal, the first of which were presented in special ceremonies November 14. The silver Outstanding Service Medals are identical in appearance except for the change in wording to designate type of award.

Principal Personnel Changes

The President appointed on October 26, 1956, three new members of the General Advisory Committee of the Atomic Energy Commission, to hold the posts for 6 years, expiring August 1, 1962.

The three new members are Dr. T. Keith Glennan, president of Case Institute, Cleveland, Ohio, and former Atomic Energy Commissioner; Dr. Edward Teller, an associate director of University of California Radiation Laboratory, Berkeley, California, and Robert E. Wilson, President, Standard Oil of Indiana, Chicago, Ill. They were sworn in by Atomic Energy Commission Chairman Lewis L. Strauss in his office on October 29. Dr. Warren C. Johnson was named chairman of the committee.

The new members replace Dr. I. I. Rabi, retiring chairman, who was one of the original General Advisory Committee, Eger V. Murphree and Dr. Walter G. Whitman, whose terms had expired.

Organizational Development

An area office was established by the Atomic Energy Commission at Los Angeles, California, primarily to administer contracts with the North American Aviation Co. The office reports to the San Francisco Operations Office, Oakland, Calif.

The Burlington, Iowa, Area Office was established to work with Army Ordnance and the Mason and Hanger-Silas Mason Co. in the performance of appropriate Commission functions related to the weapons program. The Burlington Office reports to the Albuquerque Operations Office, Albuquerque, N. Mex.

Representatives abroad. Establishment of offices of Commission representatives in certain foreign countries is reported in the section dealing with International Activities.

SAFETY AND FIRE PROTECTION

Industrial Safety

All frequency rates (personal injuries per million man-hours) for the 11-month period ended November 30, 1956, showed an increase over the exceptionally low rates for the same period last year:

	Nov. 30, 1955	*Nov. 30, 1956*
Production, Research, Services	1. 62	1. 97
Construction	3. 23	5. 28
Federal Employees	2. 18	1. 80

These rates compare favorably with the National Safety Council overall industrial rate of 6.96 published for 1955, the latest available figures.

From January 1 through September 30, 1956, 7 fatal accidents occurred in Commission activities; 1 involved a fall, 1 an electrocution, 1 a motor vehicle, and 4 resulted from explosions of which 3 involved metal reactions.

Fire, Explosion, and Property Damage

The total property damage losses due to fires and explosions during the first 11 months of 1956 were estimated at $3.7 million. This loss is far below private industrial property loss expectancy for an amount of property equivalent in evaluation to that of Commission-owned facilities.

The fire loss for the fiscal year ending June 30, 1957, will be increased by approximately $3.5 million because of a fire which partly destroyed one of the smaller buildings at the Paducah Gaseous Diffusion Plant on November 11, 1956. Activities in the building were partly resumed next day; repairs are being made. The original cost of the building was about $14 million.

Radiation Incidents

"A Summary of Accidents and Incidents Involving Radiation in Atomic Energy Activities, June 1945 through December 1955," TID-5360, was published during this reporting period, and is available from the Office of Technical Services, Department of Commerce, Washington 25, D. C. Details are reported in chapter V of the special section on Radiation Safety in Atomic Energy Activities included in this report.

Accident Reporting

Definitions of injuries or overexposures to radiation, similar to the definitions in the American Standard Method of Recording and Measuring Work Injury Experience, Z16.1–1954, were adopted. This action will improve reporting procedures.

Research

A research program has been initiated to resolve some of the unknown factors involved in the pyrophoric and explosive properties of a number of metals widely used in the atomic energy program.

Training and Education

In order to improve the understanding of problems related to radiation in fire fighting by public fire departments, arrangements have been made to inform teachers and instructors in State fire schools and large municipal firefighting groups.

Safety Performance Awards

Eleven Commission Awards of Merit and five Awards of Honor were made to contractors, during the period January 1 through September 20, 1956. On July 12, 1956, the National Safety Council Award of Honor was presented to the Commission in recognition of the improvements in the industrial safety performance of the Commission and its contractors during the year 1955.

EMPLOYMENT, EARNINGS, LABOR-MANAGEMENT

Employment Increases

Total employment increased in the last half of 1956 from 110,143 in June to 115,241 in November. Contractor employment increased to 108,605 during the period while Commission employment remained level at 6,636.

Operating contractor employment continued upward and the November 1956 figure of 93,476 was more than double the strength 6 years ago. The ratio of operating contractor to Commission personnel rose from 8 to 1 to 14 to 1 over this same 6-year period. The increase in recent months is chiefly related to expansion of reactor projects. Other research and development activities account for the remainder of this year's rise.

Following a plateau during the first half of 1956, construction and design employment rose by about 1,500, or 11 percent, numbering 15,043 in October. The greatest activity in the second 6 months of this year was at Savannah River, Hanford, Oak Ridge, St. Louis, Idaho Falls, and Pittsburgh.

Earnings of Atomic Energy Workers

Gross earnings of production and other manual workers employed by the Commission's operating contractors have increased 3.7 percent during 1956 to an average of $2.49 an hour in October. Earnings among atomic energy contractor employees continued to average between the two industries selected for their similarity in process and equipment. During the period earnings of production workers in products of petroleum and coal increased 7.1 percent to $2.57 and those for the industrial inorganic chemicals industry increased 4.4 percent to $2.36.

Labor-Management Relations Panel

The Labor-Management Relations Panel intervened in five labor-management disputes during the 6-month period between June 1 and November 30, 1956. Two of these involved construction contractors and building trades unions.

In a dispute between Hanford construction contractors and Teamsters, Operating Engineers, and Cement Finishers, which was reported in the Twentieth Semiannual Report (p. 133), the panel issued recommendations on July 12. The dispute concerned whether or not to abandon special project conditions which had been in effect for several years and to follow area practices since construction had decreased. The panel recommended that the parties continue isolation payments and free transportation for the remaining period of the area agreements.

Following objections to the recommendations by the Associated General Contractors who head bargaining rights for Hanford contractors, the panel held further hearings on August 18, 19, and 20 in Spokane, Wash., and later the parties were asked to maintain status quo for one year. Status quo in this case was interpreted to mean continuation of the travel conditions of the project agreement. Although no formal agreement was entered into, the parties returned to work under conditions as recommended by the panel.

A second construction dispute at Hanford, this one involving carpenters and laborers, was settled by a panel recommendation issued during its hearings on August 20. This dispute involved applicability of building, or heavy construction and highway, rates under the parties' area agreement. In its recommendation the panel interpreted the agreement to mean building construction rates.

The three disputes in Commission operations involved: (1) Sandia Corp., a subsidiary of Western Electric Co., at Albuquerque and three unions representing production and maintenance employees, office and clerical workers, and guards; (2) ACF Industries, Inc., and the International Association of Machinists, AFL–CIO, representing ACFI production and maintenance workers at the Commission's South Albuquerque Works; and (3) ACF Industries, Inc. at Buffalo and the United Steelworkers, representing office and clerical employees.

The Sandia dispute involved failure of the parties to agree on wages under their contracts which were opened under wage reopener provisions. The three contracts, one involving Atomic Projects and Production Workers, Metal Trades Council, AFL–CIO, the second, Office Employees' International Union, AFL–CIO, and the third, International Guards Union of America, expire in 1957.

After meeting separately with the various parties to the disputes, the panel issued recommendations on August 14 which were accepted by the parties as a basis for settlement. On August 16, following similar discussions with ACF and the International Association of Machinists, the panel issued recommendations in the second dispute. These were also accepted by the parties as a basis for settlement. Neither of these disputes involved a work stoppage.

The dispute at the ACF–Buffalo plant arose out of the inability of the parties to agree on the terms of an initial collective bargaining agreement following certification of the union to represent office and clerical employees. The office and clerical workers walked out on June 29 and established a picket line. The production and maintenance workers, who were also represented by the Steelworkers, respected the picket line and the plant was closed down from June 29 until August 16 except for 2 days immediately preceding and following the July 4 holiday when there were no picket lines. The plant would normally have been closed down for vacations during the week of July 9. On August 16, work was resumed in accordance with a panel request that the status quo be maintained while the case was being considered. On August 21, before the panel had an opportunity to hold hearings, the parties gave notice that they had come to agreement on all issues and that a dispute no longer existed.

The lengthy work stoppages on Hanford construction and at the ACF–Buffalo plant resulting in sizable increases in the percentage of time lost as a result of work stoppages during 1956. During the first 11 months of 1956, the time lost as compared to scheduled hours in the Commission construction program was 2.9 percent. This compared with 0.9 percent in 1955 and 2.2 percent in 1954 during comparable periods. In the operation of atomic energy plants, time lost during the first 11 months as a percentage of scheduled working time was 0.2 percent. This is twice as great as the figure for the same period in 1955 and 1954.

Transfer of labor disputes panel. The Atomic Energy Labor-Management Relations Panel, located within the Federal Mediation and Conciliation Service for the last 3 years was transferred to the Atomic Energy Commission, effective July 1, 1956. This change was recommended by the Service's Director, the Chairman of the Commission, and the Chairman of the Panel, and was made with the approval of the President. The panel membership remains the same: Cyrus S. Ching, Chairman; The Rev. Leo C. Brown, S. J.; Vice Adm. O. S. Colclough, USN, Retired; Thomas W. Holland; Arthur M. Ross; and Russell A. Smith. Members are selected by the President but serve under contract with the Commission.

Patents

The portfolio of Commission-owned patents available for licensing on a nonexclusive, royalty-free basis, including 111 added during this reporting period, now totals some 1100 (see Appendix 5). About 580 nonexclusive licenses have been accorded to private industry.

On September 24, the Governments of the United States, the United Kingdom and Canada entered into an interchange agreement as respects inventions and discoveries in the atomic energy field on which patents were held or applied for by one Government in one or both of the other countries as of November 15, 1955. Each Government acquired all rights in the inventions in its own country and assigned to the other Governments the rights owned by it in the other two countries. Each assigning Government retained a nonexclusive license for its own governmental purposes, and for purposes of mutual defense, in the other two countries.

The agreement permits the United States Government to grant royalty-free licenses to American industry with respect to the United States patents and patent applications acquired from the United Kingdom and Canadian Governments. At the same time it permits the United Kingdom and Canadian Governments to follow their domestic policies as respects patents in their countries. A nondiscrimination provision in the agreement binds each Government to grant licenses to nationals of the other governments on the same terms and conditions as it accords licenses to its own nationals.

The agreement is deemed to be of particular benefit to the growing American atomic energy industry by eliminating the question of patent infringement as respects United Kingdom and Canadian inventions patented in the United States and assigned to the United States Government. Furthermore, the nondiscrimination provision prohibits discrimination against United States industry by United Kingdom and Canadian Governments as respects the issuance of licenses on United Kingdom and Canadian patents and patent applications under the agreement.

The inventions embraced within the agreement fall into two classes: (1) inventions which arose from wartime cooperation among the three Governments in which the rights have been held in trust pending final settlement; and (2) inventions within the cooperative arrangements which were independently developed and owned by one government. The date of November 15, 1955, was selected as the terminal date for the latter group of inventions since that date ended the period before which atomic energy operations were largely a government monopoly in each of the three countries. The agreement does not commit the governments as respects future inventions, nor as respects inventions made under Agreements for Cooperation negotiated between the United States and a number of friendly nations (see International Activities).

The power Agreements for Cooperation with other countries have patent provisions which provide for acquisition from signatory countries of rights in inventions resulting from the exchange of classified information. These are somewhat similar to the provisions of the Tripartite Agreement reported above. These agreements also have a nondiscrimination provision. The research agreements contain no patent provisions.

Detailed procedures were worked out with the United Kingdom and Canada for handling patent applications based on classified inventions which come within the purview of the United Kingdom and Canadian Agreements for Cooperation. Detailed procedures were being developed with other governments for handling of classified inventions resulting from the exchange of information under power bilateral agreements.

During the last 6 months, the number of patent applications referred to the Commission by the Commissioner of Patents under Sec. 151c of the Atomic Energy Act of 1954 has doubled.

Since January 1956, the Commission issued waivers of rights under Section 152 of the Act of 1954 as respects three general categories: (1) Inventions and discoveries made or conceived as a result of access to restricted data (the waiver was incorporated in Part 25 of Title 10, CFR, Section 25.3, issued on February 4, 1956); (2) Licenses issued by the Commission (the Opinion of the General Counsel was published as an interpretation in Title 10, CFR, Part 8 on March 2, 1956); and (3) Inventions and discoveries made as a result of use of materials sold, distributed or leased, or otherwise made available, including radioactive and stable isotopes and services sold or otherwise made available including irradiation services. (Final rules were published in the Federal Register in December 1956, as Part 83 of Title 10, CFR; the proposed rules were published on September 10, 1956.)

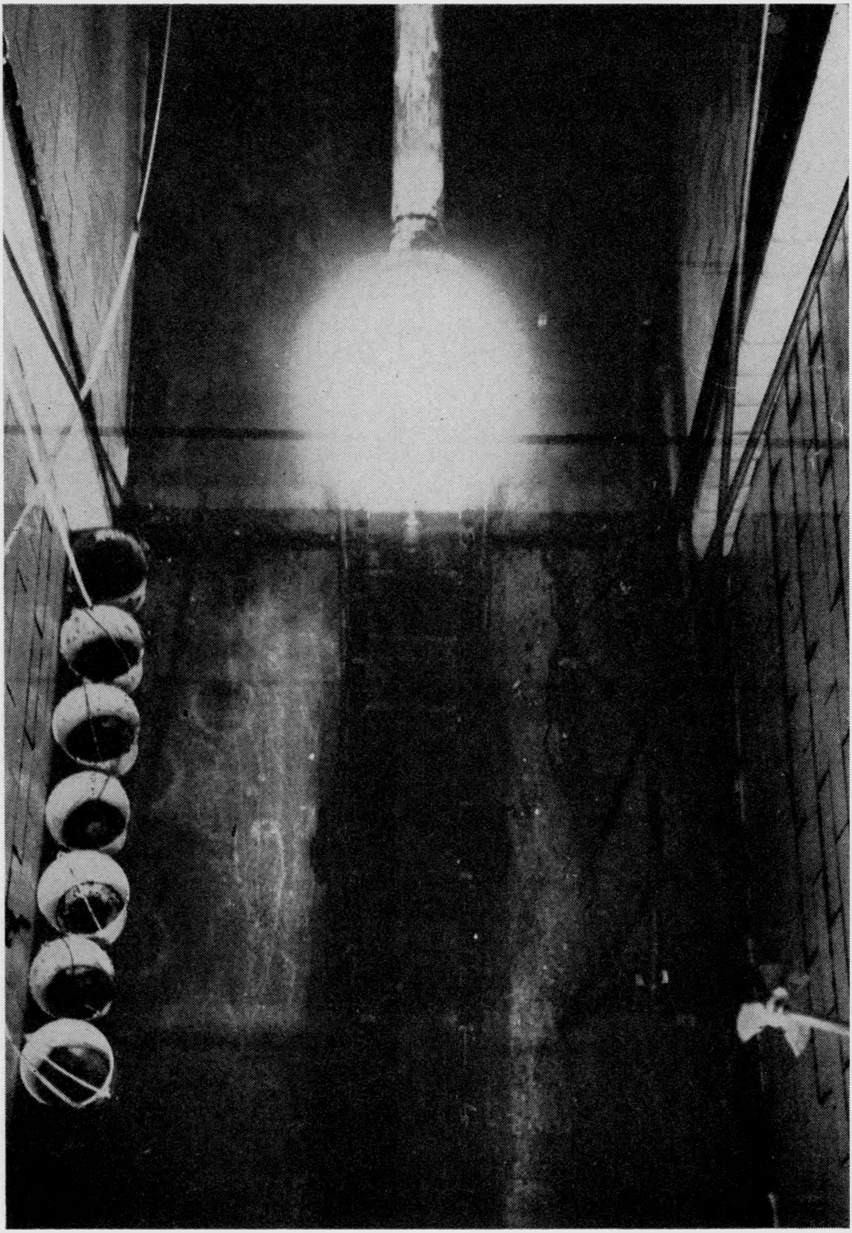
The Commission has pursued a policy of having contractors, when reporting inventions, indicate whether the contractor desires to file a United States or foreign patent application. If the contractor desires to file a United States application, the Commission has promptly notified the contractor to file a patent application. If no classified subject matter is involved, approval has been given to file foreign applications as the contractor deems advisable. Where restricted data is involved, the filing of a United States application has been authorized, provided the contractor complies with security requirements. A United States Patent Office Secrecy Order prohibiting dissemination of information on any such application is promptly issued.

Where restricted data is involved in the filing, the filing of foreign applications can be accomplished only where the subject matter falls within the scope of an Agreement for Cooperation. However, in these instances where contractors have indicated a desire to file on inventions falling within the scope of such an agreement, filings have been accomplished by the contractor under appropriate security safeguards, or the Commission, after determining that the subject matter was of sufficient value to warrant the filing, has proceeded to file the foreign application.

Part Two

Radiation Safety in Atomic Energy Activities

411053—57——9



Radiation. Under 20 feet of shielding water, a fuel element withdrawn from the Material Testing Reactor at the National Reactor Testing Station, Idaho, throws off violent radiation. The radiation itself is not visible, but the so-called Cerenkov effect, caused by the effects of radiation on the surrounding medium, is visible as a white blur in the photograph. The Cerenkov halo actually is a clear blue.

Radiation Safety in Atomic Energy Activities

A STAFF REPORT TO THE ATOMIC ENERGY COMMISSION

This special report was prepared at the direction of the Commission by the Divisions of Biology and Medicine, Civilian Application, Information Services, Inspection, Organization and Personnel, and Reactor Development, with the assistance of the Commission's field operations offices and a number of contractors operating Commission installations. The purpose was to bring together in one place the data, the policies, and the procedures, that apply to this important field of atomic energy activities for the information of the Congress. The resulting report is included in the Twenty-first Semiannual Report.

I

RADIATION HAZARDS AND THE COMMISSION'S ROLE

Encouraged under the Atomic Energy Act of 1954 to develop peaceful uses of atomic energy, private and public organizations throughout the country are undertaking to design, construct, and operate nuclear reactors for the generation of electricity, to perform testing and experimental functions, and to carry out other types of activities formerly reserved to the Federal Government. Greater numbers of engineering and research groups are undertaking experiments in support of reactor design and reactor safety, and helping develop other peaceful uses of atomic energy. All these activities involve placing increased quantities of radioactive materials, or special nuclear materials in more hands; in many cases, nuclear reactors will generate considerable additional quantities of radioactive material.

This wide participation is permitted only under Federal control. The Act of 1954 made the Atomic Energy Commission responsible for licensing, regulating, and inspecting all atomic activities other than certain ones performed under contract with the Commission and the Department of Defense. The Commission is charged with assuring that the common defense and security are safe-guarded, and that the public, including workers are protected against the hazards of nuclear radiation arising out of these programs. Under the Atomic Energy Act of 1946, the Commission exercised these same responsibilities over Federal installations and over the distribution and use of Federally produced radioisotopes for research, industrial, or medical activities. Before December 31, 1946, when the Commission took over, the Manhattan Engineer District, Corps of Engineers, U. S. Army, which was in charge of the atomic energy program beginning in 1943, had a similar responsibility.

In this special section of the Commission's Twenty-first Semiannual Report to the Congress, the Commission summarizes its record and experience in assuring radiation safety in its own operations.[1] It reports the steps it has taken to provide for the protection of the public, including workers against nuclear radiation in the expanding field of private and other atomic energy activities.

Nuclear radiation exists in nature and everyone is exposed to it throughout his life. This so-called natural background radiation comes from radioactive materials like radium which exist in the soil and from cosmic rays which descend from space. Many people also are exposed to X-rays in medical or dental work.

The nuclear radiations from atomic energy operations are generated in many steps of the Government's production chain, as well as in research. In the handling of raw materials, exposure to the radioactive gas, radon, has to be controlled; in the processing of uranium concentrates, the dust of uranium compounds is a possible hazard. Problems also arise from concentrations of fissionable uranium or plutonium which could, if improperly handled, initiate a chain reaction and throw off very powerful radiations. Plutonium and various other substances of importance in the atomic energy program are poisonous if allowed to enter the body. Problems arise also from the processing of materials which have been passed through reactors; from radioactive industrial wastes; and from the testing of atomic weapons. Many of these same problems arise with development of nuclear power by private, city, State, and cooperative organizations, or with industry's efforts to advance other peaceful uses of atomic energy.

Public hazards could arise from excessive releases of process gases; from plant or reactor ventilation which might contain radioactive gases and airborne radioactive material; from reactor coolants where these are released to the environment; from radioactive fall-out after weapons tests; from radioactive industrial wastes that are not stored;

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[1] A detailed report of protection methods was given in July 1950 in the Commission's Eighth Semiannual Report (January–June 1950).

and from miscellaneous contaminated materials—tools, machinery, clothing, etc.—from atomic energy installations. The safeguards taken by the Commission and its operating contractors have protected the public against these hazards.

The hazard of nuclear radiation arises from the fact that the various types of these radiations are capable in quantity of harming living things. Some radiations are thrown off from the fission of special nuclear materials in reactors or weapons tests. Others are emitted by unstable radioactive elements as they gradually decay toward stable conditions. (In the process known as "radioactive decay," they emit energetic particles or electromagnetic rays from their nuclei, or cores.) One type of nuclear radiation is the gamma ray, which is like the X-ray used in medical diagnosis and therapy except that generally, it is more powerful. Other radiations are nuclear particles such as neutrons, alpha and beta particles. Gamma rays may penetrate deeply within the body; so may neutrons, but neutrons are produced in quantity only in chain reactions or by the machines known as particle accelerators, or "atom-smashers." Gamma rays may be emitted in radioactive decay. The alpha and beta particles are dangerous chiefly if the substances emitting them manage to get inside the body. Beta particles also can cause severe skin burns if a beta-emitting material is allowed to remain on the skin, or over close to it, for a sufficient time.

All these radiations affect living things in much the same way: basically, the radiations have the power of disrupting the forces which hold together the molecules, such as proteins, that make up the body. One of the main consequences of the nuclear radiation, therefore, can be the death of the cells which contain the damaged molecules. For example, if enough radium were to lodge in the bones, the continual bombardment of the cells by alpha particles could cause tumors to form and have other deleterious effects. Large amounts of gamma rays or neutrons striking a person's entire body could cause damage to various organs and bodily functions. Severe damage could cause sickness or, in extreme cases, death.

The Commission, and the Manhattan Engineer District before it, have met the problems of safely handling radioactivity with such success that, during the 13 years since the atomic energy program began, radiation injuries to workers have been infrequent,[2] and the exposure of atomic energy workers usually does not exceed that they receive from such natural sources as radium in the earth and cosmic rays. Over 9 years and more of Commission operation, the record of routine operations is that 99.4 percent of nearly 200,000 workers of the Commission's 32 principal contractors have averaged an exposure of less than one-third the amount of radiation allowed by strict safety

[2] See Chapter V for details.

standards. In accidents, only two persons have been killed by radiation in the atomic energy program, and these deaths occurred in 1945 and 1946. In the 13 years the program has existed, a total of 69 persons in the Federal program (including the two who died) has received overexposures in accidents and some of these were minor. Eight workers among the 69 suffered skin burns; 8 others were exposed in the criticality accidents that killed the 2 workers in 1945 and 1946. Of the remaining 51 overexposures, more than half—28 in all—occurred in fall-out from a weapons test. Among these, 11 suffered skin injuries.[3]

During that same period, no member of the public is known to have suffered an overexposure to radiation as a result of living near atomic energy production or laboratory centers. No significant exposure of the public is known to have occurred as a result of weapons tests at the Nevada Test Site. Tests at Eniwetok Proving Ground in the Pacific did cause overexposure and radiation injuries in the Marshall Islands.

Unexpected weather conditions after a weapons test on March 1, 1954, at the Eniwetok Proving Ground caused heavy radioactive fall-out on four Pacific Islands.[4] In this same test, 23 members of a Japanese fishing boat, the *Fortunate Dragon*, were exposed by fall-out. In the island fall-out, 28 members of the Armed Forces (included in 69 exposures listed earlier) received 78 roentgens[5] on Rongerik Island. On three other atolls, 239 Marshall Islanders were exposed: 157 to 14 roentgens on Utirik; 18 to 69 roentgens on Ailinginae; 64 to 175 roentgens on Rongelap. Ninety percent of the islanders from Ailinginae and Rongelap developed skin injuries, compared to 40 percent among the service men on Rongerik. The Utirik people did not develop any skin injuries that could be attributed to irradiation. After 2 years, residual findings were minimal for all of those exposed to this fall-out accident except for four cases which showed various amounts of skin damage.

The total record of radiation safety in atomic energy operations is believed to be without parallel in industrial history. In this industry, the most careful precautions to protect the public and workers were taken from the first, and thorough study of its problems con-

[3] These occupational incidents, through December 31, 1955, are reported in "A Summary of Accidents and Incidents Involving Radiation in Atomic Energy Activities," by D. F. Hayes; Office of Technical Services, Department of Commerce, Washington 25, D. C.; 45 cents.

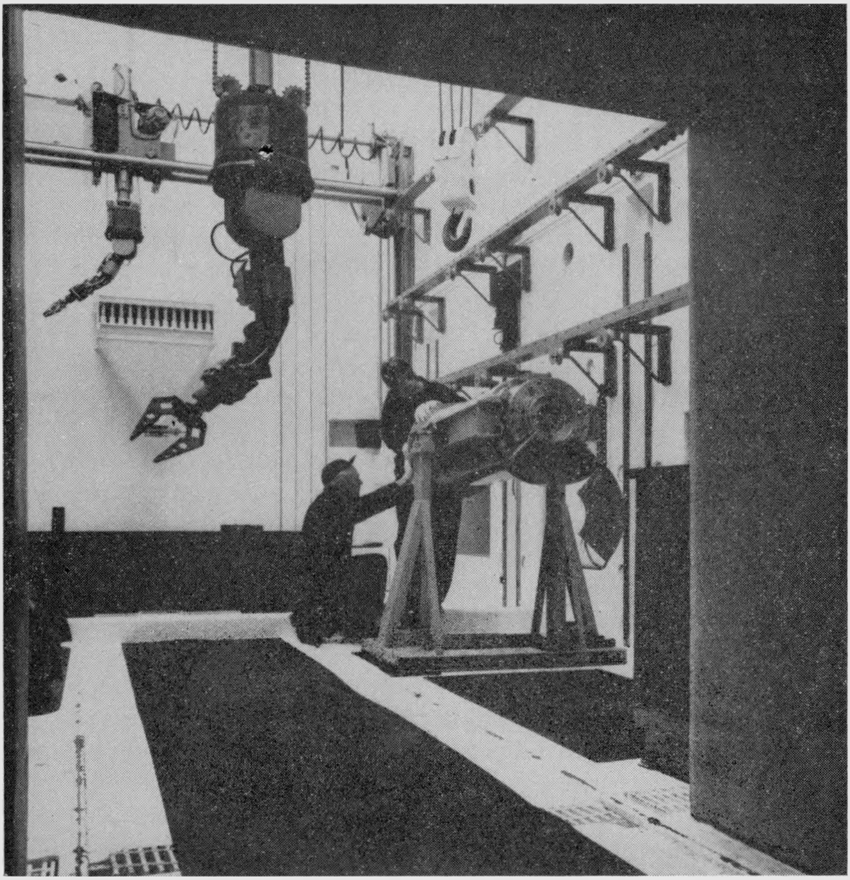
[4] Full details are given in "Some Effects of Ionizing Radiation on Human Beings," by E. P. Cronkite, V. P. Bond, and C. L. Dunham; Superintendent of Documents, Government Printing Office, Washington 25, D. C.: $1.25.

[5] The roentgen is a unit of radiation measurement, which with other units similarly used is explained in detail in the later section on Standards of Radiation Exposure. Workers in atomic energy projects may receive the equivalent of 15 roentgens a year, or 3.9 roentgens a quarter, without exceeding permissible levels.

tinues. The potential hazards faced during the wartime program by the scientists, engineers, and other workers, were completely without precedent. The radiation produced by nuclear reactors might have proved unmanageable. Many experienced men in the program anticipated great difficulties. The problem was complicated by the fact that men might be receiving a fatal exposure to radiation without knowing it, since the unaided human senses could not detect radiation. The materials that were processed were as radioactive as tons of radium—a material usually handled only in thousandth parts of a gram, and then only with extreme caution. Many materials issuing from reactors never had been known to man in the form, and in the quantities, generated there. Knowledge about how they would behave, and the toxic threat they posed, was extremely fragmentary. Yet they were handled successfully, as the record shows.

The Manhattan Engineer District, the Commission, and their contractors, met the potential hazards with a strict take-no-chances caution at every point. The levels of exposure to radiation which workers might be allowed to undergo were set at a point which people experienced with medical and experimental radiation—chiefly with X-rays and radium—believed would be acceptable. The machinery of plants, the industrial management, the discipline and supervision of all activities, were all designed to prevent unnecessary radiation exposure of workers or the public, and to assure that those most exposed would receive much less than the amount of radiation believed to cause detectable injury.

To limit exposure to radiation, various safeguards have been used since the beginning of the atomic energy program. Massive shielding around all sources of highly penetrating radiation enables workers to operate within a few feet or yards of the chain reactions within reactors. Where massive shielding is not possible, workers are protected by using remote-control instruments, or by keeping a safe distance from a radioactive source. Limits may be set on the time a worker may stay in an area where radioactivity exists, or combinations of these various methods may be used. The danger of getting radioactive material into the body by inhalation is controlled by ventilation and air-cleaning that keeps concentrations of harmful gases, vapors, and dusts, out of the air. This is reinforced by strict "housekeeping" to prevent or limit radioactive surface contaminations. Housekeeping, and personal hygiene and discipline reduces the possibility of ingesting harmful materials. As necessary, respirators, dust-masks, and other protective clothing may be worn. Workers are trained to respect radiation and to maintain a disciplined handling of any radiation source. Day-by-day records of exposures are measured by instruments and radiation-sensitive films worn by workers, and period-



Protection. Two key methods of protecting workers against radiation: massive shielding, and tools for handling radioactive materials from a distance, are shown here. At the National Reactor Testing Station, Idaho, a "hot cell" has concrete walls seven feet thick. The general purpose manipulators—the clawlike instrument pendent from a motor in the center of the photograph—are operated from outside the cell.

ical medical examinations help to assure that radiation exposure standards are maintained.

The release of industrial wastes is strictly regulated and regularly monitored. Many highly radioactive wastes are stored indefinitely. Under rigid restrictions, diluted or mildly radioactive materials may be released under controlled conditions to the environment. Protection of the environment is guided by automatic monitoring of wastes, and of air and water near installations, supplemented by tests of soils, vegetation, wild life, and other useful indicators of radiation contamination in the environment.

The contractors of Manhattan District and the Commission who, from the first, have carried out atomic energy operations deserve primary credit for the methods of radiation control that have been worked out, and for their successful administration. The necessity of protection against radiation, as established by the Manhattan district and its contractors during the war, was emphasized in the first Atomic Energy Act (1946), which after the war established civilian control over atomic energy activities by the Atomic Energy Commission. The Atomic Energy Act of 1954 which authorized licensing and non-Federal ownership of materials and facilities continued this insistence on radiation safety, making the point in section after section of the Act.[6]

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[6] Typical of provisions of the Atomic Energy Act of 1954 dealing with health and safety in the conduct and management of atomic energy activities are the following excerpts from the act:

SEC. 2. FINDINGS.—

* * * * * * *

b. In permitting the property of the United States to be used by others, such use must be regulated * * * to protect the health and safety of the public.

d. The processing and utilization of source, byproduct, and special nuclear material must be regulated * * * to protect the health and safety of the public.

e. Source and special nuclear material, production facilities, and utilization facilities are affected with the public interest, and regulation by the United States of the production and utilization of atomic energy and of the facilities used in connection therewith is necessary * * * to protect the health and safety of the public.

SEC. 3. PURPOSE.—It is the purpose of this Act to effectuate the policies set forth above by providing for—

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d. A program to encourage widespread participation in the development and utilization of atomic energy for peaceful purposes to the maximum extent consistent with * * * the health and safety of the public.

SEC. 31. RESEARCH ASSISTANCE.—

a. The Commission is directed to exercise its powers in such manner as to insure the continued conduct of research and development activities in the fields specified below, by private or public institutions of persons, and to assist in the acquisition of an ever-expanding fund of theoretical and practical knowledge in such fields. To this end the Commission is authorized and directed to make arrangements (including contracts, agreements, and loans) for the conduct of research and development activities relating to—

* * * * * * *

(5) The protection of health and the promotion of safety during research and production activities.

* * * * * * *

c. The arrangements made pursuant to this section shall contain such provisions (1) to protect health, (2) to minimize danger to life or property. * * *

SEC. 41. OWNERSHIP AND OPERATION OF PRODUCTION FACILITIES.—

* * * * * * *

b. Operation of the Commission's Production Facilities.— * * * Any contract entered into under this section shall contain provisions * * * (2) obligating the contractor * * * (C) to comply with all safety * * * regulations which may be prescribed by the Commission.

SEC. 53. DOMESTIC DISTRIBUTION OF SPECIAL NUCLEAR MATERIAL.—

b. The Commission shall establish, by rule, minimum criteria, for the issuance of specific or general licenses for the distribution of special nuclear material depending upon the degree of importance to the common defense and security or to the health and safety of the public. * * *

* * * * * * *

e. Each license issued pursuant to this section shall contain and be subject to the following conditions—

* * * * * * *

(7) special nuclear material shall be distributed only pursuant to such safety standards as may be established by rule of the Commission to protect health and to minimize danger to life or property; * * * (Continued on next page.)

The Commission requires that licensed activities conform to standards for protection against radiation based on Federal experience throughout 10 years of Commission operations. It prepared regulations and set up enforcement machinery which it believes will assure radiation protection while allowing management freedom of action for efficient operation (see Chapter II, Radiation Safeguards for Licensed Activities).

To improve safety in future design of Government reactors, and to assist Commission administrators in licensing, regulation, and inspection, as well as to advance the knowledge available to the public and to interested industry, the Commission is carrying out a broadening series of experiments and research programs. One group of programs is dedicated to reactor safety, in design, in instrumentation, in controls (see Chapter III, Safety Factors in Reactor Design and Operation). The Commission's program of studies on handling, processing, and disposing of radioactive wastes will reinforce national efforts on radiation safety; it is designed to hold to a minimum the possibilities of environmental hazards (see Chapter IV, Radioactive Wastes). Chapter V, Radiation Protection in Commission Activities, reports on how the Commission and its contractors ad-

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SEC. 63. DOMESTIC DISTRIBUTION OF SOURCE MATERIAL.—

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b. The Commission shall establish, by rule, minimum criteria for the issuance of specific or general licenses for the distribution of source material depending upon the degree of importance to the common defense and security or to the health and safety of the public. * * *

SEC. 81. DOMESTIC DISTRIBUTION.— * * * The Commission shall not permit the distribution of any byproduct material to any licensee, and shall recall or order the recall of any distributed material from any licensee, who is not equipped to observe or who fails to observe such safety standards to protect health as may be established by the Commission. * * *

SEC. 103. COMMERCIAL LICENSES.—

* * * * * * *

b. The Commission shall issue such licenses on a nonexclusive basis to persons applying therefor * * * (2) who are equipped to observe and who agree to observe such safety standards to protect health and to minimize danger to life or property as the Commission may by rule establish. * * *

SEC. 104. MEDICAL THERAPY AND RESEARCH AND DEVELOPMENT.—

* * * * * * *

b. The Commission is authorized to issue licenses to persons applying therefor for utilization and production facilities involved in the conduct of research and development activities leading to the demonstration of the practical value of such facilities for industrial or commercial purposes. In issuing licenses under this subsection, the Commission shall impose the minimum amount of such regulations and terms of license as will permit the Commission to fulfill its obligations under this Act to * * * protect the health and safety of the public. * * *

SEC. 161. GENERAL PROVISIONS.—In the performance of its functions the Commission is authorized to—

* * * * * * *

b. Establish by rule, regulation, or order, such standards and instructions to govern the possession and use of special nuclear material, source material, and byproduct material as the Commission may deem necessary or desirable to * * * protect health or to minimize danger to life or property;

i. Prescribe such regulations or orders as it may deem necessary * * * (3) to govern any activity authorized pursuant to this Act, including standards and restrictions governing the design, location, and operation of facilities used in the conduct of such activity, in order to protect health and to minimize danger to life or property;

minister radiation safety and give details of the record of achievements in controlling radiation exposures.

To gain greater knowledge about the effects of radiation upon people, the hazards from different radioactive materials, the tolerance levels for various forms and compounds of radioactive materials, and the treatment of radiation injuries, the Commission is continuing its comprehensive programs of biological and medical research (see Chapter VI, Research on Radiation Effects and Treatments). Studies are carried out not only in Federal laboratories and installations but also through contracts in research hospitals, universities, and other scientific institutions throughout the country. These and other contracts for research on radiation safety and on handling radioactive wastes are periodically reported to the Congress. The current list is contained in Appendix 7. Classified and unclassified information generated in these programs is circulated as appropriate through professional and scientific journals, or through the Commission's own publishing and distributing activities.

Research through contracts totals about $8.8 million a year for biology and medicine projects, and an additional $22 million is expended in general support of national atomic energy laboratories and special university projects in the biology and medicine field. While not all this expenditure goes for research which will contribute to radiation safety, either through better understanding of effects, prevention, or treatment of injuries, by far the major portion of the funds does go for these purposes. In the field of reactor safety, expenditures are increasing as experiments are undertaken to develop new and economical methods of generating power. In the current fiscal year, ending June 30, 1957, expenditure of $6 million for reactor safety research has been scheduled. Waste disposal takes a portion of the biochemical research budget, and, as sanitary engineering in the reactor program, was at a level of nearly $1.5 million during fiscal 1957, with another $900,000 for studies of waste treatment systems which might reduce storage requirements and costs.

The Commission believes that the record of radiation safety in Federal activities achieved by the Manhattan Engineer District, the Atomic Energy Commission, and the operating contractors is one in which the people of the United States may well take pride. The effort of the Commission is to assure continued safety in its own activities, and in those it will license, regulate, and inspect. The goal is to limit radiation exposure to acceptable limits, to prevent accidents and to take such steps, that, if in spite of all precautions, accidents should occur, the unfavorable results are minor.

II

RADIATION SAFEGUARDS FOR LICENSED ACTIVITIES

Under the Atomic Energy Act of 1954, private individuals and organizations and non-Federal public organizations, such as those of cities, states and cooperative groups, as well as Federal agencies other than the Commission may own and operate nuclear facilities and possess and use nuclear material and otherwise engage in nonmilitary uses of atomic energy. In laying the statutory groundwork for a private atomic energy industry, the Congress gave the Atomic Energy Commission responsibility for licensing, regulating, and inspecting these activities in the interest of the common defense and security and to protect the public health and safety. The emphasis in this special report is on protecting health and safety.

The regulation of the licensed atomic energy industry during its formative period posed a unique problem. The Commission possesses wide experience, of course, in coping with radiation in its own industrial and research installations. It has licensed the milling and manufacturing of source materials, and the use of radioisotopes and source materials for research, industrial, and other purposes throughout its history. The problem was to convert this experience into an effective pattern of licensing, regulation, and inspection during the formative period of the private industry, instead of permitting form and methods of enforcement to grow out of industrial experience.

In meeting the problem, the Commission determined to avoid a rigid pattern of licensing and regulation that might in practice prove unworkable or excessive and, instead, proposed to seek a maximum feasible degree of flexibility in its controls.

The Commission believes that its regulations, as issued, adhere to this basic principle—that within the limits of assuring protection of public health and safety, they do not impose unnecessary restrictions upon private participation in the development of the civilian uses of atomic energy, or unnecessarily interfere with management practices. Too, enforcement of the regulations is believed to be practical.

Six basic regulations designed to protect the health and safety of the public have been put into effect:

10 CFR Part 20—Standards for Protection Against Radiation, effective February 28, 1957.

10 CFR Part 30—Licensing of Byproduct Material, effective February 10, 1956.
10 CFR Part 40—Control of Source Material, effective March 31, 1947, and amended from time to time.
10 CFR Part 50—Licensing of Production and Utilization Facilities, effective February 18, 1956.
10 CFR Part 55—Operators' Licenses, effective February 3, 1956.
10 CFR Part 70—Special Nuclear Materials Regulations, effective March 4, 1956.

These regulations prescribe such things as the information which must be submitted by applicants for licenses; the criteria for radiation protection; the criteria for approval or disapproval of licenses; rules respecting the transfer of licensed materials; record-keeping requirements; and rules relating to the amendment, modification, suspension, or revocation of licenses. The text of these regulations has been published in the Federal Register and in the Semiannual Reports.[7]

Basically, the regulations make such requirements as:

a) Each licensee or his staff must have suitable training or experience to possess and use the material or facility safely for the purpose for which it is licensed.
b) Equipment and facilities of each licensee must be appropriate to protect health and minimize danger to life and property.
c) The location of the proposed activity must be suitable for the purpose.
d) The material or facility may be used only for a purpose stated in the license.
e) The material or facility may not be transferred except to persons authorized to receive it.

Because of the complexity and diversity of technical problems the Commission's regulations do not spell out precise requirements as to the kinds of training or experience, or equipment and facilities, which licensees must have. The general health and safety regulation—10 CFR Part 20 "Standards for Protection Against Radiation"—applies to all persons who receive, possess, use, or transfer source material, special nuclear material, or byproduct material (radioisotopes) under a general or specific license from the Commission. It establishes maximum limits on radiation in two categories: the permissible limits for exposure to external radiation which the licensee may allow for workers in areas under his control, and the maximum permissible concentrations of radioactive materials which a licensee may release

[7] See especially Appendix 7, Twentieth Semiannual Report (January–June 1956).

into the environment or areas not controlled by him. Other provisions prescribe requirements for personnel monitoring, protective equipment, caution signs and signals, waste disposal, storage of licensed material, instruction of personnel on safe procedures for handling the material, and records and reports.

The basic standards of the radiation protection regulations are designed to conform generally with the Commission's experience in its own operations, and with the recommendations of recognized technical authorities. They take into consideration the latest knowledge of the biological effects of radiation, and are subject to change as new data or conditions develop.

The regulation on standards for protection against radiation, like other new regulations, was initially published in proposed form in the *Federal Register* on July 16, 1955. After comments were received, from the general public from the Advisory Committee of State Officials with whom two conferences were held, from State health and labor departments, and other interested groups, the regulation was published in the *Federal Register* on January 29, 1957, to go into effect 30 days after publication.

Safety Evaluation in Licensing Reactors

Organization for Evaluation

The safe operation of nuclear reactors and associated facilities has been of paramount importance throughout the history of the Federal atomic energy program. During the first year the responsibility of the Atomic Energy Commission—the Commission took over December 31, 1946—the Commission determined to reinforce the safety evaluations of its own technical staff by drawing upon the experience and judgment of outstanding scientists and engineers in private enterprise and universities. Accordingly, in June 1947, it established a Reactor Safeguard Committee to advise with the Commission, through the General Manager, in reviewing, analyzing, and evaluating the hazards of each proposed new reactor and associated facilities, and of significant modifications of existing reactors and facilities.

Late in 1950, the Commission established an additional advisory committee, the Industrial Committee on Reactor Location Problems, which in 1951 undertook to study sites of Government reactors and to evaluate environmental factors of reactor hazards. In July 1953, the two committees were combined into the Advisory Committee on Reactor Safeguards.[8] This committee, like its two predecessors, has given invaluable service in the field of reactor safety.

[8] P. 27, Fifteenth Semiannual Report (July–December 1953), see Appendix 2 for membership.

With the advent of a licensed atomic energy industry, safety evaluation of an increasing number and variety of proposed reactors and other nuclear facilities became necessary. In organizing to meet these enlarged responsibilities, the Commission established in April 1955 a Reactor Hazards Evaluation Staff as a part of the General Manager's Office. In October of that year, in recognition of the vital part that hazards evaluation would play in licensing, the staff and its responsibilities were transferred to the Division of Civilian Application which administers the licensing program for the Commission. The staff, composed of experienced nuclear physicists and engineers, and members versed in other branches of science and engineering pertinent to the nuclear industry, reviews and analyzes proposed design and operating procedures of all Federal or non-Federal projects. Their advice and recommendations provide assistance to the Division of Civilian Application in evaluating a project to determine whether or not it can operate at a proposed location without undue risk to public health or safety.

Process of Reactor Safety Evaluations

The accidental release of the radioactive materials contained in a nuclear reactor could constitute a hazard to public health and safety. The primary purpose of the Commission's hazard evaluation procedure is to assure that the probabilities of accidentally releasing this material are kept to an acceptable minimum.

Each applicant for a permit to construct a nuclear reactor is required to provide, to the Commission's satisfaction, reasonable assurance that the proposed reactor can be constructed and operated at the selected site without undue risk to public health and safety, either from accidental release or from routine operations.

Upon completion of construction, the applicant must satisfy the Commission that issuance of a license to operate the facility will not be inimical to the health and safety of the public, and that the reactor can be operated without undue risk to the health and safety of the public.

Ultimately, the Commission hopes to develop detailed standards, codes, and regulations, which will make it possible for the designer of a nuclear reactor to know that, by incorporating certain design features, establishing certain relationships between his location and the containment plan of his reactor, and following certain operating procedures, he will meet the Commission's safety requirements for a license. At present—while the industry is in the developmental stage and each reactor differs from others in important aspects—it is undesirable to issue as regulations anything more than general standards and guides for reactor safety.

Even with a unique design, public hazards from normal operations of a reactor are relatively easy to govern. In routine operations, the problems are chiefly those of governing the release to the environment of reactor coolants such as air or water in such a way as to avoid excessive concentrations of radioactive materials.

Determining the probability of a nuclear accident in a reactor is much more difficult. The present versatility of design is highly desirable at this time from the standpoint of advancing reactor technology, but reactor experience has not yet accumulated to the point where formulas for assured safety can be prepared for all cases, or where experts can judge with absolute certainty the possibilities and probabilities of a nuclear accident. The technology and experience gained through some 10 years of design, construction, and operation of nuclear reactors under Atomic Energy Commission direct control do provide a sound basis for judgments.

For these reasons, the Commission's licensing procedures require a thorough safety evaluation of each separate proposed reactor project. The question of whether or not a reactor license is granted is based to a large extent on the safety evaluation made by the scientists and engineers on the Commission's staff who study the detailed design specifications of a reactor, and its proposed operating procedures.

Working conferences and studies. Normally, the hazards evaluation of a project will begin with conferences at which the Commission's staff outlines for the license applicant the broad objectives of the reactor hazards evaluation process. These meetings may be held even before a formal application is prepared to help the applicant learn what he must do to qualify for a license.

Chief among the considerations which may be offered for the applicant's guidance are the following:

a) Responsibility for the safety of the reactor rests with the licensee; a license by the Commission in no way relives him of this responsibility.

b) The engineers and scientists of the license applicant must prepare a detailed hazard analysis of the proposed reactor.

c) Before any reactor, regardless of its size or intended use, may be licensed for operation, the Commission, through its detailed review and evaluation of design specifications and operating procedures and conditions submitted by the license applicant, must determine that there is reasonable assurance that operation will not endanger the health and safety of the public.

d) The evaluation of hazards will require a complete study of all aspects of the reactor and its operation to determine, on the basis of the best available information, what could possibly go wrong with the reactor and what steps are being taken to prevent an accident. For this purpose the applicant's engineers and scientists must critically review each phase of the reactor design and operating procedure both in itself and also in its relationship to the integrated whole. They must carefully consider the inherent nuclear, chemical, metallurgical, physical, and mechanical characteristics of the fuel, the moderator, the coolant, the neutron absorbers and structural materials, in relation to the similar characteristics of the control and safety systems, the heat removal system, the pressure systems, etc. The objective will be to assure that the probability of an operating mishap has been brought to an acceptably low level.

e) Further, the engineers and scientists, while concerned with determining that reasonable steps have been taken to prevent escape of radioactive fission products from the reactor core, must recognize that, in spite of all precautions, the most unlikely series of events might take place. Therefore, the designers must consider what events could occur which would release radioactive materials from the reactor core, and determine what further safety precautions should be provided to prevent serious consequences from such highly unlikely accidents. This aspect of the safety evaluation must deal with: the relationship of reactor location to its containment; selection of the site on the basis of pertinent radiological safety factors: comparison of the hydrology meterology, and seismology (earthquake possibility) of alternative sites; estimates of present and future population density of the surrounding areas; estimates of the use to which surrounding areas will be put, whether for industrial, commercial, agricultural or residential purposes; the possible use, by man or animals, of surface or ground waters that might be subject to contamination by the reactor.

After the initial discussions in which these factors and considerations are offered the applicant will submit to the Commission, as a part of his formal license application, a preliminary hazard report which, taking into account the current status of design, presents the applicant's statements with regard to:

a) His best technical opinion as to what events could possibly take place in his reactor which could result in releasing radioactive materials from its core.

b) His judgment concerning the adequacy of the counter-measures which he has taken, either by design or operating procedures, to minimize the probability of such events occurring.

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c) His conclusions concerning the effectiveness of his containment and isolation in minimizing the effects of such events should they occur.

As more experimental and design information on the reactor becomes available the applicant will submit supplemental summary reports.

The Commission reviews these reports and holds further meetings with the applicant. It considers the progress of the developmental programs which are being carried out by the applicant, by the Commission, or by others working in the same field. In unique or unusually complex cases, the Commission solicits the views of the Advisory Committee on Reactor Safeguards.

The construction permit. When the Commission arrives at a point where it is satisfied that it has information sufficient to provide reasonable assurance that a facility of the general type proposed can be constructed and operated at the proposed location without undue risk to the health and safety of the public, the Commission may issue a construction permit on a provisional basis. Before taking action on applications for construction permits for production or utilization facilities (except in export license cases and in cases not involving material alterations of facilities), the Commission will either direct the holding of a hearing, or will publish a notice 15 days in advance of taking its proposed action as provided in its Rules of Practice (10 CFR 2). The Commission may specify a longer preiod than 15 days in the notice.

Since at the time the permit is issued, the final design generally has not been determined and the actual design and operation procedures not finally evaluated, the construction permit will be issued on a provincial basis if the Commission finds that there is reasonable assurance that a reactor of the type proposed can be designed for operation at the proposed site without undue risk of the health and safety of the public. Such a permit will reserve entirely the decision on the final hazard evaluation, and will not contain definitive technical specifications of the reactor. As detailed design information becomes available it may be submitted to the Commission, and after evaluation it may be incorporated by amendment of the construction permit. Through this procedure, and by final hazard evaluation, the Commission makes its safety findings on the reactor as it is built.

Licensing. If the Commission finds, after a review of the final hazards summary report and the statement of proposed operating procedures, that the reactor can operate safely and if the Commission finds through inspection that the reactor has been constructed in accordance with the conditions of the construction permit, the construction permit may be converted to an operating license. The license may contain such restrictions on the reactor's operation as deemed necessary by the Commission for the safety of the public.

Administration of procedures. The Commission places in its Division of Civilian Application the responsibility for making the necessary evaluation and review of hazard analyses, for assessing the reasonableness of the assurances that the health and safety of the public will not be endangered, and for recommending the terms and conditions to be included in construction permit and license. In the discharge of these responsibilities, the division asks the technical advice of other divisions of the Commission in addition to using its own technical staff, and relies in many cases on the Advisory Committee on Reactor Safeguards. The Advisory Committee on Reactor Safeguards is available to advise the Commisison in this field and there is a close working relation between it and the Commission's evaluation staff.

The responsibility for inspecting facilities and operations for compliance with the conditions of licenses rests with the Division of Inspection, as defined later in this chapter.

Licensing of Source and Special Nuclear Materials

Protection from radiation hazards is a principal factor considered in the licensing of use or processing of source and special nuclear materials, as it has been throughout the 10 years that the Commission has licensed processing and minor industrial uses of source materials, and some research with it.

Source material is defined in the Commission's regulations as any material, except special nuclear material, which contains by weight 0.05 percent or more of uranium, thorium, or any combination of these two elements. For example, one form is the raw ore or mineral as it comes from the earth. Source material also includes concentrates of uranium or thorium, salts, compounds, alloys, or the refined uranium or thorium metal itself. The information required from an applicant for a license to employ any of these forms of source material will vary according to the degree of potential hazard presented by use of the particular form of the material, and the manner in which it will be handled under the license. Uses of source materials which are licensed by the Commission include the milling of ores for concentrates, for example, and will include processing of source materials into feed materials for various production or reactor purposes where plants are not operated under Commission contract.

In general, the applicant for a source material license is required to furnish only minimal information to establish his competency to handle the material safely.

In limited quantities, uranium enriched in uranium 235, which comes within the definition of "special nuclear material," may be handled and processed with little more radiation hazard than that which prevails in the case of normal uranium. Plutonium, because of its extreme toxicity, must be handled with considerable caution—in any quantity—and applicants are required to furnish detailed procedures for handling the material in order that there may be assurance that health hazards will be adequately controlled. Such procedures are required, for example, in connection with the use of plutonium-beryllium neutron sources in construction and operation of subcritical assembling used in universities and colleges for research and training.

When larger quantities of special nuclear material, such as uranium 235 or plutonium, are to be used by a licensee, an additional hazard must be considered—that of the possibility of an accidental assembly of a critical mass of the material which would initiate a chain reaction. This is, of course, the case in connection with the building or construction of a nuclear reactor. The licensing process for reactors has been reported. Other cases where an accidental condition of criticality might occur include fabrication of fuel elements or processing material for fabrication into fuel elements. For these activities, the applicant for a license is required to describe in detail his proposed equipment, procedures, and training, to avoid criticality accidents. There must be adequate information from the applicant to assure the pattern of handling is such that no one human error can cause a criticality accident. Among other things the applicant must demonstrate the adequacy of management and administrative techniques which will be employed to assure that safety procedures will be followed.

Source and special nuclear material licenses currently issued by the Commission provide that the licensees must conform with the regulation entitled "Standards for Protection Against Radiation" (10 CFR 20).

Byproduct Material Licensing

The Commission's program for assuring safety in the use of byproduct material (radioisotopes) has been developed throughout the 10 years of its direction of Federal atomic energy activities. The program has four phases: information and education, licensing, radiological advisory services, and inspection.[9]

[9] See pp. 71–78, Eighth Semiannual Report (January–June 1950).

Information and Education

As aids to users of radioisotopes, the Commission assists in developing and presenting training courses in safe techniques of using byproduct materials, and in the production of technical training films and other aids to radiological safety.

The Commission early realized the necessity for basic training in radioisotope uses and safe-handling techniques. The application of these new tools in the many areas of medicine, industry, agriculture, and research, can be expanded only as fast as people learn to use them safely. The Commission, therefore, has actively encouraged and participated in establishment of training opportunities, both in its own laboratories and in private institutions and industrial organizations.

Licensing

Primary control of radiation safety in use of byproduct material is exercised through the Commission's licensing activities. Radioisotopes are distributed in quantity only to those who are properly trained to use them.

The prospective user submits an application form giving information on the kind and amount of radioisotope desired, the proposed use of the material, instruments available for measurement of radiation, and the procedures to be used in assuring radiation safety. A license for possession of the material is issued only if careful technical review of the application gives reasonable assurance that the material will be used properly and safely.

For outside advice and assistance on difficult isotope licensing problems, an Advisory Committee on Isotope Distribution was appointed by the Manhattan Engineer District before the first shipment of byproduct material in 1946.[10] To evaluate the qualifications of medical users and proposed uses of radioisotopes in human beings, a Subcommittee on Human Applications was organized as part of this committee. The committee is composed of leading radioisotope users from various parts of the United States, and continues to offer valuable assistance to the Commission's byproduct material licensing activities.

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[10] See pp. 8, 44, Third Semiannual Report (July–December 1947), and Appendix 2 for membership.

Radiological Advisory Service

The Commission's radiological advisory service is supplied through a program of consultation and laboratory visits that complements the licensing activities in the following way:

a) By providing a mechanism for evaluation of the adequacy of criteria used and procedures followed in licensing byproduct materials through observation of actual conditions of use of isotopes;
b) By developing new licensing requirements and recommending modification of existing criteria based upon on-the-spot analysis;
c) By providing to the fullest extent possible an educational relationship with users rather than relying entirely upon enforcement inspection; and
d) By providing technical assistance and guidance in the development of radiological procedures, special facilities and equipment, of licensing requirements, rules and regulations of the Commission, as well as of recommendations of national advisory groups on radiation protection.

Cooperation. Other agencies besides the Commission have responsibility and interest in the control of radiation hazards.

The Commission cooperates with the National Committee on Radiation Protection and Measurement which prepares recommendations on safe handling of radioisotopes, maximum permissible limits of radiation exposure, disposal of waste radioactive materials, and similar subjects. This committee is supplied background information by the Commission and assists in making studies to determine radiological standards.

The Commission cooperates with the Federal Food and Drug Administration on problems of mutual interest such as possible use of radioisotopes in food processing, and the application of radiation to food and drug sterilization.

The Commission cooperates with the National Bureau of Standards in determining the need for new radiation standards and sources, and participates in the activities of various committees such as the National Research Council subcommittee for beta and gamma ray standards, American Standards Association subcommittee on specification of sealed beta and gamma sources for industrial use, and the American Hospital Association Committee on use of radioisotopes in hospitals.

In developing its policies and procedures for regulating private activities in the atomic energy industry the Commission has recognized that the regulatory agencies of the States have important interests in the same field. For this reason it has followed the policy of keeping the States informed of the issuance of licenses for byproduct and special nuclear material and for nuclear material and nuclear facilities. In 1955 the Commission established a 12-member Advisory Committee of State Officials to advise on regulatory matters of mutual interest.[11] In these and other ways the Commission is cooperating with the States in its regulatory programs and is alert to further opportunities for broadening the areas of cooperation and rendering assistance to the States.

Inspection of Licensed Activities

All licensees, whether they operate major facilities such as nuclear power reactors, or whether they are using radioisotopes for industrial, research, education, or medical purposes, are subject to periodic Government inspection to assure that regulations, and the terms and conditions of licenses, are being complied with. Under the Act of 1954 the Commission has authority to take procedural action to revoke, suspend or modify any license where action is necessary to assure, among other things, the full protection of health and safety.

The Commission has assigned to its Division of Inspection the responsibility of gathering factual data on compliance of a licensee with applicable rules and regulations, and with special conditions incorporated in his permit or license. In connection with making its compliance inspections, the Division of Inspection has a responsibility for assisting the Division of Civilian Application in the gathering of information which will be of use in determining whether or not rules and regulations, policies and licensing practices are effective and adequate.

Atomic Energy licensees, as stated earlier, have the basic responsibility for safety. The greatest realization of safety potential is accomplished through cooperative efforts of the licensee and the regulatory agency, through continual attention by the licensee to safety of operation, and continual effort by the agency toward utilizing operational experience in the improvement of standards and regulations.

If inspection should indicate noncompliance with applicable rules and regulations of the Commission, the licensee will be advised and findings will be reported to licensing authorities within the Commission. The Commission may then issue an order under its Rules of Practice requiring the licensee to take appropriate corrective action. Where, in the opinion of an inspector, a practice of a licensee constitutes an immediate danger to the health and safety of employees or the public, or immediate danger to the common defense and security, the inspector suggests that such minimum action as the licensee or permit holder deems advisable be taken to overcome the immediate danger. Prompt compulsory action may be taken by the Commission

[11] See p. 91, Nineteenth Semiannual Report (July–December 1955) and Appendix 2, this report.

under its Rules of Practice in cases of extreme importance to the common defense and security or the health and safety of the public.

Arrangements for inspections. Licensed activities can be divided, for purposes of practical administration, into two categories:

a) The use of licensed materials;
b) The construction and operation of production and utilization facilities.

Use of materials. In the first category, activities are licensed by the Commission for the use of byproduct material, source material and special nuclear material. About 4,000 such licenses have been issued and are increasing at a rate of about 15 percent a year. Under these licenses, activities range from the use of small and relatively harmless quantities of materials in exhibits and demonstrations to the application of powerful and potentially dangerous quantities in academic and industrial research, in medical applications, and in radiographic testing of materials.

The technical standard for inspection of the activities is the newly issued regulation, 10 CFR 20, "Standards for Protection Against Radiation," mentioned earlier in this section, which has been published in the *Federal Register* and will become effective early in 1957.

In order to accomplish effective and continuing inspection of the large number of licensee activities distributed throughout the United States, inspection groups are being organized in Commission operations offices. Each office is assigned responsibility for inspection of licensed use of materials in a geographic area.

The Commission has formulated its policy and has established programs for performance of this inspection function. Through continual review of field experience and frequent contacts with field groups, uniformity and adequacy of inspection procedure is maintained. This arrangement brings licensees into prompt contact with Commission representatives in their own geographic areas as the occasion may demand. It also makes unnecessary the establishment of a large central organization in Washington to service the entire United States.

When Commission inspectors visit the installations of licensees, officials of interested State agencies are invited to attend. At present, representatives from several State inspection services accompany Commission inspectors when byproduct licensees located within their respective States are inspected. This cooperation between Federal and State agencies assists development of competent technical personnel able to perform inspections and observes the traditional relationship between the State agencies and private industry on other types of health and safety matters.

It is anticipated that the area of cooperation between Federal and State agencies in the inspection of Commission licensees will be enlarged as inspection programs are further developed.

Facilities inspection. The inspection of licensed utilization facilities, at present limited to nuclear reactors, is somewhat different. Although the "Standards for Protection Against Radiation" are being incorporated into facility licenses, the present stage of reactor development does not permit the Commission to formulate general standards of design and operation which can be applied to each reactor. Sound inspection procedures and practices followed by reactor experts will be of assistance in gathering data which will be of use in formulating standards of design and operation.

The factors that govern the safety of an operation arise from two sources:

a) The facility, its material, structural, instrumental, and control characteristics, and
b) The people who operate the facility.

The first factor defines the potential hazard. The second factor determines the extent to which the potential hazard is further minimized or eliminated.

Inspectors officially enter the picture upon issuance of a construction permit. As construction approaches completion, inspectors observe tests of equipment and preoperational integrated test runs. At this stage, an initial trial of a licensee's operation procedure is possible.

On the basis of the tests and trial of procedure, and on observation of the licensee's operating organization, discipline and familiarity with procedure, a recommendation is made which is one of the considerations bearing upon the issuance of a license for operation of a facility. When a license is granted, inspectors observe intial startup and operation. At this stage, the effectiveness of regulations and the stipulations of the license can be evalutaed by the Commission from actual operational experience.

After licensing, periodic inspection visits are made to the facility, and the findings and recommendations are transmitted to the General Manager and to interested divisions of the Commission organization.

The function of the Division of Inspection in the promotion of reactor safety is not to provide direct assistance and advice to a licensee. However, an objective and thorough inspection does assist both the licensee and the Commission in demonstrating the extent to which all aspects of design and operation have been thoroughly considered. On occasion, the advisability of further study, or for amendment or supplement to procedure, may be brought out during inspection.

III

SAFETY FACTORS IN REACTOR DESIGN AND OPERATION

In the 14 years since the first nuclear reactor in the United States was successfully operated, no known injury to the public has occurred through operation of a reactor. Of the 69 persons who have suffered reported overexposure in radiation "incidents" in Federal atomic energy activities, only 15 received more than the permissible dosage in connection with reactor operations, and 12 of these were in experimental activities of various kinds.[12] There have been essentially no reactor accidents in the United States leading to serious consequences. In fact, one current problem in evaluating reactor hazards is that the United States has had no experience with reactor accidents.

The human hazards from nuclear reactors arise from the fact that the reactors generate huge quantities of radioactivity. The radiation from the core of a nuclear reactor, if it were not enclosed in shields, would inflict lethal dosages of radiation in a matter of seconds or minutes to anyone within a radius of several hundred feet—and the unaided senses of the people exposed could not detect the danger.

Nevertheless, men work on nuclear reactors in complete safety because the deadly radiations are absorbed by thick shields of special concrete and other materials, or controlled by airtight containers and ventilation, by rigorous industrial housekeeping, and by worker discipline (see Chapter V, Radiation Protection in Commission Activities). Public protection from radiation is provided by strict control over reactor design, including location and containment; reactor operation; reactor coolants and similar materials that might be released to the environment; by continuous vigilance and monitoring against accidental releases, and by careful management of reactor wastes (see also Chapter V, and Chapter IV, Radioactive Wastes).

The record of operations under the Atomic Energy Commission, and under the earlier Manhattan Engineer District, demonstrates that the radiation hazards can be managed in safety. There is, however, a remote possibility that all the multiple safety devices of a reactor might fail by an unforeseen combination of events. In this case a reactor might undergo a "nuclear runaway", or a chemical reaction might occur that could burst the reactor-containing vessel and shield, and release radiation and radioactive materials.

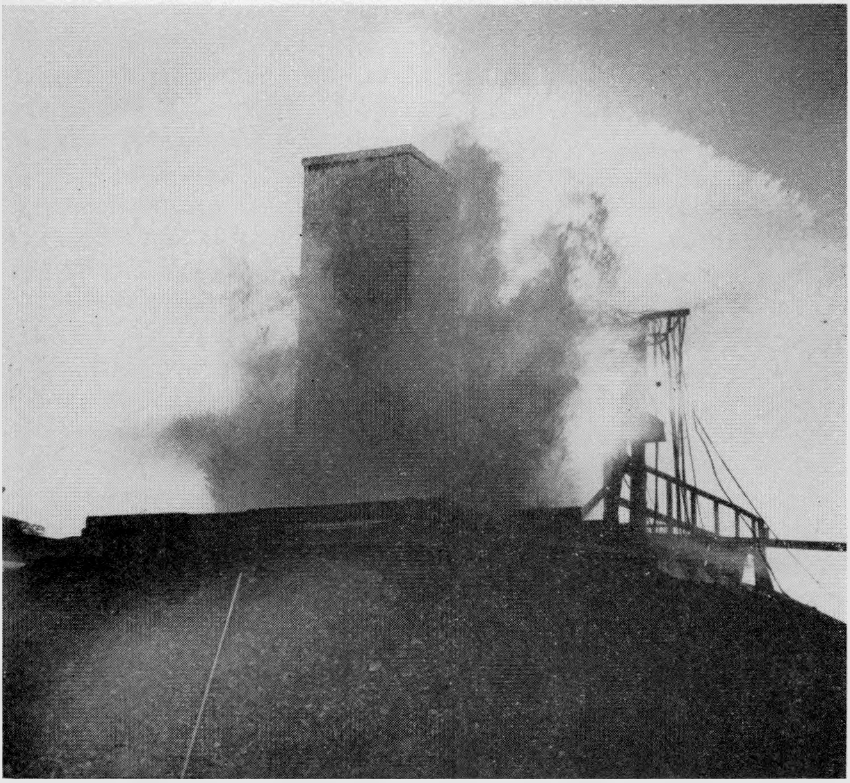
[12] For details, see Chapter V, Radiation Protection in Commission Activities.

Nevertheless, none of the 70 or more reactors that have been operated in the United States has ever accidentally run away.

In one case, experimenters of the Argonne National Laboratory deliberately sacrificed a small reactor (Borax–1) to learn more about its safety factors, as has been reported earlier.[13]

Another planned reactor experiment (Experimental Breeder Reactor No. 1) was stopped just short of runaway. In this second case reported in July 1956,[14] normal controls that would have shut down the reactor had been removed, and coolant flow stopped, so as to conduct power experiments which risked the possibility of a runaway. During the experiment an appreciable amount of the reactor core was melted, but the shell was not breached.

In neither of these cases was anyone injured.



Reactor safety. Experimenters force a boiling water reactor to have a nuclear runaway at the National Reactor Testing Station, Idaho, the only such event in the history of atomic energy operations in the United States. The water used as moderator and coolant was expelled from the open reactor pit. Earth bank in foreground is part of the shield; the rectangular box housed control equipment.

[13] Pp. 22–23, Sixteenth Semiannual Report to Congress (January–June 1954) and pp. 22–23, Seventeenth Semiannual Report to Congress (July–December 1954).

[14] Pp. 45–46, Twentieth Semiannual Report to Congress, (January–June 1956).

Hazards of Reactors

The hazards of reactor operation actually arise from the same basic circumstance which makes it desirable to use nuclear materials as fuel: Vast amounts of energy are concentrated in a very small volume. This energy can be released swiftly in an explosion. In use for constructive purposes, such as generation of heat for the manufacture of electricity, the energy must be released gradually over a considerable period of time. The release of energy is accomplished through what is termed a "chain reaction."

After German and Danish physicists discovered that bombardment with neutrons would cause uranium atoms to fission, or split, and also to throw off more neutrons, it became feasible to attempt to establish a chain reaction—a continuous series of atomic fissions, each triggered when the previous fission released neutrons. Scientists found that, in order for a fission reaction to become self-sustaining, a certain minimum amount of uranium 235 [15]—an isotope of uranium that occurs in nature—would have to be assembled. Without this minimum amount, called a "critical mass" of the fissionable isotope of uranium, there could be no such thing as an atomic bomb or a reactor.

A critical mass of uranium 235 is not, however, a fixed quantity of the fissionable material. A quantity of uranium 235 might be a subcritical mass if simply suspended in the air, and become supercritical if it were encased in a material—such as graphite—which would improve the efficiency of neutron capture and fission within the mass, both by reflecting escaping neutrons back into the uranium, and by slowing them down. Most reactors use the device of a reflector to bounce back escaping neutrons. Among other factors that may affect the amount of uranium necessary to form a critical mass are the percentage of uranium 235 in the fuel elements of a reactor and the number of neutrons absorbed by cooling and structural materials, by moderating material, and by fission fragments or "poisons" that build up as the reactor continues to operate. The amount of uranium 235 necessary to form a critical mass will also depend on whether the reactor is designed to operate on slow, or thermal, neutrons, or whether the spectrum of neutron velocities will be close to those at which neutrons are emitted during fission as in a fast reactor.

Each reactor contains a quantity of uranium 235 or another fissionable isotope which—after the factors cited, and other matters

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[15] The number 235 after the word uranium is the mass number of this particular isotope, or variety, of uranium, and indicates the total number of protons and neutrons found in its nucleus. All uranium has exactly 92 protrons, corresponding to the element's "atomic number" in the periodic table of elements. This isotope differs from the more common isotope, uranium 238, in that it has 143 neutrons rather than 146. Mass numbers of other materials—uranium 233, plutonium 239, carbon 14, potassium 40, etc.—are used from time to time in the text.

that affect the neutron economy, are fully computed—is calculated as being close to a critical mass. A reactor normally also will include an additional amount of fissionable material to compensate for the loss of neutrons which will occur as fission product poisons build up in the reactor and increase their capture of neutrons. Most reactors contain slightly more than a critical mass, but are controlled by inserting neutron-absorbent rods, or removing reflectors, or using other devices which affect neutron economy and so prevent a chain reaction from starting until the reactor operators are ready.

These control rods, or similar devices, permit the operator of a reactor to keep the chain reaction under careful control, or to shut down the reactor if a malfunction should threaten. Potentially, a reactor can achieve an extremely high power level in a very short time if adequate and properly timed control is not exercised. What would happen if a reactor ran away would be that its rate of increase in neutron production, and consequently its power and temperature, would rise very rapidly. Even if there were absolutely no operating controls on the reactor, the runaway would soon stop itself. Either nuclear reaction would disrupt the fuel in the reactor, or the heat would melt down the fuel. Under extreme circumstances, this could happen in less than a second. If the nuclear runaway were checked short of damage, the temperature still would continue to rise for a short while as a result of continuing heat from radioactivity, and this "after-heat" could melt down fuel.

A melt-down also might precipitate a chemical explosion. In fast reactors, design must make sure that a melt-down accident cannot drop core parts together in such a way as suddenly to assemble a critical mass and thus cause a supercriticality accident.

A nuclear runaway, however, is a very sluggish reaction compared to that of a bomb, and neither a runaway nor a supercriticality accident, could produce a nuclear explosion even remotely approximating that of an atomic bomb.

Reactor experts have declared[16] that, for large thermal reactors, "nothing like an explosion really occurs. For very fast reactors with a nonthermal spectrum of velocities of neutrons and heavily loaded with enriched uranium, it does appear possible to have an accident which is fast enough so that portions of the machine may be propelled with velocities of a few meters per second. This again does not resemble an atomic bomb explosion, or even the explosion of ordinary chemical explosives; rather it is similar to the events that might occur in an automobile accident. Therefore, a nuclear runaway, in itself, does not represent a serious hazard to off-site people."

[16] "The Safety of Nuclear Reactors," by C. Rogers McCullough, Mark M. Mills, and Edward Teller, The International Conference on the Peaceful Uses of Atomic Energy, Geneva, Switzerland, August 1955.

In some reactors, it would be possible to have a chemical or steam explosion, because of the heat of an incipient nuclear runaway, from some malfunction of the cooling system of the reactor or from an accidental combination of noncompatible chemicals. Such an explosion might be more severe than any possible nuclear reactor blast, but would not be more severe than might occur in many other types of industrial plants. A chemical explosion might occur, for example, between molten aluminum cladding and cooling water, if the aluminum reached extremely high temperatures through reactor malfunction. Chemical explosions might rupture the reactor vessel and shielding and release radioactive materials.

However, any fracture of a reactor structure could be expected to release considerable quantities of highly poisonous radioactive material. It has been calculated that, one day after its shutdown, a reactor capable of generating 60,000 kilowatts of electricity would contain the equivalent in radioactivity of 300 tons of radium. The possible release of a portion of this radioactivity would be the major hazard from a nuclear runaway in a reactor.

What danger would result to the environment if all containers of a reactor were breached by an accident would depend on a number of factors which lend themselves to research, some of which is reported later in this chapter. Basically, the hazard would depend on the volume and kind of radioactive materials released, the rate at which they were distributed and fell to earth, and the area of distribution and population affected. Factors which would influence these aspects of the hazard include:

a) The kind of accident that occurred, whether the explosion was nuclear or chemical.

b) The degree and intensity of heat generated within the reactor at the time of the accident.

c) Whether vaporization of fuel elements or other reactor materials occurred, and the extent of the vaporization.

d) The type of reactor and the kind of materials present in the reactor subject to vaporization and heat.

e) The rate of release of radioactive materials from a reactor, and the manner of its release, whether slowly through leakage, for example, or broadcast by explosion.

f) Weather conditions as they affect dispersion and dilution of radioactive materials, and the pattern of fall-out.

g) Use and type of land and bodies of water affected by fall-out and effect of weather on leaching after fall-out.

Built-in Safety

The philosophy of reactor safety points first, of course, to designing a reactor in which a nuclear runaway, or a chemical blast, would be extremely unlikely. Reactors also incorporate means of positively assuring cooling so that "after-heat" cannot cause melt-down. Control instruments and mechanisms are an additional major safety factor. Reactor "fuses" may be incorporated when suitable ones are available. One low-power reactor already has a fuse incorporated into its design. Further steps are taken to protect the public if, in spite of all precautions a nuclear runaway or chemical explosion should occur. The facility may be isolated so that release of radioactive materials in a reactor accident would not endanger concentrations of population. Where isolation is infeasible, strong gas-tight containers may be erected about the reactor, so if radioactive materials escaped from the reactor itself they nevertheless would not be allowed to disperse into the environment.

Basically, the safety of a nuclear reactor depends upon two things: the built-in stability and reliability of the design of the machine and its controls, and the administrative control and operation of the reactor. The administrative control which the Atomic Energy Commission and its contractors exercise over reactor operation to assure safety has been fully reported in the Eighth Semiannual Report (January–June 1950), and are reviewed in Chapter V. The previous chapter has detailed the series of studies and requirements which the Commission applied to licensing new nuclear reactors so as to assure, not only sound administrative and operating procedures, but also safety of design.

Temperature as a Brake

The precise safety characteristics that can be designed into a nuclear reactor vary considerably with the type of reactor. For example, the key factor that operates to promote safety in some reactors is that excessive heat tends to reduce the neutron efficiency of the reactor, and hence to reduce or quench the chain reaction. In effect, the higher temperature resulting from higher neutron reactivity so affects the operation of the reactor that the reactivity falls off. This factor, called a "negative temperature coefficient," operates in different ways in different types of reactors.

For example, in boiling water reactors—those in which the water serving as coolant, moderator, and reflector is permitted to boil in passing between the fuel elements—there is a very high negative temperature coefficient. If the rate of neutron production surges upward, the heat generation in the fuel elements increases, and more water boils increasing the quantity of steam bubbles. The density of the water is thus reduced, lowering its efficiency as a moderator and reflector of neutrons. As a result, fewer neutrons are slowed down to the level where they are readily captured, and more neutrons leak out of the reactor core. This loss of neutron efficiency results rapidly in lowering the rate of neutron production.

The pressurized water reactor being built at Shippingport, Pa., similarly has a negative temperature coefficient. In this reactor also, water serves as a coolant, moderator, and reflector, but operates under high pressure that prevents boiling even at high temperatures. Nevertheless, sharply rising temperature as a result of excess neutron activity in the core would lessen the density of the water, and by making a percentage of the neutrons less effective for fission, would slow down the reaction. The five plutonium production reactors at the Commission's Savannah River, South Carolina, installation use heavy water as a coolant-moderator-reflector and have this same type of built-in safety-factor.

In homogeneous reactors, the fuel is carried in solution, in molten material or in slurries, that is mixtures of finely divided materials in a fluid. Excessive heat will cause the fluid carrying the fuel to expand—expansion chambers are provided—and thus the concentration of fuel is reduced and the reaction slowed. The negative temperature coefficient proved so effective in the Homogeneous Reactor Experiment No. 1 at Oak Ridge National Laboratory, Oak Ridge, Tenn., that HRE No. 2 now being constructed will not need mechanical control or safety rods. Instead, temperature control will be accomplished by regulating the composition of uranium in the fuel solution, and the power level will be set by the rate at which heat is removed from the reactor. The HRE–2 will operate at high pressure like the Shippingport reactor.

A number of other types of negative temperature coefficients are effective in reactors. A reactor containing large amounts of uranium 238, for example, will lose neutron efficiency with higher temperatures because at greater heat the nonfissionable uranium captures a larger fraction of the neutrons. This reduces the number of neutrons available to cause fission. An additional type of negative temperature coefficient would operate only when temperatures became high enough to warp fuel elements. A reactor could be constructed so that overheated fuel elements would warp away from each other. This would change the spacing of fuel elements, and would reduce the neutron efficiency of the reactor.

Safety of Fast Neutron Reactors

Provision of a good, swiftly-acting negative temperature coefficient also is basic to the design of fast reactors. Fast reactors operate with high-velocity neutrons which are more difficult than thermal neutrons for fissionable uranium and other materials to capture. Therefore, the weight of material necessary to create a critical mass is quite large. The critical mass is further increased by placing in the reactor the cooling channels which will carry off the generated heat. This large inventory of fissionable material increases the likelihood of power surges which can be caused, for example, by the introduction of coolant material that has a moderating effect, or by extensive melting in an incipient runaway which might cause movement of the fuel toward the center of the core or other rearrangement of fuel.

Another characteristic of the fast reactor is the short average time between birth of a neutron in one fission and its capture by uranium 235 to produce another fission. This is much shorter than in thermal reactors. The difference is not very manifest as long as the excess reactivity is less than the fraction represented by the "delayed neutrons." In any chain reaction, some neutrons are not released as soon as fission occurs, but may be delayed by up to 80 seconds. The delayed neutron fraction is approximately ¾ of 1 percent of all fission neutrons. As long as the reactor's excess reactivity is appreciably below this delayed neutron fraction, the reactor is sluggish and easy to control. This is equally true of fast and thermal reactors. However, if the rate of increased activity in a fast reactor reaches the point where only "prompt" neutrons (that is, those neutrons that are not "delayed") are needed to sustain the chain reaction, the rate of increase of power can be several orders of magnitude faster than in thermal reactors. Consequently, fast reactors must be carefully designed so that amounts of reactivity large enough to enable the reactor to operate on prompt neutrons alone cannot be introduced by error or malfunction.

Fast reactors, in certain respects, have special safety advantages. Although the critical mass is large, the initial amount of excess fissionable material which must be used, and compensated for by control mechanisms, is reduced. This is because the accumulation of fission products will not capture the fast neutrons as readily as they would thermal neutrons, and therefore accumulation of these "poisons" need not be compensated for with as much additional fuel as for thermal reactors. Fast reactors also can be designed as breeder reactors: that is, they can generate in time more fissionable material than they consume. This fact further reduces the initial requirements for excess reactivity and the compensation needed in controls. The gradual

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depletion of reactivity in the fuel is partly compensated by the buildup of fissionable material through breeding.

These safety characteristics of the fast reactor make it possible to keep the total reactivity available to the control system within the amount dependent on delayed neutrons, so that malfunction of the controls alone cannot bring about extremely rapid power surges. The control system could not throw the reactor into a condition where it would operate on prompt neutrons alone.

A second safety advantage of the fast reactor is that it lends itself particularly well to the use of liquid metal coolants, which permit relatively high temperatures at low pressure. This means that the danger of leaks from the channels carrying the coolant is greatly reduced, and a leak would be much more easily controlled. Moreover, liquid metal coolants are much less likely to cause explosive chemical reactions on contact with fuel elements and other structural materials, than are some other coolants.

Chemical Safety in Reactors

Major chemical reactions that might result in an explosion within a reactor may be caused by excessive heat. High temperatures might be generated by a nuclear runaway, by "after-heat" from an arrested nuclear runaway or a failure in the reactor's cooling system. A chemical explosion that reached its maximum potential could have considerably more power than a nuclear incident occurring within a reactor.

One type of chemical explosion, for example, might result if uranium fuel melted and spewed into water used as a coolant or moderator. Design for safety seeks to avoid such potential chemical mishaps, first, by building in negative temperature coefficients, second, by positively assuring cooling, and third, by eliminating components that will react—for example, uranium oxide would not have the violent chemical reaction with water that might occur from pure, unreacted uranium.

Safety Through Control Systems

A reactor control system is designed so that it shuts down the reactor quickly enough to minimize danger. The extremely short time—less than a second in extreme conditions—in which a reactor could get out of control makes it of utmost importance that each reactor have automatic control and safety systems that are reliable and relatively rapid in operation.

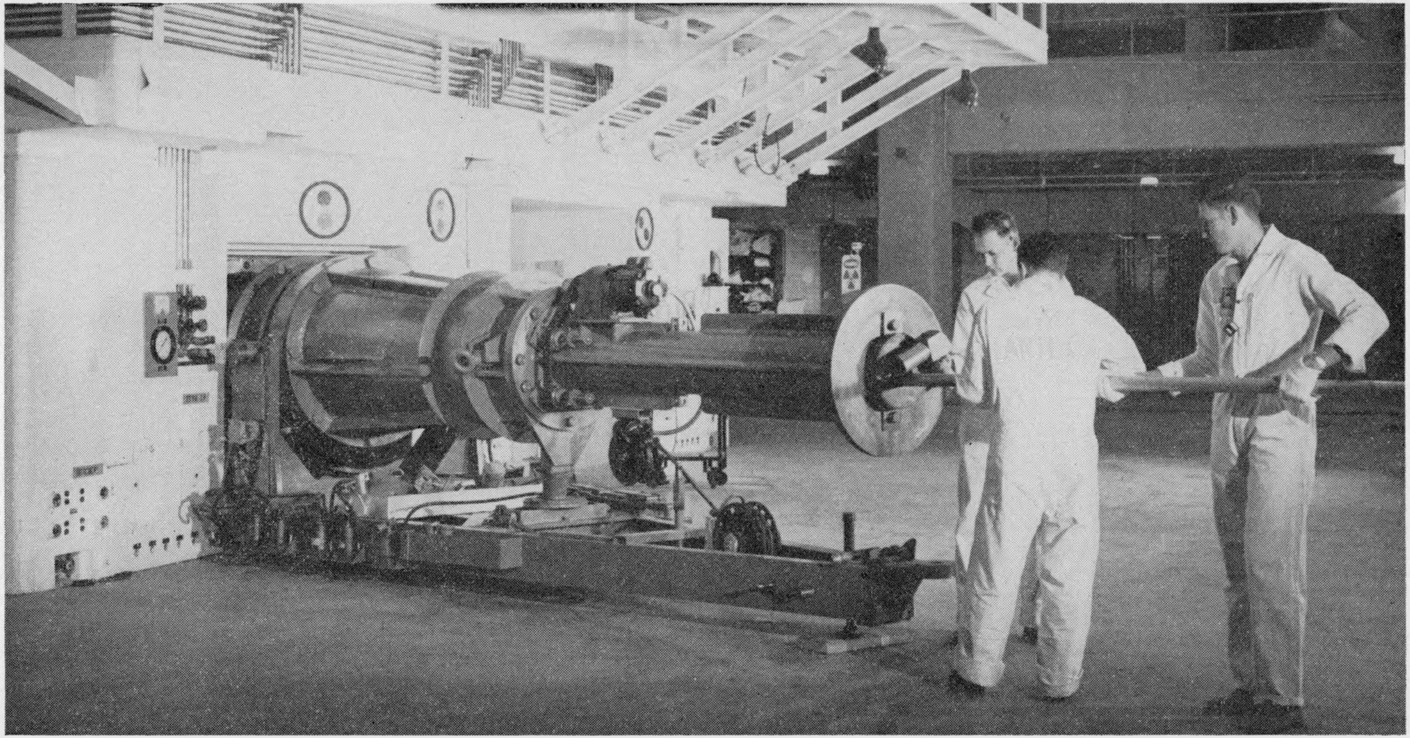
Instruments are inserted into the reactor to measure and record temperature, the number of nuclear fissions per unit of time. They monitor the rate of increase in fissions as a function of time, functioning of the cooling system, and the amount of radioactivity in coolants. The shut-down systems are attached to these instruments which are used at least in duplicate, operate independently of each other, and often are of entirely different types. A further safety device shuts down the reactors if anything happens to incapacitate the monitoring instruments.

In typical large reactors, there are at least two levels of automatic response to instrument readings which indicate an abnormality. The first is cautionary, or warning, calling attention to a relatively minor condition not affecting safe operation. For example, in the Experimental Breeder Reactor No. 1, the air that cools the reactor blanket is vented through the stack and monitored to record its level of radioactivity on a strip chart. If the activity were to rise above a safe level, an alarm bell would sound and a warning light would go on. Secondly, some abnormalities, such as temperature overruns or excess reactivity, will result in shutting down a reactor in a fraction of a second. Most reactors have about the same type of interlocked system and will shut down automatically from the same causes, which include:

a) An overrun in temperature;
b) Excessive neutron reactivity (power);
c) Too rapid a rate of increase in neutron reactivity (power);
d) Any malfunction in the cooling system, such as leaks in valves or failure of pumps;
e) Leakage of radioactivity into coolants or through reactor containers; and
f) On large reactors, an earthquake recorded by a seismograph.

The devices used to scram a reactor are of various types. The Materials Testing Reactor, for example, has control rods made of cadmium, which is a high absorber of neutrons. These rods are raised into position by means of a magnetic coupling during operation. Should any instrumentation indicate that hazardous conditions are developing within the reactor, the supply of electricity to the magnetic system is interrupted, causing the control rods to drop under gravity and the pressure of the cooling water. The rods immediately absorb enough neutrons to stop the chain reaction.

Another example is a device used in the Homogeneous Reactor Experiment No. 1 and the Experimental Breeder Reactor No. 1. Instrumentation indicating an alarming situation can cause the water reflector, which normally reflects escaping neutrons, to be dumped from the reactor. This will cause shutdown of the reactor by increasing



MTR in use. The "coffin" used to place test material in the Materials Testing Reactor without exposing workers. A health physicist uses a detection-measuring instrument to assure radiation is below tolerable levels.

neutron leakage, thus reducing neutron efficiency and stopping the chain reaction.

Safety fuses for reactors. Over and above ordinary instrumentation and automatic controls, Commission research is seeking to develop automatic fuses which would prevent a nuclear runaway in the event a reactor started to get out of control, as an electrical fuse does in case of shortcircuit or overload. The fuses would have two characteristics: first, each would be a unit in itself, wholly automatic, and not subject to errors of maintenance or adjustment, or to tampering; second, each would be set off by an abnormally high-power-level of the reactor, and would operate in less than a second.

Reactor Containment

The final safety device in protection of the environment is isolating a reactor or, failing that, enclosing the entire reactor plant with a secondary air-tight container or containers which would protect surrounding population from radioactivity should a major accident release it from the reactor itself. The amount of this secondary containment needed for an individual reactor can be balanced with the relative isolation of the reactor. In the case of the Shippingport Pressurized Water Reactor, for example, which is to be relatively close to Pittsburgh, Pa., the reactor and its auxiliaries are isolated in four separate containment vessels constructed of steel up to 1¼ inches in thickness. These huge closed tanks are designed to hold any radioactive gases and steam that might be released by a failure in the reactor or any part of the coolant system. Further, except for the turbine generator, the entire plant will be underground, the reactor itself being buried about 70 feet below the surface.

Reactor Safety Research

With the advent of new types of reactors, operating at increased pressures and temperatures for the sake of greater efficiency in producing electricity, the Commission's program of experiment and research in reactor safety was greatly expanded. As contrasted with an expenditure in this field of $336,000 during the fiscal year ended June 30, 1955, the Commission appropriation was $6 million for the program during the fiscal year 1957. The aim of this increasing program is to protect public health and safety, and to achieve reactor safety in less costly ways so that the goal of economic electric power from nuclear sources may be brought nearer.

Experimental work to determine the effects of adverse operating conditions on reactor behavior has been performed at the various national laboratories. An example of this is the deliberate sacrifice in 1953 of the boiling water reactor, BORAX-1, at the National Reactor Testing Station. In this instance valuable information was obtained when this low cost facility, located in a physically isolated area was allowed to blow itself apart as a result of a nuclear excursion.

The Commission currently has under way a reactor safety research and development program which has grown out of this earlier work and which is designed to obtain answers to such important questions as:

a) Under what operating conditions will a given type of reactor damage itself?
b) What built-in reactor characteristics tend to limit the damage?
c) What built-in reactor characteristics tend to increase the damage?
d) Under what conditions will fuel elements melt?
e) How will molten fuels react with reactor coolants?
f) What and how much radioactivity is released from molten fuel?
g) Can the reactor vessel itself contain the nuclear and chemical energy released?
h) If not, what kind of outer containing structure is needed to prevent the release of fission products?
i) Can fuses be made to shut down a reactor before damage occurs?
j) How can all the information developed in the program be integrated into a set of design criteria for safe reactors?

Reactor Safety Test Facilities

The experiments to determine what reactor characteristics are inherently safe, and which are not, are concentrated in a number of projects, each concerned with a different major concept of reactor design.

A heterogeneous reactor test facility, Special Power Excursion Reactor Test (SPERT), located at the reactor testing station in Idaho, is operated by Phillips Petroleum Co. The specific reactor projects are in various stages of operation, construction, and design as described from time to time in Commission reports to the Congress. The SPERT facilities are planned to provide test information on several heterogeneous reactor concepts. The installation consists of a central building for remote control of test pits located one-half mile from the operating center. Each pit is isolated from others so that an unexpected energy release in one would damage only that specific experiment.

SPERT–I is a heterogeneous unpressurized reactor using water as moderator and reflector. Very large surges of power are being produced and studied in this reactor in order to gain a better understanding of the behavior of reactors of this type. It already has been learned that power surges in which the power increases as much as three times in a hundredth of a second will not damage the reactor.

SPERT–II was in early design stages late in 1956. This reactor will operate at pressures up to approximately 300 pounds per square inch, and is designed so that moderator and reflector can be changed.

SPERT–III, expected to be ready for tests in 1957, is designed to operate at a pressure of approximately 2,500 pounds per square inch and at a temperature of the order of 350° Centigrade. The water which will serve as both moderator and coolant can be circulated at rates up to 20,000 gallons per minute. This reactor will yield infor-

SPERT. Final inspection of SPERT I control rod drives before a test, Air pressure on center transient control rod (note air hoses) permit rapid movement of the rod to trigger test. The test will be carried out from about half a mile away.

mation on power transients and safe operating conditions which will be applicable to the Shippingport reactor and certain other advanced pressurized water reactors now being designed. The experimental program also includes excursion and stability tests.

A reactor known as KEWB–I (Kinetic Experiment on Water Boilers) has been built by Atomics International, a division of North American Aviation, Inc., at their proving ground in Santa Susana, Calif. This reactor is intended to supply the same kind of information about small homogeneous reactors that the SPERT facility is providing for heterogeneous reactors.

Studies of Chemical Mishaps

Metal ignition. The importance of learning more about the mechanism of spontaneous ignition of metals has been underscored by the occurrence of some spontaneous uranium, thorium, and zirconium fires in Commission installations. Similar spontaneous ignition has been observed in other metals important to the atomic energy industry. While this phenomenon is not known to have occurred in any reactor core assembly, the possibility must be studied.

Argonne National Laboratory, Lemont, Ill., accordingly has undertaken a fundamental study of the mechanism and characteristics of spontaneous ignition in uranium, plutonium, thorium, zirconium, and their alloys.

Argonne laboratory approached the problem by studying the reactions of uranium under controlled conditions of temperature and pressure in an atmosphere of oxygen. It was found that, among other things, metal purity and grain-size affect the rate of heat liberation in the uranium oxidation experiments.

The work will be extended shortly to other reactor fuels, construction materials, and alloys.

Explosive chemical reactions. To increase understanding of such explosive chemical reactions as are caused when molten metal comes in contact with water, experimental and theoretical studies have been undertaken for the Commission by the Aerojet-General Corp. at Azusa, Calif. The studies will assist in developing materials which may retard the explosive reaction.

Operation of a pressurized water moderated reactor develops mixtures of hydrogen, oxygen, and steam within the pressure vessel. The Commission has contracted with the Bureau of Mines, Department of the Interior, to conduct studies to determine the limits of explosiveness of this mixture. The experimental work involves producing mixtures of hydrogen, oxygen, and steam of known composition and determining the ignition temperature for each mixture.

In addition, the Bureau is attempting to determine the energy release of these mixtures that explode. The results of this work should make it possible to predict with some accuracy the hazards that will be incurred in given reactor designs.

Fuel element burnout. The danger has been mentioned that during a rapid increase of power in a reactor one or more fuel elements may melt and spray molten fuel into the moderator water with sufficient speed to form steam at an explosive rate.

Experimenters at Columbia University, New York, N. Y., have been electrically melting simulated fuel elements to determine the mechanism of explosions.

Fission Product Release and Containment

Rate of release. Since fuel elements in a reactor may melt as a consequence of accidental excessive temperatures, it is important to know the rate and type of fission products a melt-down would release under various conditions.

At Oak Ridge National Laboratory, Oak Ridge, Tenn., experimenters are melting down small discs punched from irradiated reactor fuel plates. The discs are heated in a gas-tight system and the fission products released from the molten fuel are trapped selectively. Conventional counting techniques record the rate of release of fission products as a function of time.

Better control is being sought over the rate at which the fuel sample melts. The studies are to be extended to other fuel elements and materials.

Reactor core vessels. The first defense against release of radioactivity in the event of a major reactor accident is the strength of the reactor core vessel itself. The Naval Ordnance Laboratory, White Oak, Md., is presently under contract to the Commission to examine this aspect of the containment problem.

Using scale models of reactor core vessels, the laboratory has developed a suitable simulant of a reactor excursion by blending a rocket propellant with high explosive. When this charge is detonated, it releases energy at the same rate as that expected in an actual reactor accident. The present experimental program aims at determining the strength of the scale models as a function of such variables as the relative dimensions and the temperature. Future experimental work will include the effects on strength of the models when holes and ducts have been cut into them.

Reactor containment vessels. A final line of defense against release of radioactivity in the event of an accident that ruptures the core vessel and shields is an outer containment vessel which will prevent escape of fission products to the environment. The Ballistics Research Laboratory, Aberdeen Proving Ground, Aberdeen, Md., is conducting a theoretical and experimental study to determine what design features an outer containment vessel should have to provide the desired degree of safety.

Scale models of various containment vessels, an inner vessel which simulates the reactor core vessel, and a suitably modified explosive are used. Experimental work to date demonstrates that the rupture of the simulated core vessel by static pressure does not generate a shock wave. Rupture of this core vessel by an explosive which functions on the same time scale as expected in a reactor accident, however, does produce a shock wave and builds up pressure on the outer containment vessel at a very high rate.

The Ballistics Research Laboratory, as a separate undertaking, is conducting limited destructive tests on a one-quarter scale model of the containment system to be used for a test reactor facility at Wright Air Development Center near Dayton, Ohio.

Fuse Development

Work has been under way for some time to develop a reactor fuse which would supplement routine devices to help control reactors more effectively and inexpensively. A number of types of fuses are under development by Atomics International at Canoga Park, Calif. for the Commission.

One type of fuse which shows promise is a capsule of boron trifluoride gas under considerable pressure placed inside a large container and inserted in the core of a reactor. This gas has a quality of absorbing many neutrons and, in the fuse designed, would release from the capsule into the larger vessel within the core whenever a critical neutron flux was exceeded.

The can-in-a-can fuse operates by increasing the space filled by the neutron-absorbing gas. The absorption of neutrons is a function of the total space occupied by the gas rather than of the number of atoms of the gas, which makes this arrangement feasible. The neutron-absorbing gas thus is not released to poison the entire reactor. The fuse operates to reduce the neutron flux locally at the point needed in the reactor, and a large reactor might not be shut down by the action of a single fuse. Activation of multiple fuses would be needed.

The action of the fuse has been found to be sufficiently rapid in the face of an increasing neutron flux that the unit will react and release the neutron-absorbing gas in a matter of a few thousandths of a second.

Speed of response is one of the basic requirements of reactor fuses, and extensive studies are being carried out to improve the speed of response of fuses, and to control more closely the neutron flux at which a fuse is set off.

Fuses that operate on quite different principles also are under investigation, including a so-called "flashbulb" fuse, in which a neutron absorber is built into a single thin wire. When triggered, this wire would flash and release the neutron absorbing material as a gas of much larger volume.

Future Program Plans

The Commission has under consideration many extensions of the present program of research related to reactor safety.

Chief among the contemplated projects is a fast-reactor facility to undertake studies similar to those planned for SPERT and KEWB. Safety studies at the fast-reactor transient facility are expected to begin with investigations of this type of reactor's nuclear stability under normal operating conditions. As information about the reactor characteristics is obtained, the study would progress to the effects of deformation of the core by temperature and radiation-induced stresses. After these effects were understood, it would be possible to carry studies of power surges to the point where melt-down of individual fuel elements occurred.

Limited destructive tests in actual operating thermal reactors appear necessary to give a clear understanding of the magnitude and mechanism of energy release in an actual runaway. Consideration is being given to the feasibility of a test facility in which single fuel elements could be subjected to explosive transients, but the resulting explosion could be wholly contained.

An objective analysis of the containment problem will shortly be undertaken under existing Commission contracts. It is necessary to establish several important factors, such as the necessity for elaborate facilities, the cost versus the protection afforded by containment structures, and the various methods available for containment. This analysis will also be supplemented by a theoretical study of the production of shock waves, and of the possibility of incorporating into a reactor structure shields which would minimize damage and reduce the required strength of the outer containment vessel.

It is important continually to improve the quality of the instrumentation of operating reactors. While some work on instrumentation development is under way among contractors participating in the reactor safety program, substantially more effort will have to be devoted to this important area. Special instruments also are needed, for example, to measure temperature, pressure, and neutron flux during rapid power surges. This instrumentation must be small enough to be placed wherever desired in the reactor, must resist corrosion, and operate adequately in a high radiation field.

Other safety projects will include:

a) Improving arrangements for reactor control, the so-called man-machine interrelationship, so that the operator can most quickly give a correct response to an emergency situation.

b) Devising burnable reactor poisons—neutron absorbers which are placed in the core to be slowly converted by radiation to non-absorbers, so as to reduce the need for additional fuel to be placed in a reactor core to override the accumulation of fission product poisons.

c) Development of an operational definition of a "safe reactor."

d) Studies of the relation between safety and cost of reactors. The Commission must insist upon an adequate degree of safety for the public. At the same time, it is clearly not feasible to increase the cost of the reactor indefinitely to provide certain increments of safety. Ultimately what is required is a rational basis for relating the cost of a given degree of safety to the economic worth of each particular reactor. It will then be possible to decide the merits or demerits of a particular reactor and site in a relatively objective way.

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IV

RADIOACTIVE WASTES

The problem of handling and disposing of radioactive wastes runs through the entire fabric of nuclear energy operations. Wastes in gaseous, liquid or solid form, are evolved in mining of ore, production of feed materials, operation of reactors, chemical processing of spent reactor fuels, and in research work. Because of the long life of some radioactivity, the ability of radiation to cause injury to human, plant and animal life, and its potential danger as an environmental contaminant, the safe handling and final disposal of wastes is important to the successful application of nuclear energy to peaceful uses.

It is the Commission's policy to be conservative in all matters of radioactive waste disposal, and to rely on operative experience and the results of research to establish better methods and to reduce costs. Methods of waste-disposal and waste-handling were reported in detail in the Eighth Semiannual Report (January–June 1950), and research and developments in this field have been reported from time to time as activities warranted.[17] Here, the Commission summarizes its research and development program for waste handling, briefly reviews general methods, and describes some current research efforts.

The major objectives of the Commission's current waste disposal research and development program are:

a) To develop better and cheaper ways for safe handling and disposal of gaseous, liquid and solid wastes—particularly those from reactor and chemical processing plant operations;

b) To evaluate quantitatively natural dilution and concentration factors determining the degree of treatment required before wastes are released to the ground or to the atmosphere or surface areas, thereby taking advantage of such natural factors;

c) To learn more about fundamental phenomena and the processes inherent in disposal of radioactive and toxic wastes so that more efficient and economical methods may be devised;

d) To aid in integrating the nationwide efforts of other Federal agencies, which deal with waste disposal and environmental sanitation problems in industry, with the newer and unique operations in the field of nuclear energy to the mutual advantage of waste disposal specialists; and

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[17] For the most recent summary, see pp. 62, 113, Twentieth Semiannual Report (January–June 1956).

e) To assist State and local officials concerned with waste disposal and related environmental problems in better understanding of related problems in the atomic energy industry.

Gaseous and Other Airborne Wastes

Gaseous or airborne particulate wastes vary greatly with their origins. Tiny particles of radioactive material originating from failure of a fuel element in an air-cooled reactor, particulates and iodine from fuel processing plants, and particulates from plutonium fabrication facilities, have from time to time presented problems. The development of special high-efficiency filters, and of iodine gas removal units, has solved many of these problems.

Air used as a coolant for a reactor is prefiltered to remove particulates which would become radioactive when irradiated. High-efficiency filters also are used to remove radioactive particulates from gas that has passed through a reactor. Filters of glass or kraft paper and asbestos are available in several sizes. Large sand-bed filters are used where the volume of air to be treated is great. Short-lived radioactive isotopes of gases, such as iodine, in the waste streams from chemical processing plants can be released to the atmosphere through a tall stack if conditions are favorable for large dilution at safe altitudes.

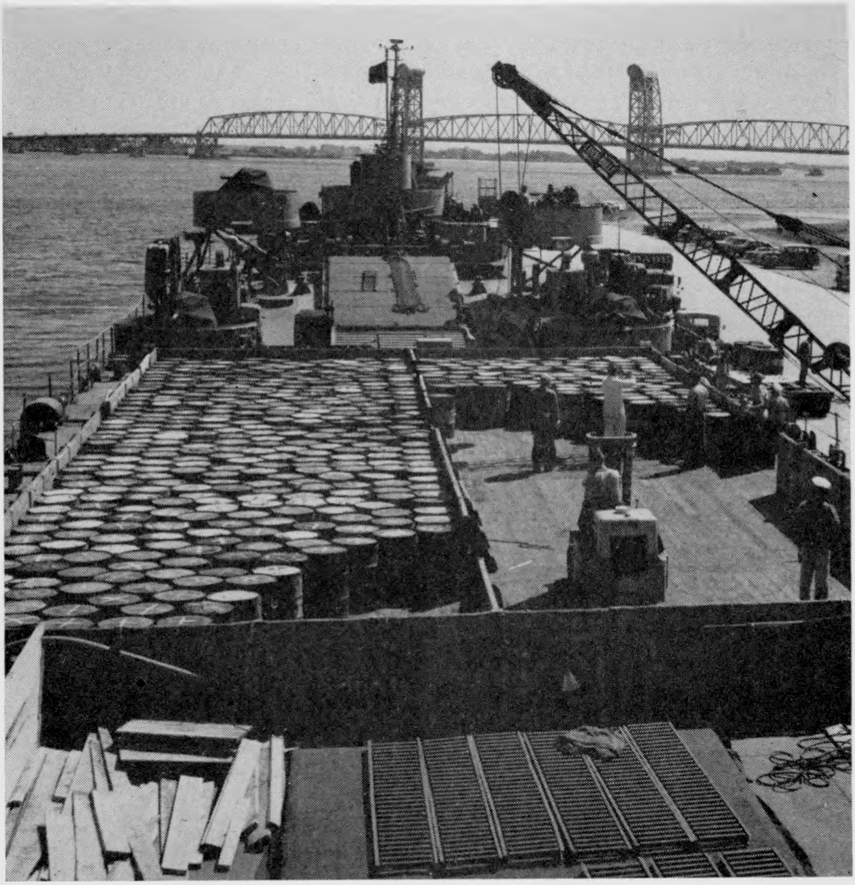
Studies in micrometeorology at all major Commission installations have shown how a variety of conditions will affect the dispersal of stack discharges, and what hazards would arise should serious disruptions occur in normal operations involving radioactivity. A sensitive method for studying gaseous diffusion from stacks has been developed at Argonne National Laboratory. Harmless freon gas, the kind used to cool refrigerators, is released through a stack, or from a meteorological tower, and its diffusion to various areas is measured with a device which can detect as little as one molecule of freon in a million molecules of air. With information derived from these studies, plans have been devised for coping with unexpected operating incidents.

Disposal of Solid Waste

Solid radioactive wastes, such as machine turnings, contaminated equipment, and contaminated trash, do not constitute a serious technical problem. The levels of activity range from very slight to contaminations severe enough to require special or remote handling equipment.

To date, such wastes have been buried under controlled conditions, on land or in the sea. Established burial grounds exist only at certain production and research sites (Oak Ridge, Tenn.; Savannah River Plant, S. C.; Idaho Falls, Idaho; Los Alamos, N. Mex.; and the Hanford plant, Richland, Wash.). Other installations ship solid wastes to established areas.

A burial ground for radioactive wastes is fenced to limit access, and is a dedicated plot that will not be usable for other purposes for a long period of time. Monitoring wells are maintained in the periphery of such plots and a periodic analysis is made of water or soil samples to determine the extent to which wastes have moved away from the burial area.



Sea disposal. Solid wastes, incorporated in concrete and sealed in steel drums, being loaded aboard Navy ship for transport to sea and sinking at depths of 1,000 fathoms—more than a mile deep—alongside a wharf at Floyd Bennett Field, Brooklyn, N. Y. The ship is an LST (Landing Ship, Tank).

Material also may be disposed of by Navy vessels which sink refuse in established areas at sea along with naval wastes consigned to similar dumping. For such disposal all material must be suitably packaged in concrete within steel drums to guarantee sinking and containment on the bottom.

Liquid Radioactive Wastes

Liquid radioactive wastes of low radioactivity and large volume originate in laboratory and plant operations, including the laundering of contaminated clothing. Wastes of this type originate also from some reactor operations, particularly from water-cooled reactors in which the water passes through the neutron flux of the reactor, as at Hanford.

Under suitable environmental conditions, low-level wastes can be disposed of directly after receiving minimum treatment. The Hanford reactor coolant wastes, for example, total millions of gallons per day. Costs for treatment tend to be high, so that to the extent that it is safe to do so, dilution factors available in nature are used as much as possible.

Waterways. At Hanford, the cold water of the Columbia River is used as coolant for the eight Hanford plutonium-production reactors. The water is extensively treated before use, but retains traces of minerals which become radioactive as the water passes through the reactor. The water therefore is held in retention basins for a short time, so that radioactive decay will reduce the amount of short-lived activity, and then is released to the river where residual activity is greatly diluted.

Extensive studies have been made on various methods of water treatment, seasonal changes in water quality, and on the effect of reactor operation practices in producing radionuclides in the cooling water. The hydrology of the river is under continuing study with particular regard to flow velocity, temperature and channeling effects.

Where liquids with low level activity are disposed of in lakes and streams, as at Oak Ridge, and Brookhaven National Laboratory, Upton, Long Island, N. Y., it is essential to have rapid continuous analysis of the kinds of activity, since some less hazardous radioisotopes can be discharged in much larger quantities than others. Advances in gamma ray spectrometry, as at Hanford, now make possible simple, accurate analyses for many isotopes without chemical separation. For example, sodium 24, maganese 56, zinc 65, copper 64, chromium 51 and neptunium 239 can now be determined in reactor effluent water in one tenth of the time previously required.

For isotopes with no gamma emission, beta counting is necessary. Beta proportional counting systems and scintillation counters replace the Geiger-Mueller counters and allow greater sensitivity and speed. Such analyses as these, together with the diluting potentials of the waterways and the adsorbing properties of the muds in the stream bottoms, have come in for intensive study.

Other wastes. Disposal of large volumes of low activity waste to ground pits is practiced in several places, notably Oak Ridge, Idaho, Hanford, and Savannah River installations. Intensive research is carried out on the penetration of the waters and radioactive ions through the soil beds toward ground water.

Geochemical and geological research started at *Hanford* in 1947, and methods were developed for predicting the movement and behavior of contamination in ground water. Research was carried out on the ability of soils to remove from solutions such radioisotopes as plutonium 239, uranium 238, strontium 90, cesium 137, and rare earths.

Expanding investigations have revealed some areas of unusually high permeability that indicate the existence of channels where ground water movement is faster than elsewhere. The possibility that ground water contaminated with radioactive materials could migrate into these channels of rapid flow has intensified hydrological research, and new techniques have been developed to study the rate of flow through soil. The conservative policies on release of wastes have prevented any actual significant transmission to drinking water sources.

At *Oak Ridge*, three pits have been excavated in the relatively impervious Conasauga shale, and since 1951 more than 4 million gallons of low-level waste containing 57,000 curies of cesium 137 and ruthenium 106 have been released to this system of open, seepage pits. Detailed studies have shown that primary movement of these wastes underground is along interfaces of strata. The shale removes positive cations effectively, but is relatively ineffective in removing negative anions such as ruthenium 106 and stable nitrates. Present concentrations downstream from these pits, however, are safely below the levels set for drinking water. The U. S. Geological Survey, Department of the Interior, assists in these studies.

At *hospitals and laboratories* using radioisotopes, the problem wastes are chiefly liquids containing residues of the radioactive material used in experiments or treatment of patients. Scientists and physicians generally use minute amounts of these materials, which with few exceptions, notably carbon 14, have short lives.

Most Commission installations have laboratories which use radioactive materials. The degree of activity varies over a wide range, from radioisotope tracer work to levels many thousand times higher

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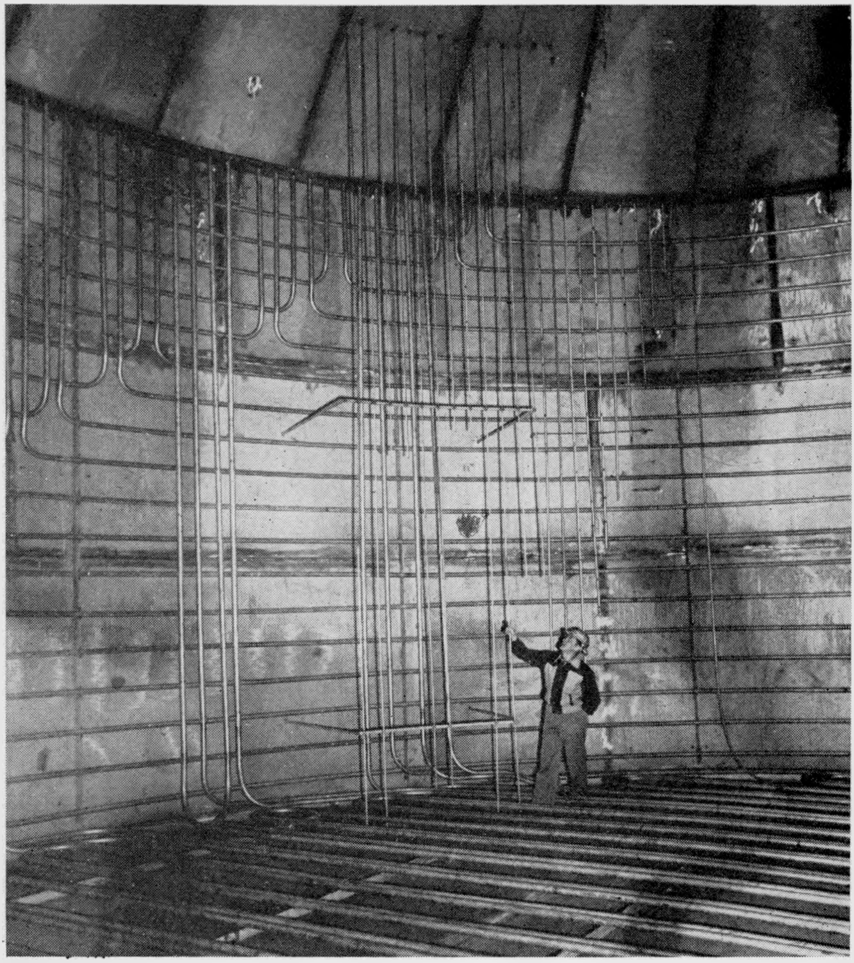
which require special safeguards and "hot" laboratory facilities. In these laboratories research studies are conducted in fundamental chemistry, physics, metallurgy, biology and medicine, engineering development, and in some cases component and pilot plant testing.

High level liquid wastes resulting chiefly from chemical processing of reactor products present the major problem of disposal. The quantity of wastes depends on the reactor fuel and the chemical process being used. In the case of uranium, it may vary from one-tenth of a gallon to 1 gallon per pound of uranium processed, and totals



Waste storage. Storage tanks to contain wastes with a high-level of radioactivity may be equipped with cooling machinery to remove the heat of radioactivity and reduce the corrosion. Photograph shows the cooling coils installed in a stainless steel tank in the Chemical Processing Plant area of the National Reactor Testing Station.

millions of gallons a year. These wastes are stored in tanks, and not disposed of in the sense that low-level wastes are.

Storage tanks may vary in size from tens of thousands of gallons up to 1 million gallons or more. Heat generated by radioactive decay may be used to concentrate wastes in some cases; in other cases waste solutions must be cooled by circulating water in pipes to reduce corrosion.

Storage in tanks is not a final economical answer. On the other hand, sufficient dilution probably is not available in nature for any safe, continuing dispersal to the environment of materials having high levels of long-lived radioactivity.

A number of approaches is being studied in an attempt to solve the long-term problem of safe disposal of high level wastes.

One way is to convert fission product waste material associated with aluminum nitrate salts to a dry oxide powder by heating to high temperatures. Under proper conditions it may be possible to make the fission products nonleaching. Packaging of the solids in sealed steel containers may offer added protection.

A promising method is to mix wastes with native clays and then fuse them in a kiln into a ceramic mass at 1,000 degrees centigrade. In this form there would be no leaching and the wastes could be stored or buried. Another system provides for the adsorption of the prepared wastes in a volume of montmorillonite clay. The clay is drawn out as a small diameter thread which is placed in an absorption column. This form of the clay provides good hydraulic conditions for flow of the waste solution in the column. Subsequently the saturated clay is heated to about 800 degrees centigrade and fused into a ceramic state. The finished product has the appearance of small rods, and present information strongly suggests that it will be relatively nonleaching.

Another approach is to separate chemically from the liquid wastes the especially hazardous and long-lived beta emitting strontium 90 and gamma ray emitting cesium 137. The cost of removing cesium and strontium might be offset in part by revenues from sale of these materials for industrial, medical, or experimental use. With these two separated for special confinement or practical use, the remainder of the wastes would be at least a hundred times less hazardous and possibly could be disposed of to the environment.

A self-sintering pit method is now under development at Oak Ridge National Laboratory. The high-activity waste solution is slurried with earthen materials, and placed in a lined pit. The heat of the radioactive decay forms the materials into masses without actually melting it—a process called "sintering." The sintered mass needs to be further studied for mechanical strength and insolubility to determine how and where it could be disposed of. Vapors leaving the self-sintering mass are radioactive, and suitable means must be devised for filtering them

Fluidized-bed calcination of aluminum-type wastes has been demonstrated on a pilot-plant scale by Phillips Petroleum Co. at the National Reactor Testing Station. The volume of liquid waste is reduced seven-fold in the process of creating a free-flowing granular solid which can be transported by an air conveyor system to large, partly buried, concrete vaults covered with sheet-metal roofs. This type of waste can be treated with leaching solutions to remove usable fission products.

Geologists are considering the possibility of direct discharge to: spaces prepared by dissolution in subterranean salt beds or salt domes; basins 5,000 to 15,000 feet in depth containing brines with no geologic connection to potable waters or other natural resources; special excavations in selected shale formations; and surface excavations in selected locations where control against contamination of the environment can be assured.

Disposal to the sea offers possibilities of interest to many nations, but is presently carried out only under very limited conditions. Small amounts of wastes from University of California Radiation Laboratory, Berkeley, and Brookhaven National Laboratory, are now deposited more than a mile deep in the ocean in steel drums. Bulk process wastes might be similarly deposited in some type of larger container—perhaps in something as temporary as a plastic balloon. Wastes might be pumped in bulk to cold depths below the level where there is very little sea life, and evidence of slow circulation exchange with waters nearer the surface.

Various features of physical and marine oceanography bearing on the feasibility of sea disposal are under study by several American oceanographic institutes, and data produced by the oceanographic program of the International Geophysical Year may help. Problems of primary consideration are: the amount of radioactivity which would be picked up in ocean spray and held in the atmosphere; the manner in which radioactivity would affect sea life and human food resources; the deep water flow from cold latitudes to the equator and the rate at which it mixes with the surface waters; the eventual dilution of deeply deposited radioactivity if and when it becomes available to sea life; and the effect of eventual surface concentrations of certain radioactive materials by various forms of sea life.

All these questions are under study, through research contracts with Woods Hole Oceanographic Institute, Woods Hole, Mass., Lamont Geological Observatory, Columbia University, New York

City, and Texas Agricultural and Mechanical College, System, College Station, Tex.

Research Programs

Current projects in research on disposal of high level wastes include:

Research and Development Project	*Participant*
Fixation of Radioactive Materials. (At Brookhaven National Laboratory a pilot plant in which radioactivity is fixed on montmorillonite clay has been successfully operated. Currently work is being done on conversion of waste materials to oxides for fixation purposes. At the Johns Hopkins University Laboratory work is being done on the fixation of strontium and cesium in synthetic feldspars.)	Brookhaven National Laboratory, Upton, Long Island, N. Y., and The Johns Hopkins University, Baltimore, Md.
Disposal of high-level wastes into pits. (ORNL studies of the sintering process and field experiment leading to design of self-sintering pits are under way. Investigations on selective removal of strontium and cesium are in progress.)	Oak Ridge National Laboratory, Oak Ridge, Tenn.
Evaluation of geologic and hydrologic problems involved in disposal at or near the earth's surface. (Studies are in progress at various Commission installations and include determination of the adsorption capacity for radioactivity of natural earth materials.)	U. S. Geological Survey, Washington, D. C.
Appraisal of environmental and operational aspects of ultimate disposal systems. (Through active cooperation of such organizations as the Woods Hole Oceanographic Institute and the Earth Sciences Division of the National Research Council, progress has been made in delineating and assessing problems associated with sea disposal and land burial or storage of high-level wastes.)	The Johns Hopkins University.
Assessment of geophysical problems connected with disposal of high-level wastes to various geologic formations. (Preliminary feasibility studies are being made on the use of salt formation, deep geologic basins, special excavations and other geologic strata for receiving high-level wastes.)	National Academy of Sciences, Earth Sciences Division, Washington, D. C.
Investigation of hydraulic and chemical phenomena involved in disposal of liquid wastes into reverse wells. (The nature of the ion-exchange and flow of radioactive liquids in permeable media is being investigated.)	University of California, Berkeley.

Research and Development Project	*Participant*
Quantitative evaluation of dilution factors in surface waterways.	Harvard University, Cambridge, Mass., and Northwestern University, Evanston, Ill.
(The capacity of surface waterways to receive safely radioactive materials is under study. Harvard University is investigating the basic phenomena involved. Northwestern University is making a specific study of a pilot stream preliminary to a more comprehensive evaluation of the Des Plaines River in relation to wastes from Argonne National Laboratory operations.)	
Investigation of meteorologic factors in disposal of gaseous wastes.	U. S. Weather Bureau, Washington, D. C.
(The capacity and limitations of the atmosphere to receive safely radioactive materials are being studied.)	
Air cleaning research and development.	Harvard University.
(Developments seeking to improve air cleaning systems have been in progress for about 5 years. Assistance is provided in evaluating air cleaning operations and problems at various Commission installations.)	
Aerosol investigations.	University of Illinois, Urbana.
(Properties and behavior of aerosols, particulates, as they relate to air and gas cleaning operations are under study.)	
Relation of fall-out to water supplies.[18]	Massachusetts Institute of Technology, Cambridge, Mass.
(The ability of municipal water treatment systems to remove fall-out activity has been studied.)	
Radioactive waste incinerator development.[19]	U. S. Bureau of Mines, Washington, D. C.
(Based on pilot plant tests, design and specifications for 30- and 100-pound-per-hour units for handling contaminated combustible wastes are in preparation.)	
Treatment of low-level wastes by algae concentration.[19]	University of Texas, Austin.
(The feasibility of utilizing radioactivity concentrating ability of algae for handling low-level liquid wastes has been determined.)	

Related research and development work at other Commission sites is reported elsewhere and is not included in the above tabulation. This additional research represents sums substantially greater than expended annually in the sanitary engineering program listed here.

[18] Project completed.
[19] Project completed.

Future Research Programs

The major objective of future research and development activities in disposal of high-level wastes is to bring to engineering reality such ultimate disposal systems as are established as being technically and economically feasible.

Actual work in the future program will fall into two main categories: First, extrapolation of laboratory studies which have already indicated practical ultimate disposal systems, such as fixation of radioactive materials and removal of strontium and cesium.

Second, the initiation of laboratory and field investigations on ultimate disposal systems shown by preliminary evaluation to be promising. The outstanding priority in this category is disposal into various geologic formations. Specific problems include control of the heat of radioactive decay; evaluation of chemical and physical reactions between wastes and various earth materials; development of suitable environmental control systems; and investigation of problems involved in physical handling and transportation of highly radioactive materials.

Future work will require actual field investigations with associated geophysical exploration, drilling and instrumentation.

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V

RADIATION PROTECTION IN COMMISSION ACTIVITIES

The Atomic Energy Commission has followed a policy of keeping to a minimum the radiation exposures of workers in the installations of its contractors. Usually, the exposure is less than those levels believed acceptable on the basis of research, or of calculations based on experience with other sources of radiation. Permissible levels for the public are set even lower, generally at one-tenth of industrial levels. Large and continuing programs of research are directed and sponsored by the Commission to determine accurately the levels which may be considered harmless from a chemical and radiological standpoint. These studies on radiation dosage and chemical toxicity, and the standards derived from them, are reported later.

In practice, few workers are exposed even to the allowable limit for radiation. Some accidents have resulted in injury, and some workers have undergone technical overexposures, but average exposure of workers within atomic energy installations are well below the standards established.

The following series of tables lists radiation accidents in atomic energy activities, and reports the general exposure records in routine operations of Commission contractors. Accidents are reported, beginning in August 1945. The exposure records for operations start with the period of responsibility of the Atomic Energy Commission in January 1947.

In 11 years between August 1, 1945, and July 3, 1956, there were 16 radiation accidents in which 69 persons were overexposed to radiation. In 8 cases, only one person was involved. In another single instance, 28 servicemen were overexposed by an unexpected concentration of fall-out after a 1954 weapons test. Of the 69 exposed, only two died—in 1945 and 1946. Of the remainder, 19 suffered skin injury, and several exposures were comparatively minor.

The following lists give occupational radiation exposure experience in the Government atomic energy operations from August 1945 through July 1956:

Incidents Involving Radiation Overexposures Which Resulted In Injury or Death

Date	*Location*	*Number Involved*	*Extent of Exposure*	*Nature of Incident*
Aug. 21, 1945	Los Alamos	2	1 fatal; 1 other received 32 roentgen (r).[20]	Inadvertent criticality in experiment.
May 21, 1946	Los Alamos	8	1 fatal; 7 others exposed to descending amounts resulting in hospitalization; all 7 recovered.	Inadvertent criticality in experiment.
May 19, 1948	Pacific	4	Radiation burns to hands.	Failure to handle radioactive air filters properly after collecting by airplane following weapons test.
Sept. 7, 1948	Los Alamos	1	Radiation burn on ankle.	Allowed radioactive material he was unpacking to rest against his leg.
July 9, 1952	Los Alamos	1	Radiation burn on fingers of right hand.	Handling material with torn gloves.
Mar, 1954	Marshall Islands	28	78 r	Fall-out from weapons test, 40 percent suffered skin lesions.
July 25, 1955	Idaho Falls	1	Radiation burn in external ear.	While welding, particle lodged in ear.
Apr. 30, 1956	Los Alamos	1	Slight suspected radiation burn on hand.	Handling radioactive source.

Other Incidents Involving Radiation Overexposure

Date	*Location*	*Number Involved*	*Extent of Exposure*	*Nature of Incident*
June 2, 1952	Chicago	4	12, 71, 146, and 189 *rep.*[21]	Accidental criticality during control rod test on experimental reactor
Feb. 16, 1955	Hanford	1	Est. 1½ times permissible body burden of plutonium	Maintenance of contaminated equipment
Mar. 1, 1955	Nevada	1	39 r	Guard entered contaminated area
May 11, 1955	Hanford	3	Whole body estimate 3.5 *rad.*[21]	Handled irradiated metal from a reactor
Jan. 18, 1956	Nevada	4	28, 14, 4, 19 r	Overexposure during recovery operations
June 16, 1956	Savannah River	1	7 *rad*	Operator inhaled radioactive gas
June 18, 1956	Hanford	1	Probable significant body burden of plutonium	Break in instrument line
July 24, 1956	Idaho Falls	8	21.5 to 2.5 r	Placing experiment in materials testing reactor

[20] A unit of measurement of gamma ray and X-ray radiation; see later section of this chapter for detailed definition.

[21] A unit of measure of effects of radiation see later section of this chapter for full definition.

In addition, a number of other incidents which involved radiation are listed:

Other Incidents Involving Radiation

Date	*Location*	*Number Involved*	*Extent of Exposure*	*Nature of Incident*
May 7, 1954	Hanford	4	Slight plutonium body burden	Explosion in pot of turnings from plutonium machinery
December, 1954	Savannah River	1	Records indicate employee could not have received injurious exposure	Handling contaminated material. After a hearing before a member of the South Carolina State Compensation Commission, there was a finding that employee had in fact been injured
Jan. 10, 1955	Idaho Falls	1	Records indicate employee could not have received injurious exposure	Employee claims radiation sickness. Matter is now before the Idaho State Industrial Accident Board
June 11, 1955	West Milton, N. Y.	1	1.5 r.	Fire involved radioactive sodium at reactor
Oct. 31, 1955	Savannah River	1	Records indicate employee could not have received injurious exposure	Alleged radiation injury. Employee has since died. Case is now before the South Carolina State Compensation Commission
Jan. 17, 1956	Hanford	1	Plutonium contamination to hands required 50 days to remove all plutonium	
Jan. 18, 1956	Bridgeport, Conn.	1	Employee took home a piece of string with cobalt source attached	
Feb. 1, 1956	Oak Ridge	4	Possible 1.5 rep. maximum	Unanticipated criticality during experiment
May 14, 1956	Fort Belvoir	15-25	Possible exposure to not more than 6 r	Cover left off radioactive source
July 2, 1956	Bayside, N. Y.	4	1 fatal; 3 others required hospitalization	Thorium explosion. No radiation injury was involved

The following series of five tables was prepared on the basis of summary reports of experience from the Commission's 32 principal operating contractors with respect to radiation exposure in routine operations. The incidents reported earlier are not included in these statistics. Although the periods reported by the 32 contractors do not in 8 cases cover the full span from January 1947 through June 1956, the coverage is good and the figures as given are considered statistically representative.

Table No. I summarizes exposures of nearly 200,000 contractor personnel to external radiation in routine operations over a period of 9 years ended December 31, 1955. No. II lists highest accumulated exposures in routine operations during the same period. No. III itemizes annual totals of single exposures to external whole-body radiation above permissible limits for 9½ years ended June 30, 1956. Table IV similarly reports on single exposures to internal radiation for the same period. Tables Nos. V–A and V–B report on workers exposed to the possibility of acquiring body burdens of radioactive materials for the same 9½-year period.

The exposures, reported in Table I for nearly 200,000 contractor employees show that during the 9-year period covered, more than

Table I—Exposures of Contractor Personnel to Penetrating Radiation, Summarized for Period 1947–1955, Inclusive

Range of Annual Total Exposure in Rem[a]	1947-1955 Number of Workers	1947-1955 Percent of Total Number of Workers	1955 only Number of Workers	1955 only Percent of Total Number of Workers
0–1	186, 836	95. 34	56, 708	94. 21
1–5	8, 468	4. 32	3, 157	5. 24
5–10	569	0. 29	285	0. 47
10–15	73	0. 04	41	<0. 07
>15[b]	19	0. 01	3	<0. 01
Total	195, 865	100. 0	60, 194	100. 0

[a] Rem is a unit used to measure the potential damage to man or mammal caused by radiation. Later section on Standards of Radiation Exposure gives details.

[b] Exposures exceeding 15 rem/year include both routine technical overexposures and accidents. There were no deaths during this period which were attributable to radiation.

(Note: the symbol > means "more than;" < means "less than.")

99.4 percent were exposed to less than 5 *rem* [22] a year, as compared with present permissible limits of 15 *rem* a year.

Table II summarizes the highest annual exposures of contractor employees in routine operations, including weapons tests and cases in which workers accepted for specific tasks higher levels of radiation exposure than customary (but not above quarterly limits). Accidents reported elsewhere are not included. The average of the highest individual doses received during the 9 years is 16.4 *rem*. The average

Table II—Highest Accumulated Yearly Exposures in *Rems* to Individual Contractor Employees During Routine Operations in Years 1947–1955, Inclusive

Exposure	*1947*	*1948*	*1949*	*1950*	*1951*	*1952*	*1953*	*1954*	*1955*	*Average 1947–55*
Highest Dose[a]	23. 5	20. 3	13. 6	9. 0	7. 1	15. 7	12. 9	27. 8	17. 9	16. 4
Average of Highest Doses[b]	7. 4	7. 8	4. 0	3. 9	2. 8	5. 0	4. 9	6. 5	5. 8	5. 1
Average of 10 Highest[c]	5. 2	4. 2	2. 6	2. 2	1. 8	2. 9	3. 4	3. 9	4. 1	3. 4

[a] Indicates highest exposure which occurred during the year in the Commission program in the course of routine plant, laboratory, and test operations. It does not include accidents which are reported elsewhere.

[b] Indicates average of the single highest annual exposures which occurred in each of the contractor's operations for each year covered.

[c] Indicates average of the 10 highest annual exposures which occurred in each of the contractor's operations.

[22] The rem is a unit for measuring the damage to mammals or man caused by various kinds of radiation. Details of this and other units of radiation measurement, and of the permissible levels which govern atomic energy operations, are given in a later section on Standards of Radiation Protection.

of the 10 highest exposures for any one year reported was only fractionally above 5 *rem*, and for the 9 years the average was 3.4 *rem*.

Table III gives single above-limit exposures of contractor employees to whole-body radiation in routine operations. The accidents reported elsewhere are not included, and quarterly exposure levels were not exceeded. In single exposures of more than 3 *rem*, many of them accepted during special operations, a total of 139 persons was involved during 9½ years in routine activities, and 98 at weapons test sites during the same period. These single over-exposures are not necessarily serious.

Tables IV, V–A and V–B, report exposures of contractor personnel through inhalation or similar means to radioactive material taken inside the body. Table IV shows the number of cases in which radioisotopes were taken internally on a single occasion in amounts comparable in degree to the acquisition of 3 rems of external radiation. These single overexposures are not necessarily serious but the table indicates the frequency with which safety guides were exceeded.

Tables V–A and V–B are indicative of the frequency with which body burdens of radioisotopes are incurred, and the amounts incurred indicate the level of exposure—rarely above the limits prescribed except in the case of uranium, which is more toxic chemically than radiologically.

The tables show, in the last line of Table V–A, that during the period covered possible exposure to intake of radioactive materials is estimated to have involved 137,723 man-year units (not 137,723 different persons, since the same individual may be tallied in successive years). Of the 137,723 involved, 71,122 man-year units showed detectable body burdens and 4,910 man-year units showed body burdens greater than the recommended maximum values for continuous exposure. In only 66 of these cases were radioisotopes other than uranium involved.

The excretion of uranium from the body is so rapid that it is measured in terms of days rather than of years or of decades as with some other materials. Thus, although the transient values of the body burden of uranium may exceed from time to time the recommended maximum permissible average values, it is relatively easy, on the basis of information provided by bioassays, to limit the average body burdens of individual employees to permissible values by rotation of job assignment or other appropriate methods of control. For this purpose, measurements of body burdens of uranium in individuals may be made many times per year, the frequency depending upon the risk of intake.

Table III—Number of Single Exposures of Contractor Employees in Routine Operations to More than 3 Rems of Whole Body Radiation, 1947–1956

No. of Exposures	*1947*	*1948*	*1949*	*1950*	*1951*	*1952*	*1953*	*1954*	*1955*	*6 mo. 1956*	*Total*
Operational	1	0	3	2	7	13	[d] 63	23	21	6	[a] 139
Test Sites	---	---	---	---	---	[b] 36	[b] 33	[c] 20	[b] 5	[b,c] 4	98

[a] 53.1 percent of the 32 contractors reporting had no single exposure greater than 3 rem.

[b] At the Nevada Proving Ground, it was necessary for operational reasons to permit single exposures greater than 3 rem for 36 persons in 1952, 33 in 1953 and 3 in 1956, although no one exceeded his permissible quarterly dose of 3.9 rem.

[c] At the Eniwetok Proving Ground, during recovery operations 20 persons in 1954 and 1 in 1956 received single exposures greater than 3 rem.

[d] There were 31 planned exposures in 1953 during the clean up after a Canadian reactor incident at Chalk River, Quebec, but no one was exposed to more than the quarterly permissible dose.

Table IV—Number of Single Exposures of Contractor Employees Resulting in Body Retention of a Quantity of Radioisotope Greater Than Would Be Retained by Inhalation for 10 Weeks at Permissible Concentration,[a] 1947–1956

Year	*1947*	*1948*	*1949*	*1950*	*1951*	*1952*	*1953*	*1954*	*1955*	*6 Mos. 1956*	*Totals*
No. of Exposures	184	399	229	317	277	331	312	501	410	296	3, 256
Manner of entry into body:											
Inhalation											3, 092
Ingestion											23
Cuts											31
Abrasions											34
Other (includes punctures and unidentified)											76
Total											3, 256

[a] This limiting dose corresponds to 3 rem of external radiation as tabulated in Table III above. Not all contractors were able to evaluate their past bioassay data in these terms, but data tabulated here represents the greatest portion of contractor experience. They are considered to be statistically representative.

Table V–A—Number of Contractor Employees Found to Have Measurable Body Burdens During Each Calendar Year in the Period January 1947 thru June 1956

Fraction of [a] Permissible Body Burden	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	Totals [b]
Less than 0.1	472	631	1, 742	1, 807	2, 530	4, 158	5, 568	8, 392	10, 074	6, 392	41, 766
0.1–0.5	129	156	182	295	408	674	1, 965	5, 236	4, 774	2, 304	16, 123
0.5–1.0	22	115	76	136	119	218	611	2, 100	3, 084	1, 842	8, 323
More than 1.0	11	149	90	81	48	83	418	1, 619	1, 595	816	4, 910
Totals	634	1, 051	2, 090	2, 319	3, 105	5, 133	8, 562	17, 347	19, 527	11, 354	71, 122
Number of persons Subject to Exposure	5, 000	8, 019	7, 767	8, 002	8, 592	9, 903	11, 582	18, 577	21, 333	38, 948	137,723

[a] This breakdown into fractions of maximum permissible body burden applies to the maximum value observed during the calendar year.

[b] Totals represent man-year units, not individuals, since individuals might be tallied in successive years.

Table V–B—Part of Permissible Body Burden of Contractor Employees By Isotope

Fraction of Permissible Body Burden	Uranium [a]	Fission Products plus other isotopes	Plutonium	Polonium	Radio-Strontium	Fission Products	Tritium	Ruthenium	Cesium	Americium	Total
Less than 0.1	14, 481	10, 037	6, 394	4, 584	4, 537	1, 598	102	28	5	0	41, 766
0.1–0.5	15, 564	3	25	475	47	1	8	0	0	0	16, 123
0.5–1.0	8, 177	0	5	129	9	0	1	0	0	2	8, 323
More than 1.0	4, 844	0	5	59	1	0	1	0	0	0	4, 910
Total	43, 066	10, 040	6, 429	5, 247	4, 594	1, 599	112	28	5	2	71, 122

[a] Permissible body burden for natural uranium is based on chemical toxicity which is less than the value would be be if based on internal radiation hazard (see discussion of uranium toxicity, Chapter VI).

Administration of Radiation Safety

The Commission's responsibility under the Atomic Energy Act of 1954 for protection of workers and the public against radiation originating with its operations or products is carried out, under the Commission's direction, through a number of its divisions, through its operations offices in various parts of the country, and by Commission contractors.

The Commission's contractor-operators, whose employees and staffs deal with radiation, are directly responsible to the Commission for assuring protection in their operations and for their neighbors. The Commission establishes permissible levels of exposure to radiation. Commission staff and members of its operations and field offices confer with contractor organizations on proper procedures and instrumentation for accomplishing compliance with the standards, and for maintaining records of the results of radiation safety work.

Within the Commission, the Division of Biology and Medicine has responsibility for recommending policies on safeguarding the health of atomic workers and the general populations against hazards arising from atomic energy operations. It is charged with formulating Commission standards for protection against radiation, which it accomplishes through adaptation of the recommendations of the National Committee on Radiation Protection and Measurement,[23] in a form suitable for application in the Commission's plants and laboratories. A related body, the International Commission on Radiological Protection, whose membership overlaps with that of the United States National Committee, makes recommendations for limits on an interna-

[23] Until 1955, known as the National Committee on Radiation Protection.

tional basis.[24] The recommendations for United States levels are made by the various specialized subcommittees of the National Committee on Radiation Protection and Measurement (sponsored by the U. S. National Bureau of Standards), and the Commission lends assistance to their work by supporting research which provides data on which the recommendations can be based. The Committee, first constituted in 1928, is composed of experts in the fields of radiation effects and protection. It has had long experience in dealing with the various health aspects associated with radiation. The Committee's recommendations are set forth by the U. S. National Bureau of Standards in a series of Handbooks.[25] The Division of Biology and Medicine also recommends to the Commission the radiological safety criteria to be applied in weapons tests.

To provide supporting biological and medical knowledge about radiation, research is undertaken in Commission facilities and under contract with scientific organizations. This research program, administered for the Commission by the Division of Biology and Medicine is aimed at developing more precise information on the effects of various kinds and sources of radiation on biological systems, the methods of preventing, minimizing, or relieving the harmful effects of radiation, as well as the development of new radiation measuring techniques and instrumentation. Through its Health and Safety Laboratory, the Commission also has developed and maintains a world-wide monitoring network to detect and report on radioactive fall-out. Advice and asistance are provided to Commission contractors on various aspects of radiation safety, and programs are sponsored to increase the supply of scientists and technicians in this field.

Primarily through it Division of Reactor Development, the Commission directs research into methods and facilities for the safe handling and disposal of radioactive wastes (in which the Division of Biology and Medicine participates) and sponsors and administers

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[24] Appendixes 12 and 13 list members of the International Commission and National Committee.

[25] Basic guides for radiation protection used by the Commission: National Bureau of Standards Handbooks: NBS 42, "Safe Handling of Radioactive Isotopes"; NBS 48, "Control and Removal of Radioactive Contamination in Laboratories"; NBS 49, "Recommendations for Waste Disposal of Phosphorus 32 and Iodine 131 for Medical Users"; NBS 51, "Radiological Monitoring Methods and Instruments"; NBS 52, "Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water" (1953); NBS 53, "Recommendations for the Disposal of Carbon 14 Wastes"; NBS 54, "Protection Against Radiation from Radium, Cobalt 60, and Cesium 137"; NBS 55, "Protection Against Betatron-Synchrotron Radiations up to 100 Million Electron Volts"; NBS 56, "Safe Handling of Cadavers Containing Radioactive Isotopes"; NBS 58, "Radioactive Waste Disposal in the Ocean"; NBS 59, "Permissible Dose From External Sources of Ionizing Radiation" (1954); and NBS 60, "X-ray Protection". Also the American Standards Association's ASA Z54.1, "Safety Code for Industrial Use of X-rays."

research to demonstrate safe operating limits and safe design in reactors.

The functions and performances of all these agencies of the Commission are reported in this chapter, and elsewhere in this report. Chapter II "Radiation Safeguards for Licensed Activities," describes the pattern of administration for radiation safety in licensed activities, and other aspects of Commission activities are reported in Chapter III, "Safety Factors in Reactor Design and Operation," Chapter IV, "Radioactive Wastes," and Chapter VI, "Research Programs on Radiation Effects and Treatments."

In administering radiation safety in it own operations, the Commission through its Division of Organization and Personnel prepares training material designed to translate knowledge of radiation hazards into forms suitable for nontechnical people. Through this division, cooperating with Biology and Medicine, the Commission operates its accident reporting procedure, issues instructions for, and compiles reports and statistics relative to accidents which result in radiation injury. The Commission's Administrative Manual requires prompt reporting and detailed follow-up on any serious radiation accident, and this information is widely distributed for application to related situations.

Operating aspects of radiation protection are administered by the managers of the Commission's 10 operations offices in various parts of the country (see Appendix 1). At each operations office technical personnel are charged with responsibility for examining programs, procedures, and physical protection measures provided by the contractors for protection of their employees and the public.

Responsibility for designing protection procedures rests with the contractors, as does carrying out and enforcing protection measures, under the general supervision and inspection of Commission field staff. Each contractor operating a facility where a radiation hazard is possible has an organization staffed and equipped specifically to deal with the protection of his employees against the specific hazards of his operation. Since radiation hazards vary widely both in nature and degree, and management patterns differ among contractors, the radiation safety organizations operate and are administered by the contractors in different ways. All have been extremely successful in coping with radiation problems.

Health Physics Groups

Radiation protection among contractors is considered a "line" responsibility of managers of operations, superintendents, foremen, or laboratory directors and project chiefs in charge of activities. The philosophy and principles of radiation protection are applicable to engineering and other safety related fields and are applied there. Most of the actual work of radiation protection is performed by contractor employees usually under the direction of specially trained persons designated as "health physicists" or some similar title. The health physicists also conduct some related research, and supervise the monitoring of the environment to assure protection of neighbors of Commission installations.

Commission operations. In two cases, Commission staff directly carry out radiation protection activities: through the Health and Safety Laboratory and through the Idaho Operations Office for the National Reactor Testing Station.

The Health and Safety Laboratory has undertaken evaluation and control of hazards arising from a wide variety of operations. Its earliest responsibilities concerned primarily safeguarding the processing of beryllium, uranium and thorium compounds from ores. It serviced many Commission plants throughout the country. Laboratory investigations helped establish more precise definitions of the toxicity of important atomic energy materials, and consequently the development of safer plants and facilities.

As individual plant operations expanded and contractor personnel were trained in health and safety standards and techniques, the laboratory's role became more advisory. It provided consultation and personnel for field and laboratory studies, analytical facilities, and an instrument loan program. As the use of cyclotrons, Van de Graaff generators and other particle accelerators increased at both Government and university sites, investigation of radiation hazards associated with these machines was undertaken by field teams of the Health and Safety Laboratory. In addition, research has been performed on such problems as the economics of shielding, waste disposal, and neutron dosimetry.

During the past 5 years, the Commission has directed increasing laboratory effort toward measuring radioactive fall-out from weapons tests, both in the operation of a worldwide monitoring system and in laboratory analyses of samples of milk, soil, vegetation, fish, water and other materials.

The Idaho Operations Office administers the National Reactor Testing Station about 40 miles west of Idaho Falls, where four Commission contractors operate seven major facilities, with several more scheduled for early operation. In this situation, it is economical for the operations office to provide the site and area radiation monitoring, waste disposal services, instrument procurement and maintenance, film badge service and central records. Its activities to protect neigh-

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bors are reported with those of other installations in a later part of this chapter.

Health physicist staffs. At this time about 1,060 persons are employed in radiation protection work in Commission plants and laboratories. The 1,060 comprise physicists, chemists, engineers, meteorologists, radiobiologists and monitors. Senior health physicists are college graduates with scientific background, and often with postgraduate training in theoretical and applied health physics work. These specialists are in turn supported by 695 technicians and clerical staff.

The detail of personnel presently engaged in this work for the Commission and its contractors (not including several hundred who serve university, hospital and industrial laboratories) is given below. Only 69 of these are direct Commission employees; the remainder work for contractors. At the time of the Eighth Semiannual Report (July 1950) the health physicist staffs totaled 828, including 20 direct Commission employees.

Health physicist employment in the latter half of 1956 comprised the following:

Area by Operations Office	Total		Commission		Contractor	
	Professional	Support	Professional	Support	Professional	Support
TOTAL	1,060	695	69	34	991	661
Albuquerque	121	69	6	0	115	69
Chicago	77	65	4	0	73	65
Grand Junction	0	0	0	0	0	0
Hanford	309	179	1	0	308	179
Idaho	56	31	22	26	34	5
New York	33	40	17	8	16	32
Oak Ridge	134	120	13	0	121	120
San Francisco	58	80	0	0	58	80
Savannah River	237	90	2	0	235	90
Schenectady	31	21	0	0	31	21
Washington	4	0	4	0	0	0

Training programs. Radiological physics, or health physics, has common interests with a number of well-recognized fields of specialization such as physics, chemistry and biology. The health physicist is concerned with the development of sound philosophy and principles of radiation protection, and the application of these principles to practical situations through such methods and techniques. He devises suitable instrumentation, gives assistance, advice and cooperation to health authorities, assists in the education of workers and helps in civil defense planning.

The Commission provides several types of training for people interested and qualified to work in health physics. Most of its plants and laboratories have some type of in-service training on fundamentals of radiation hazards, and on how to work and live safely with radiation. In some cases, as at the Hanford plant, and Los Alamos Scientific Laboratory, Los Alamos, N. Mex., monitors may be given sufficient training on the job for routine survey work. The Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tenn., presents six sessions per year of a 4-week isotopes course, primarily to train laboratory workers in use of radioisotopes, but necessarily including radiation safety.

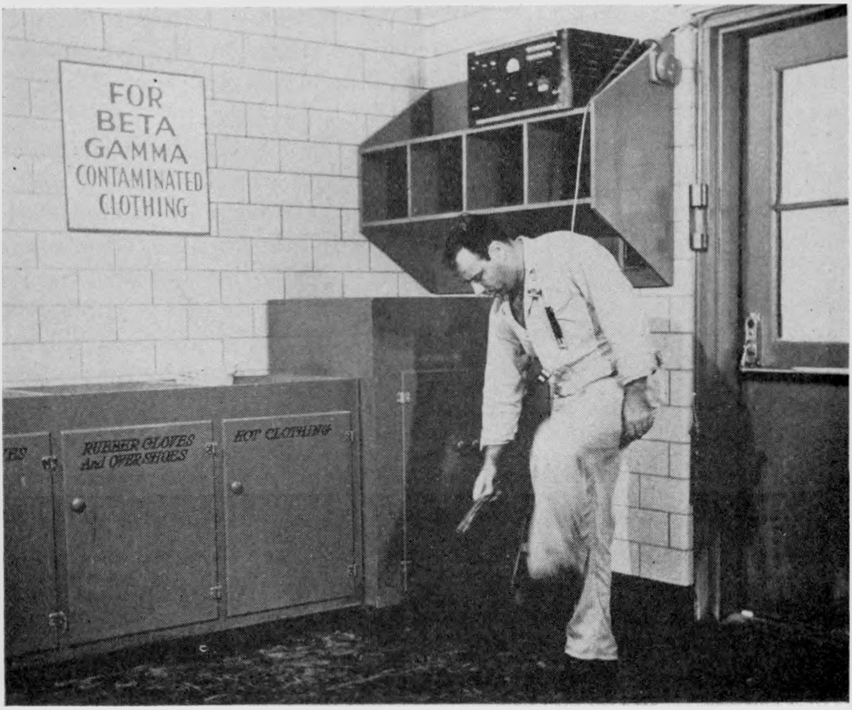
Special training fellowships in radiological physics are offered by the Commission, with the administrative assistance of the Oak Ridge Institute of Nuclear Studies, to qualified college graduates. Many courses under these fellowships carry graduate credit in the chosen academic institution (University of Rochester, N. Y.; University of Washington, Seattle; University of Kansas, Lawrence; or Vanderbilt University, Nashville, Tenn.), and a limited number of fellows are granted extensions of fellowships to complete work for the degree, Master of Science. Practical experience in a large installation—Brookhaven National Laboratory, Oak Ridge National Laboratory, or the Hanford plant—is part of the training.

Stipends are presently $2,500, with an additional $350 for each dependent, plus tuition, fees and travel allowance. At least 75 such fellowships are available each year, and applications can be made to the Oak Ridge Institute of Nuclear Studies before February 15 of any year.

On June 25, 1956, a new group called the Health Physics Society met and organized at the University of Michigan with 775 charter members. The members represent all phases of radiation protection work and are employed by Federal agencies, State and municipal governments, academic institutions, research laboratories and the atomic energy industry. One objective of the Society is to "promote and improve health physics as a profession." It is also under consideration to establish criteria upon which to base certification by the Society that a specific individual is a qualified health physicist.

Contractor Administration

Health physics organizations of the Commission's contractor-operators have grown up with the separate operations being carried out, usually along patterns designed to deal with the markedly different radiation and physical problems of each installation, and to fit customary management patterns.


FOR
BETA
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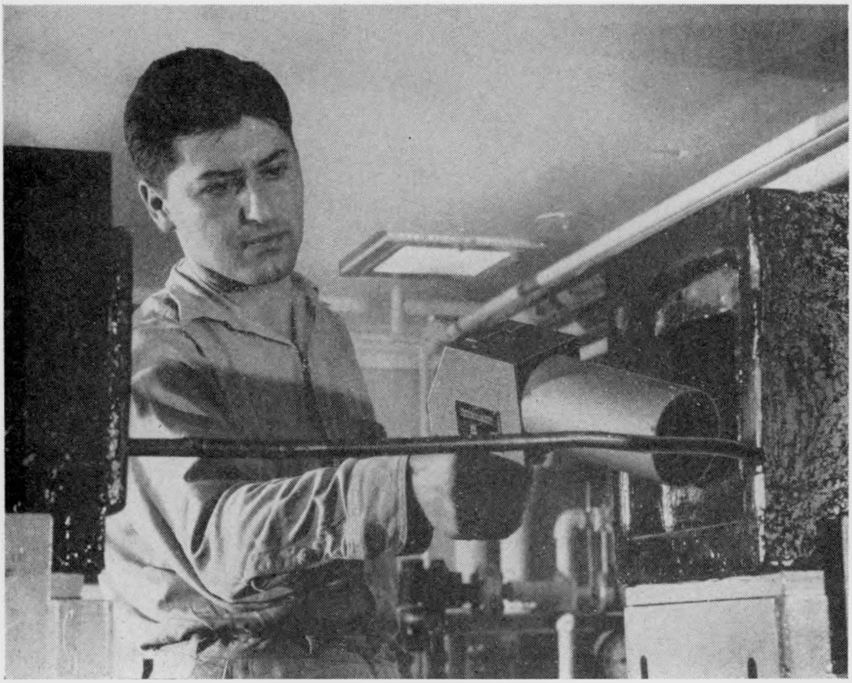
RUBBER GLOVES
And OVERSHOES
HOT CLOTHING



Health physics. At the upper left, a health physics inspector uses a "fishpole" meter in an Oak Ridge plant to measure radioactivity. Lower left, also at Oak Ridge, a worker "frisks" himself to determine whether clothing or body has been contaminated. The bins are for safe containment of contaminated clothing. Above, a health physicist monitor checks the face of the Oak Ridge pile before the lead shield is joined. The rod beside the monitoring instrument will be connected at the face of the pile to containers of radioactive isotopes which will be moved into position where they can be withdrawn by hand tongs.

Certain patterns of administration, however, are common among the contractors:

a) The role of the health physicists, where actual enforcement of radiation safety on the job is concerned, is cautionary and advisory. The supervisor in charge of a certain piece or area of work is the man who is answerable to management for the workers' protection, and for safe operations in general.
b) Close liaison exists between health physicists and medical, industrial hygiene, safety control, and appropriate research groups. In some cases, they are combined. Their related problems are worked out together.
c) Health physicists are usually assigned, where the operation is large enough to warrant it, to the separate plants and are answerable to the managers of those plants in a staff capacity for various aspects of radiation safety. In cases where it aids efficiency, some health physicist responsibilities are centralized for an entire installation.

Each pattern has special advantages from the standpoint of the contractor. All have produced results in radiation protection that have contributed to the excellent record for the Commission operations.

The patterns and particular methods followed by Commission installations were reported in considerable detail in the Eighth Semiannual Report (January–June 1950). Only some features of radiation control administration by a few contractors are reported here, particularly changes or systems at installations given in detail in the Eighth Report.

Oak Ridge. At Oak Ridge gaseous diffusion plants and the Y–12 facility, as in other phases of the accident control program, members of the line organization of the contractor—Union Carbide Nuclear Co., of Union Carbide and Carbon Corp.—have administrative jurisdiction for radiation safety in operations equivalent to their corresponding responsibilities for production and operational activities. In meeting these responsibilities, supervisors are aided by staff groups which have been established at each plant.

In general, these staff groups evaluate the effectiveness of plant control programs, and develop and provide technical information for plant use. Emphasis is placed upon an educational program for all employees, especially supervisors. The continuing effort is to see that information concerning the hazards and the methods appropriate for control under various conditions is made as widely available as possible. In many cases, mandatory operating instructions are issued for hazard controls.

Other more specific aspects of the radiation control program have included: (a) review of the design of new and revised facilities for these specific hazards as a routine part of the safety engineering review program; (b) encouragement of and participation in experimental and theoretical programs designed to make available basic information concerning these hazards and their control (this information has been applied to plant problems as rapidly as feasible); and (c) periodic audit and inspection of facilities and operations to determine actual problems being encountered, to evaluate the hazards actually involved in these problems, and to advise line supervision of the results of these studies.

Hanford. During the past decade, the staff of workers dealing with operational radiation monitoring programs at the Hanford plant operated for the Manhattan District by E. I. du Pont de Nemours & Co., Inc., and now for the Commission by the General Electric Co., has grown from 50 to over 300. These monitoring functions have been assigned to individual operating organizations of the plant to increase functional efficiency. A number of functions have remained centralized and are performed by qualified specialists of the radiation protection operation. They are: the radiological research and development functions, which include the adoption of radiation protection standards and policies, control of individual radiation meters, and bioassay sampling and evaluation.

Plant-wide radiation protection policies have been evolved, standardized, and formalized through the issuance of manuals of radiation protection standards which define, for example: radiation units and nomenclature; radiation measurements; permissible limits and working standards; radiation control procedures; exposure and monitoring records; radiation incidents; and radioactive waste disposal.

These policies are expanded into detailed specifications for each major facility through a series of radiation work-practice manuals. The lore of radiation protection has been enlarged so that the original administrative control device applied to nonroutine jobs including radiation—the Special Work Permit or "SWP" as explained in the Eighth Semiannual Report (p. 35)—has been largely supplanted by these radiation work procedures.

Other examples of centralized control which have been evolved for Hanford, and which have increased the efficiency of the overall radiation protection programs are:

a) Establishing a graphic index function designed to provide topical information on the location of all biologically significant amounts of radioactive material resulting from Hanford operations.

b) Setting up a standards establishment function that has periodically reviewed and revised published Radiation Protection Policies, coordinated activities in nationally sponsored programs such as the evaluation of personnel meters, and assisted in the standardization of signs, symbols and radiation identifying colors.

c) Establishment of a formal system to investigate any reported radiation accidents or evidences of poor radiation practices. One effect is to publicize untoward conditions, and instigate corrective plant-wide reviews of hazardous situations.

d) The instigation of plant-wide auditing of radiological work practices supplements the internal audits performed by the individual operating organizations and has resulted in more uniform controls.

e) The training and instruction of both the plant workers and specialists in radiation-zone work practices and techniques has been expanded, formalized and coordinated into lectures, demonstrations, apprentice-training programs and timely topical literature. This program has increased the number of operations which can be performed under "self-monitoring" conditions.

Savannah River Plant. Radiation protection at the Savannah River Plant, built and operated for the Commission by E. I. du Pont de Nemours is administered by a health physics department entirely separate from traditional industrial safety. Major consideration is given to protecting the plant employees from exposure to radiation, and guarding against product or byproduct release that would adversely affect the environs.

The program is formalized and directed by documented technical standards, special hazard bulletins, and standard operating procedures. These basic guides define and set forth the general limits and practices to be followed. Specific limits and practices are detailed in special work permits for all operations carried out in radiation zones.

Checks are maintained on the effectiveness of the program. Film badge service is provided to record and verify the effectiveness of the control of radiation exposure to personnel. Bioassay service, primarily by urinalysis, is rendered to evaluate and record radioisotopes introduced into the body. Regional monitoring service, established before plant startup, constantly checks for possible environmental contamination.

Radiological engineering studies and laboratory development programs are designed to improve the efficiency and overall radiation protection service. Constant training of supervisors and workers alike is aimed at developing proper attitudes of respect and understanding for radiation hazards, and confidence in the protective measures prescribed.

Standards of Radiation Exposure

The success of efforts to provide radiation protection to workers and the public depends fundamentally on knowing the amounts of radiation able to cause injury to people, and then on setting the standards of permitted exposure well below those points. The mechanisms for acquiring data on exposure effects, and for formulating standards through the National Committee on Radiation Protection and Measurement has been reported earlier in this chapter. The permissible levels of exposure to external radiation and permissible concentrations in water or air of radioactive materials that are dangerous within the body, provide the standards which guide the plans of Commission contractors, licensees and others, and which provide a norm for enforcement.

To provide the background for setting standards, general information has been assembled on the effects of acute massive doses of radiation, such as might occur by accident in a reactor excursion, or in emergencies of war, and on the effects of chronic, low-level doses of radiation, which people might receive over a lifetime. Knowledge in these areas helps to give better definition to the levels of radiation exposure which may be permitted without compromising the health and safety of the individuals, or the welfare of future generations, and yet allowing economic operation of atomic energy programs.

To this end, biological and medical research programs are conducted in the national laboratories and in universities and by the National Academy of Sciences-National Research Council at the Atomic Bomb Casualty Commission. Experimental studies have probed into the effects of radiation upon the body and means of alleviating the damage that might be caused. They deal with the effects of external radiation, and of radioactive materials taken accidentally into the body. Research also investigates the effects of low-level exposure. Much of this research is summarized in Chapter VI, Research Programs on Radiation Effects and Treatments.

Measuring Radiation Exposure

Several units of measurement of radiation exposures are in common use. Gamma rays and X-rays are measured in units called *roentgens* which represent their ionizing effect. When these rays, in fact electromagnetic waves, strike any substance they break down the electrical balance of the components of the substance and divide them into positive and negative fractions called "ion pairs." A roentgen (symbol *r*) by definition is that quantity of gamma rays or X-rays that will produce 2 billion ion pairs in a cubic centimeter of dry air under standard temperature and pressure.

Units of radiation dose applicable to all forms of radiation are the *rep* (roentgen equivalent physical), the *rad*, and the *rem* (roentgen equivalent man). The *rep* is defined as the radiation dose corresponding to the absorption of 93 ergs of radiation energy per gram of tissue. Under certain conditions, this is equal to the energy which would be absorbed per gram of tissue from one roentgen of X-rays. In general, the physical equivalence implied in the name is only approximate. As a unit of tissue dose, the *rad*, defined as corresponding to the absorption of 100 ergs of radiation energy per gram, differs from the *rep* only in size. This unit was adopted in 1954 by the International Commission on Radiological Units, an organization associated with the International Commission on Radiological Protection, to supersede the *rep* and avoid any implication of exact equivalence to the roentgen. However, under many conditions, the dose delivered by one *roentgen* of gamma rays or X-rays is sufficiently close to one *rep* or to one *rad* that, within the accuracy required for radiation protection, the terms may be used interchangeably.

The *rem* is a unit applied to biological effects. One *rem* of any ionizing radiation is the radiation dose estimated to produce a biological effect equivalent to that produced by one roentgen of X-rays. The number of *rem* corresponding to one *rad* of particle radiation depends upon several factors, including (a) the kind of particle, (b) the particular biological effect considered, (c) the size of dose and (d) the rate at which it is delivered. For the cases of most common interest in the program of the Commission, a dose of 1 *rad* from beta radiation is considered equivalent to 1 *rem;* and a dose of 1 *rad* from fast neutron or alpha radiation is considered equivalent to 10 *rems.*

These are the units used to measure radiation effects upon humans, but exposures to external gamma rays or X-rays often are stated as so many roentgens, or thousandths of roentgens (milliroentgens).

Permissible Dose Levels

Based on ever increasing knowledge about the biological effects of radiation, the National Committee on Radiation Protection and Measurement (NCRP), and the International Commission on Radiological Protection (ICRP) make their recommendations on permissible levels of exposure. These recommendations are revised from time to time. Before 1948, the permissible dose to humans was set at 0.1 roentgen, or 100 milliroentgens, a day.

In 1948, the Subcommittee on Permissible External Dose of the National Committee on Radiation Protection and Measurement decided that, because of the higher voltage and increasing penetrability of the X-rays in general use, the permissible dose should be decreased from 0.1 roentgen a day to 0.3 roentgen per week.

In 1954, the committee issued its Handbook No. 59, the recommendations of which the Atomic Energy Commission had been using for several years. Handbook No. 59 interprets the 300 milliroentgens of X-ray or gamma ray exposure into terms of the *rem*, which is actual tissue damage caused by any form of nuclear radiation. Rule I of the Handbook No. 59 (1954) states:

> For young adults whose entire body, or major portion thereof, is exposed to ionizing radiation from external sources for an indefinite period of years, the maximum permissible total weekly dose shall be 300 millirems (0.3 rem) in the blood-forming organs, gonads and lenses of the eyes; 600 millirem (0.6 rem) in the skin.

This is the fundamental rule for radiation protection, but there are a number of permissible variations from it in special circumstances:

a) Persons under 18 years of age may receive only one tenth of 300 millirems per week (0.03 rem). This level effectively limits exposure of general populations (as contrasted to radiation workers) to not more than 30 millirems per week of whole-body radiation.

b) The skin may receive 1500 millirems (1.5 rem) per week of low-energy radiation provided the eyes do not receive more than 300 millirems per week.

c) Hands and forearms, feet and ankles, head and neck, may receive 1500 millirems per week measured in the skin, provided the eyes are adequately protected.

d) Some fluctuations in permissible weekly dose may occur; the unit of time is extended to 13 weeks (¼ year) provided that the dose accumulated during a period of any 7 consecutive days does not exceed the appropriate weekly dose by more than 3 times, and provided further that the total dose accumulated during any 13 consecutive weeks does not exceed 10 times the appropriate weekly dose (3.0 rem).

e) Accidental or emergency exposure of an adult, occurring only once in the lifetime of the person, may be assumed not to affect his radiation status provided he has not received more than 25 roentgen whole-body dose and additionally 100 roentgen to hands and forearms, and to feet and ankles.

The Committee also recommended specific limitations on exposures to neutrons, ranging from an average 2,000 per square centimeter per second for thermal neutrons having an energy of 0.025 electron-volts, down to about 30 per square centimeter per second for fast neutrons of energy greater than 3 million electron-volts.

Recommended maximum permissible levels of radioactive materials in the body burdens, or concentrations in air or water, vary widely from one isotope to another, and even as among chemical forms of one isotope. In general, these limits have two broad bases. In the case of radiostrontium, for example, the limits are based on comparison with the physical and biological properties of radium. In another broad group of isotopes, limits are based on the same fundamental exposure limit as external radiation—to prevent dosage of more than 0.3 rem a week to the critical organ.

These permissible levels of external and internal exposure originated from consideration of hazards of exposure to radiation for occupational reasons. It is general practice to limit environmental levels to values which will prevent radiation exposures to the general population greater than 10 percent of the maximum permissible values recommended for occupational exposure.

Although the recommended levels of exposure have been considered acceptable for the individuals exposed, both the Manhattan Engineer District and the Atomic Energy Commission have regarded radiation in any quantity as potentially harmful and have endeavored to hold exposures to a minimum. The extent to which this endeavor has been successful is illustrated by the radiation exposure records reported earlier in this chapter. Very few workers have received more than a small percentage of the permissible dose.

This policy of caution has been justified. The continuing research program is beginning to develop evidence that, in terms of possible life-shortening for the individual, and possible genetic changes for future generations, the present permissible levels might be too great since they would permit exposures of 15 *rem* a year, or a possible total of 600 *rem* in a 40-year working lifetime. The permissible levels are rarely reached even for short terms, and are exceeded only in exceptional accidents, as reported earlier.

There exists a fair probability that several hundred rems of radiation delivered at low intensity over a long period might have the same mutational effect as the same dose delivered in a short time at high intensity. Also there is considerable evidence that accumulated radiation exposure brings about aging. For the aging effect the fractional reduction in life span per roentgen may not be as great as the result of exposure at low intensity over long periods of time as compared with a single exposure of the same total dose.

Such considerations as these, with the rapidly increasing activity in the field of atomic energy, and the corresponding potential increases in exposures of greater numbers of people, has prompted further study and analysis of possible effects on population groups. These studies have been reviewed by the International Commission on Radiological Protection, the U. S. National Committee on Radiation Protection and Measurement, the U. S. National Academy of Sciences-National Research Council,[26] and the United Kingdom Medical Research Council.[27] Based largely on considerations of possible genetic effects and reduction in life-expectancy, these groups have made recommendations which, while differing slightly in details, may be summarized as designed to limit cumulative exposures of individuals to 50 *rem* in the first 30 years of life; and to 50 *rem* for the next 10 years of life; and to limit exposures "from humanly controllable sources of radiation" so that the average dose to members of the general population should not exceed 10 roentgens in the first 30 years of life. These limits are applicable to irradiation either of the whole body or of the gonads.

These recommendations are under study by the Commission as a partial basis for the formulation of limits on average exposures to radiation which may be incurred over long periods of time.

The following table indicates whole-body exposures in Commission plants compared to natural and diagnostic exposures to external radiation.

Source of Radiation	*Amount of Radiation*
Background	0.15 roentgen (r) or 0.1 rem[a] a year
Average annual exposure of all monitored workers.	less than 0.1 *r* a year
Annual highest exposures from all atomic energy plants averaged over 9 years.[c]	5.1 *r* a year
Routine chest X-ray [b]	0.04 to 1 *r* per exposure
Commission permissible dose, present	15.0 *r* a year
Fluoroscopic examination [b]	10 to 20 *r* a minute
Cinefluorography (X-ray movie) [b]	25 *r* per examination
Estimated lethal dose for 50 to 90 percent of those exposed.	400 to 600 *r*

[a] See earlier definition. One roentgen, or *r*, of X-rays or gamma rays is considered as causing about 1 rem of damage.
[b] These exposures are to parts of the body. All others are whole-body exposures.
[c] See page 165, table II.

Limitations are placed on exposures from internal emitters, including plutonium, radiostrontium, uranium, radium, and radon among others, which are held or concentrated by certain organs of the body. Handbook No. 52 (1953) of the National Committee on Radiation Protection and Measurement recommends permissible limits for body burdens, and limits on concentrations of these and other radio-

[26] "The Biological Effects of Atomic Radiation," National Academy of Sciences—National Research Council, Washington, D. C., 1956.
[27] "The Hazards to Man of Nuclear and Allied Radiations," Medical Research Council, London, England, 1956.

isotopes in air and drinkable water. The limits are reviewed from time to time, and revisions issued as necessary.

These recommendations also are officially adopted by the Atomic Energy Commission for use by its operating contractors and licensees.

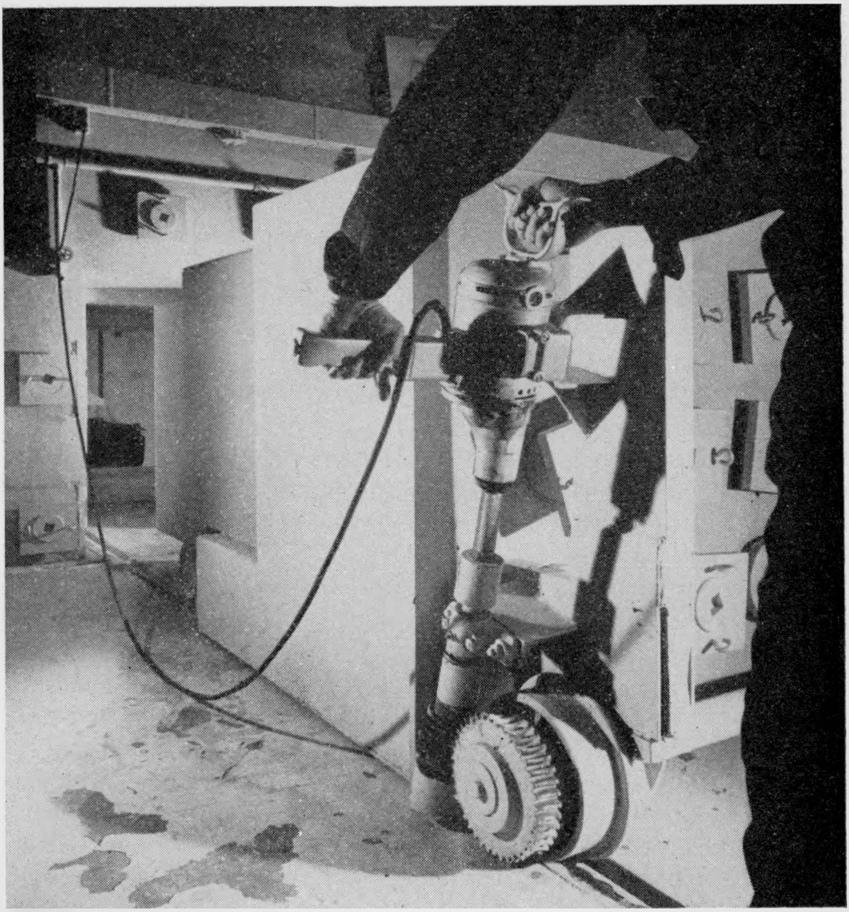
Protection Methods for Workers

Radiation exposure among atomic energy workers usually does not exceed the amounts of radiation exposure which they receive from the natural radioactive materials in the earth and from cosmic rays. This record has been achieved by making radiation safety a primary focus at all atomic energy installations involving possible hazards. Considerations of safety are an integral part of the design of atomic energy machinery such as reactors, of processes such as chemical treatment of spent fuels; of the design of plant and equipment; of the planning and scheduling of work; of medical programs for employees, the selection of personnel and their training; of work routines, and sometimes involve respirators or masks, the kinds of clothing worn, methods of washing, and limits on the areas where workers may eat or smoke.

These steps are important in protecting workers under various conditions either against external radiation, or against hazardous radioactive materials that may enter the body, or both. Precautions taken vary with the operation, and with the type and degree of potential hazards that exist. Safety against sources of highly penetrating radiation is maintained, in general, by three methods. Massive shields are placed about the radiation source, or smaller movable shields may be erected about a temporary hazard. Where workers must handle radioactive material that emits penetrating radiation, they perform their tasks from a distance or they work only for brief periods in the radioactive area and thus limit total exposure, since the amount of radiation received is a factor not only of its intensity but also of duration of exposure.

Protection against radioactive materials that might enter the body by the mouth, through inhaling, or through wounds, is achieved largely by adequate ventilation to keep fumes, dusts, and vapors at low concentration in areas where work is done; by inclosing the sources; by strict industrial housekeeping to prevent or control contamination of surfaces with which workers may come in contact; by vigorous training, discipline, by continuing radiation detection patrol, and when necessary, by special protective masks or clothing.

Radiation records and periodic medical examinations upon workers assist protection from both external and internal hazards. Methods of personnel protection and monitoring follow similar principles at



Massive shielding. Typical of shielding protection against highly penetrating radiation is the four-ton door being moved into position to close an entrance to a "hot cell" at the National Reactor Testing Station, Idaho.

all atomic energy sites; but the exact application varies with the operation and potential hazard.

Special health physics measures to assure workers protection are universal throughout the program. At the National Reactor Testing Station, Idaho Falls, Idaho, for example, employee indoctrination and education programs include health physics lectures and pamphlets, as well as detailed analyses of work. Periodic surveys are made of all operational areas, utilizing radiation survey instruments, and smear samples from floors, walls, laboratory tables and equipment, of operational and research areas which are analyzed to determine possible contamination.

Personal radiation metering devices include badges containing beta-gamma sensitive film and pocket dosimeters, both of which may be worn by those persons admitted to areas containing sources of radiation. Where indicated, neutron-sensitive film badges are issued, as are film rings and direct-reading beta-gamma pocket dosimeters. Pocket meters are read daily; film badges are developed and read at weekly, biweekly, or monthly intervals, unless pocket meters indicate an appreciable exposure.

Permanent monitoring installations are in service in various technical areas, usually including air monitors, hand and foot counters, and "friskers" set up to detect radiation as personnel pass through stiles or narrow passages. Air monitors usually are connected to alarm systems which sound automatically if normal background radiation is exceeded.

Coveralls or laboratory smocks are worn in "hot" areas or for special jobs as are shoe covers and gloves, head coverings, respirators and breathing apparatus which supplies clean air when indicated. Clothing is washed in a special decontamination laundry. Eating, drinking, and smoking are prohibited in areas where there is a chance of contamination.

Urinalyses are run at regular intervals, and special samples may be analyzed if there appears to have been any chance of inhalation or ingestion of radioactive materials.

Many steps taken to protect the workers—safe design, shielding, operating patterns—equally advance the safety of neighbors to installations, and of the environment.

In the Eighth Semiannual Report to the Congress (July 1950), the Commission reported in some detail the methods used by its contractors to control radiation hazards within the program. Some aspects of radiation safety have changed, and general methods of protection have been refined, but all remain basically the same as those reported comprehensively in 1950. The problem and methods are not again given comprehensively in this report. Instead, it describes in detail only developments or methods at installations not fully covered previously, and gives some developments as selected for reporting by principal contractors of the Commission. A later section of this chapter deals on the same basis with protection of the environment near Commission installations.

Processing Feed Materials

Once the small amount of radium present has been recovered from ores, the radiation hazard in the processing of feed materials for production reactors, and for gaseous diffusion plants, arises principally from handling a mildly radioactive material (uranium) in liquid, solid, or finely divided form, and from handling equipment or materials which have been contaminated through contact with radioactive materials.

The original chain of plants for production of feed materials was improvised under extreme wartime pressure, and the work was performed by a number of contractors. It was a difficult sector of the atomic energy program in which to achieve high standards of radiation safety. These facts were reported in the Eighth Semiannual Report. Since then, new construction has replaced earlier less satisfactory plants, and modernization of other plants, also has done much to bring these difficult conditions under control.

Although each material handled at the Mallinckrodt Chemical Works, St. Louis, Mo., for example, has a characteristic radiation and biological effect if absorbed and retained in the body, the protective measures in feed material processing can be based on standards for uranium (these standards, and the research leading to them, are reported in Chapter VI). Control of dust from the material is the major problem.

The plant and equipment are so designed that direct contact of workers with uranium is held to a minimum. Extensive ventilation and dust collection equipment are required. Vacuum cleaning systems are provided to clean dry areas. Wet areas are washed down into sumps, and the collected liquid is processed for recovery of uranium.

Possible internal exposure due to inhalation of radioactive dust is controlled by periodic surveys which measure the breathing zone concentration in working areas. The exposure for an individual then is calculated from the time required for performance of duties in each area. Exposures also are monitored by periodic medical examinations.

Employees working in regulated areas are supplied with complete outfits of work clothing, including underwear, and are required to shower before changing to street clothing. Food may not be taken into regulated areas, and smoking is forbidden. Articles may not be removed from the regulated areas without being checked for radioactive contamination and, if necessary, being decontaminated. Periodic surveys are made of all operations and exposure rates and equipment or operational procedures are modified as required to meet radiation protection standards.

Plutonium Production

Radiation protection problems differ somewhat at the two atomic energy installations at Hanford and Savannah River which produce plutonium in large reactors. These differences arise chiefly because the reactors are of entirely different types.

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At these installations, radioactivity originates from the reactors, from fuel which has been irradiated in the reactors, from any piece of equipment that could be either neutron-irradiated or contaminated with radioactive material, and from contamination in general—the presence of finely divided material such as airborne dust or moisture, or air, that has been irradiated.

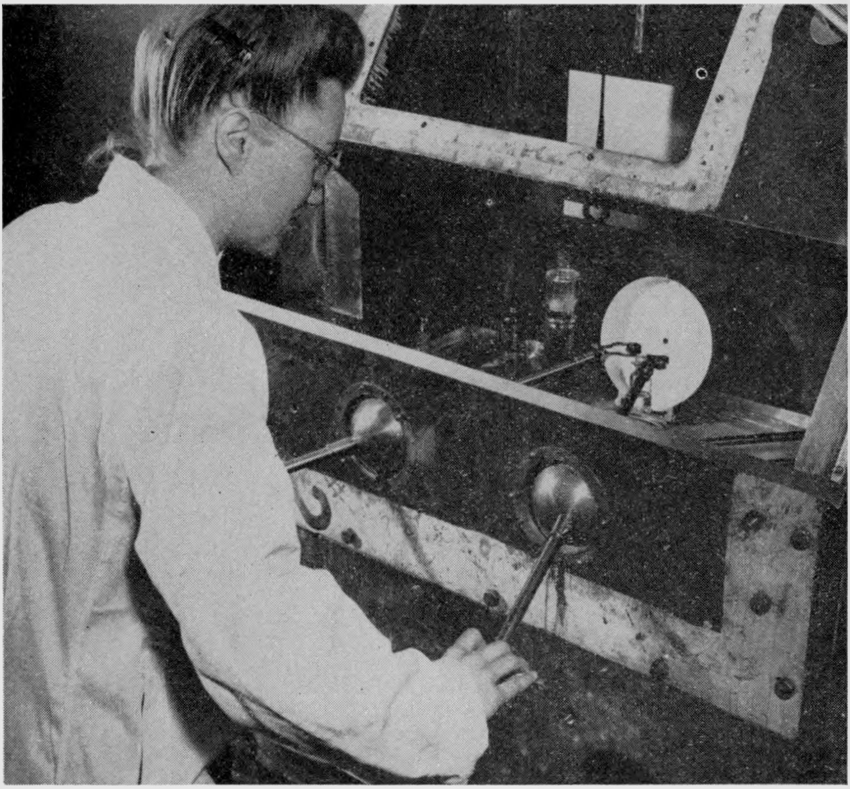
The Hanford reactors are cooled by a single pass-through of treated water from the Columbia River, which becomes somewhat radioactive in the process. The Savannah River reactors are cooled in a closed cycle by heavy water, and the heavy water in turn is relieved of its heat by water from the Savannah River in a heat exchanger which prevents the intermingling of the waters. Since the cooling water which is released to the environment has not been in the reactor itself, it is not subjected to neutron bombardment and does not become radioactive. At both reactor works, the basic protective measures are those which have been summarized earlier: shielding, remote handling, ventilation, industrial housekeeping, monitoring, etc.

An important part of assuring the protection of workers against penetrating radiation is continual automatic monitoring of the work areas. Sensitive portable neutron-flux measuring instruments have been developed and are used to determine neutron radiation levels at work sites.

Hanford. Surface contamination has emerged at Hanford as one of the most serious radiation protection problems in the operating reactors, due principally to rupture of fuel elements. The contractor at Hanford met this problem by a variety of controls, including using "step-off" mats as a disposable floor covering between contaminated and "clean" areas, by personnel monitoring check stations, and by development of a network of continuous monitoring devices which automatically sound an alarm at the first indication of an increase in radioactivity. Increased use of mechanization techniques is helping to reduce personnel exposure.

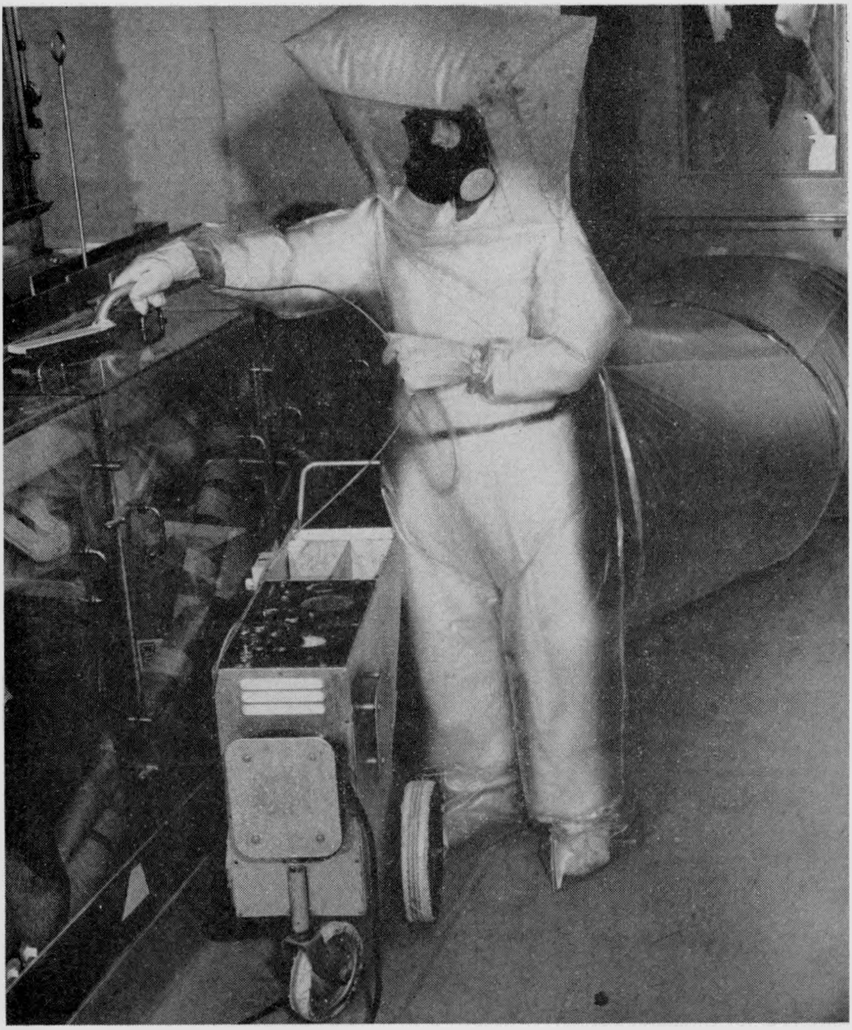
At chemical separations plants at Hanford, personnel exposures have been controlled successfully in the face of contamination hazards that can be only partly eliminated by continuous and detailed attention to decontamination, ventilation, and other controls. Techniques have been evolved for the underwater maintenance of highly radioactive process equipment—thus using the water as a transparent shield—and by the successful handling of highly contaminated material by means of flexible barriers interposed between the workers and the material.

The contamination control problems attendant upon fabrication of plutonium are gradually being reduced. Since plutonium is a highly hazardous material and handled in industrial quantities, the ventilation system was especially important. Keeping workers separated from the danger of plutonium was a major consideration in design and a principal item in cost. A major advance in controlling plutonium contamination was made by placing equipment in airtight hoods and maintaining equipment by means of gloves and glove ports. When it became evident that this technique was not adequate, remote maintenance techniques and operations were evolved and have decreased personnel exposures.



Protection by separation. A "junior cave" used by radiochemists at Hanford Works, Richland, Wash., for protection against gamma radiation. In the photograph, the opening of the cave is raised to permit a view into the interior.

Plastics have been effective in providing flexible barriers between employees and gross amounts of contamination. A spectacular development in this field was the "plastic man" which provided a ventilated work location from which specialized maintenance and operating work could be performed without direct personnel exposure to grossly contaminated areas. More prosaic, but perhaps more useful,



Plastic man. In order to test the contamination in this area at Hanford, the radiation inspector must take extra precautions. Over normal clothing, he wears a plastic suit which he enters through a flexible tunnel. The whole mechanism is inflated so that a positive pressure of air within the suit prevents possible infiltration by contamination.

has been the extended use of plastic bags, plastic spray coatings and packaging. In addition, recent developments have made possible the use of leaded plastic gauntlet gloves in reducing hand exposures in certain operations.

Equipment has been dressed in disposable shields, strippable films and distinctive coloration which has aided in the control of the general problem of radioactive contamination.

Several new types of respiratory protective equipment have been developed and adopted. The decontamination, sterilization and handling of used respiratory equipment, a major administrative problem, has been made efficient through using a central mask-handling facility. It delivers inspected, sterilized and packaged respiratory equipment to employees throughout the plant.

Savannah River. The Savannah River plant for production of plutonium has, in general, the types of problems handled successfully at Hanford since 1944, and its approach to control of radiation is the same as used throughout the atomic energy program.

A special hazard, however, arises from the fact that tritium is produced by the action of neutrons on heavy water used as a coolant and moderator in the reactors. The concentration of tritium becomes such that special precautions are required whenever the moderator system is opened in maintenance work. Though this radioactive form of hydrogen emits radiation of extremely low energy compared to most radioactive materials, it is hazardous since it readily combines with oxygen to form heavy-heavy water ($H^3{}_2O$). This water behaves chemically essentially like ordinary water or water vapor. It is readily absorbed by the lungs and through the skin, readily distributed in body fluids, and continually incorporated into the molecules of all body tissues and secretions. However, its turnover by the body is rapid.

This problem has been handled successfully at Savannah River by the contractor-operator through equipment design, employee training, accurate monitoring, proper ventilation, and special clothing and masks.

Oak Ridge Operations

At Oak Ridge, a variety of radiation hazards is controlled. Some of these arise from operation of the X–10 reactor, and from the processing and shipment of radioisotopes, others from research activities and the operation of experimental reactors at the Oak Ridge National Laboratory.

The handling and shipment of radioisotopes was reported comprehensively in the Eighth Semiannual Report (pp. 53–75), at the time that the new processing buildings and the "atomic apothecary" loading and shipping area were opened. Since then, a remote manipulator cell has been added to facilitate handling of powerful gamma emitters such as cobalt 60.[28]

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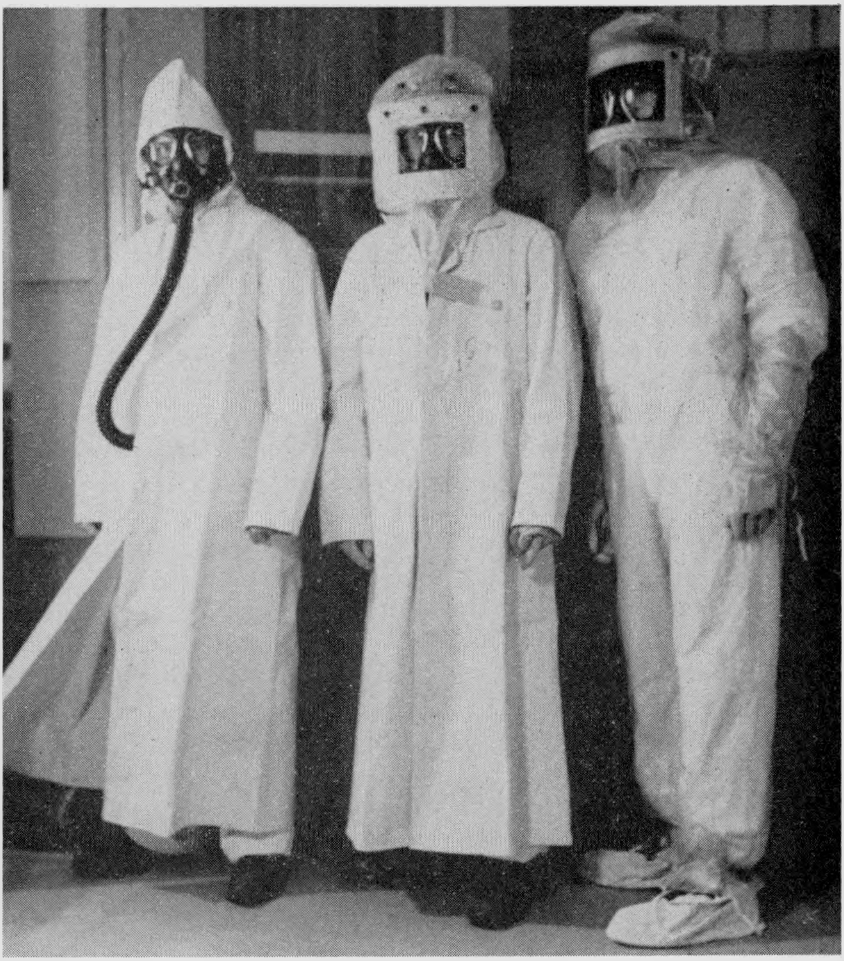
[28] See p. 82, Twentieth Semiannual Report (January–June 1956).



Protective clothing. Various types of protective clothing and protective devices worn when working in "hot" areas at Mound Laboratory, Miamisburg, Ohio. The outfit at the right is a one-piece plastic suit which includes a head covering and zips up the back.

The gaseous diffusion plant at Oak Ridge has a special problem which it shares with other gaseous diffusion plants at Paducah, Ky., and Portsmouth, Ohio. They must guard against the possibility that uranium when enriched in the gaseous diffusion plant in the uranium 235 isotope, could accidentally reach a critical mass during its processing, auxiliary operations, or storage. The possibility of plutonium or uranium criticality problems also must be dealt with, among other places, at Hanford, Savannah River, Idaho, and Los Alamos installations.

Accidental assembling of a critical mass of uranium or plutonium never has occurred in processing these materials or storing them. The shape and size of conduits and containers is carefully controlled, so that a critical mass cannot be formed.

Beyond this problem, radiation safety work in gaseous diffusion plants has been concerned chiefly with preventing internal exposure from uranium. This has been mainly accomplished by designing and operating equipment so that uranium is confined as well as practicable during all activities, both routine and nonroutine.

When confinement of uranium or other contaminants has proved impracticable as during maintenance activities requiring the opening of otherwise closed systems, the workers wear protective equipment such as masks, commensurate to the hazard. The primary emphasis is upon preventing workers from inhaling the materials as dusts, aerosols, or in other forms.

First attention is given to preventing materials from becoming airborne, especially in areas where employees work routinely. In many cases, this has required special and intricate shielding of equipment and machinery. It has meant that systems are kept tightly closed insofar as possible, and that "dusty" contaminated locations are kept clean. In all cases, appropriate monitoring devices have been used to determine the actual levels of air contamination.

Beyond the emphasis on preventing inhalation of radioactive materials, strong emphasis has been placed on normal good habits of personal hygiene, such as thoroughly cleaning hands before eating or smoking, and keeping open wounds bandaged. The use of rules on cleanliness, appropriate changes of clothing, gloves, shoe covers, and requirements for urinalysis depend upon specific conditions or jobs being performed.

Criticality control. Accidental assembly of a critical mass of fissionable material is prevented by limiting shapes and size of containers and the space between containers. The criticality control problems for example at the gaseous diffusion plants have involved uranium hexafluoride and other uranium compounds enriched in uranium 235 during all phases of the separation process and such auxiliary activities as equipment cleaning and uranium recovery. At the Oak Ridge and Portsmouth plants all enrichments from normal to about 90 percent uranium 235 have been involved in these activities, but the Paducah plant has been concerned primarily with lower enrichments. Plutonium criticality problems, where they arise, are similarly handled.

For systems handling uranium, but not concerned with uranium metal, a 5-inch diameter cylinder, a 1-gallon volume, or a 1¼-inch thickness, are safe configurations when remote from other containers, and will not allow a critical assembly under conditions most favorable for a chain reaction for the material found at the production plants. In operations where it is impracticable to prevent criticality by control of the shape and size of containers, nuclear safety is insured by limiting the amount of uranium 235 which may be placed in any container or group of containers, and by establishing careful administrative controls to see that at no time is this amount exceeded. In addition careful and frequent physicochemical analyses of the materials are required.

The dimensions listed above for safe quantities can frequently be increased if the uranium 235 enrichment is less than about 90 percent. The "safe" dimensions and quantities become progressively larger as the enrichment decreases. Similarly, if the amount of moisture which the material can absorb is strictly limited to prevent its moderating effect from increasing the likelihood of neutron capture and fission, further increases in dimensions and mass are possible. Advantage is taken of these and similar relaxations wherever practicable without incurring hazard.

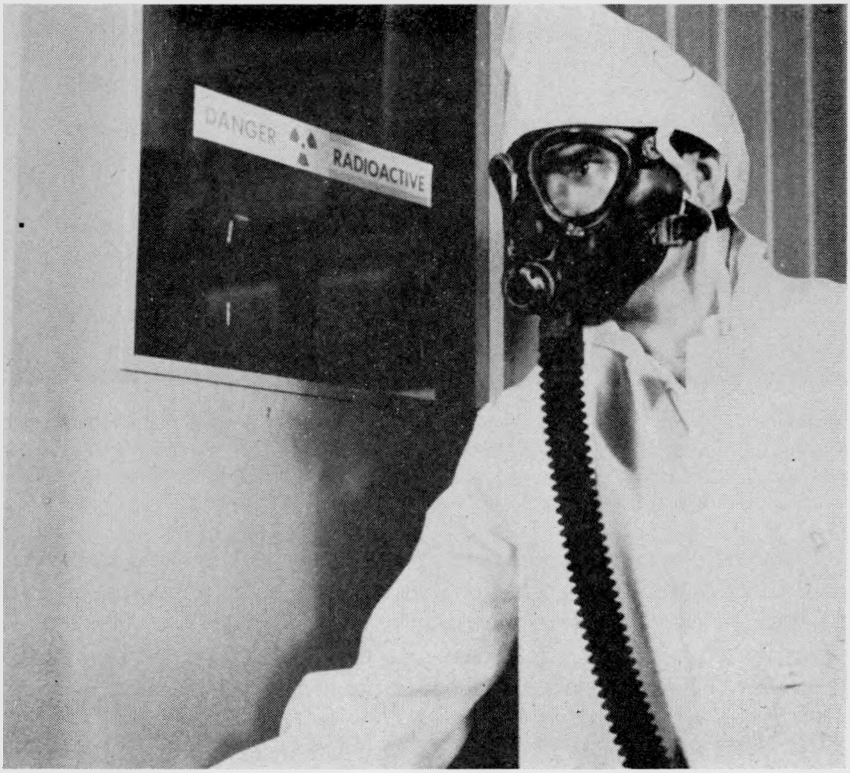
The phenomenon of neutron exchange between uranium containers which are physically separated makes it possible for containers which are individually safe to reach criticality if placed too close together, and this has necessitated, in addition to actions taken to insure the nuclear safety of individual containers, that the separate units be appropriately spaced. Where operational safety is based upon administrative controls, it is normal practice to establish these so that at least two, and frequently more, independent unlikely operational contingencies must occur before there is a possibility of a chain reaction.

In recognition of the importance of preventing an accidental chain reaction, the production plants have sponsored and participated in an experimental and theoretical program designed to determine the various physical factors upon which the initiation of a chain reaction depends. Basic plant operating criteria now include not only the values of control parameters that are safe under the most favorable conditions for a chain reaction, but also the dependence of these parameters upon container shape, the uranium 235 enrichment of the material, the degree of moderation (or moisture content) of the material, and the spacing of individual uranium-containing units.

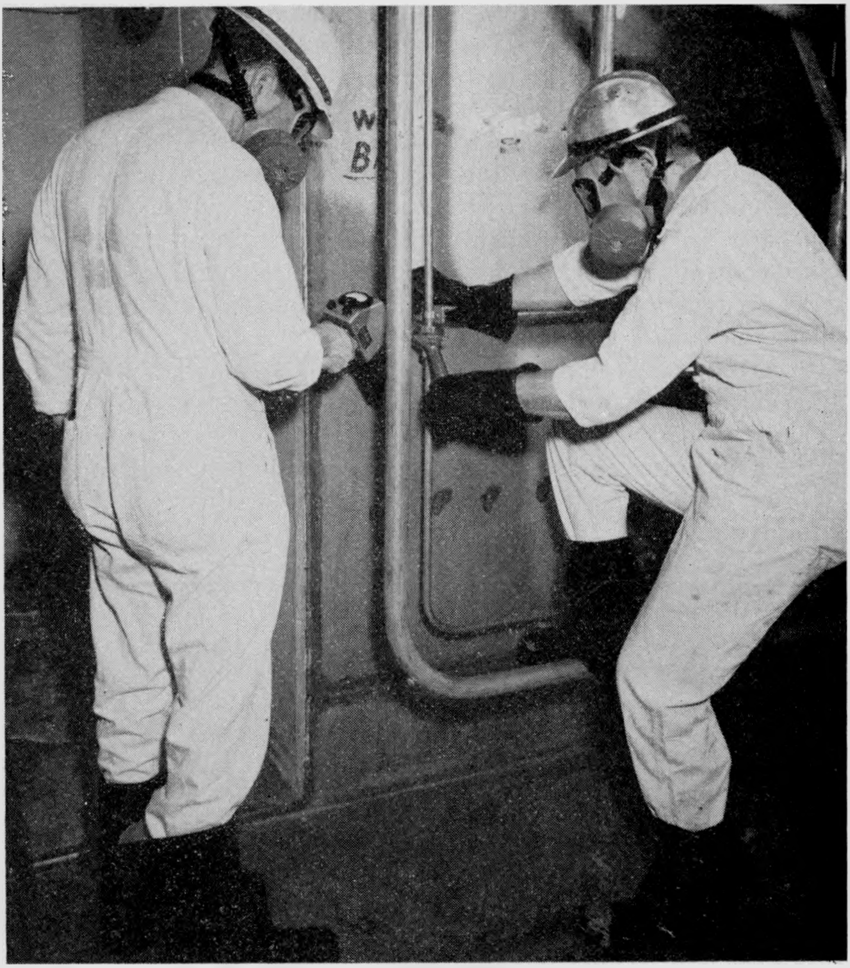
Although prime responsibility for criticality control activities rests, as does all radiation safety, with management assisted by local staff groups, the various plants have set up specific organizations to assist. For example, at the diffusion plants, general guidance of the overall control activities rests with a standing plant committee, the Special

Hazards Committee, whose membership includes superintendents of the various operating divisions where enriched uranium is handled, and other members of plant supervision who have special interests in various phases of operations where criticality control is a significant problem. In addition, at each plant, all proposed changes in operations where criticality control might be concerned are reviewed for this particular purpose by the staff group which also audits plant operations to insure compliance, through management, with established control practices and procedures. Criticality control activities at all production plants also are reviewed annually by a staff of outside consultants.

In meeting a specific problem wherein the accumulation of a too-large amount of material in an unsafe configuration is considered possible, control is based primarily upon available criticality data and criteria developed and published in a criticality-control handbook. In many cases, it has been found desirable to use direct experimental information.



Entering a "cave". Dressed for protection against contamination in a "hot cave" at Mound Laboratory, Miamisburg, Ohio, the worker wears special, discardable clothing, rubber gloves, a mask with an independent supply of oxygen.



Maintenance work. Disconnecting a process line in the Chemical Processing Plant at the National Reactor Testing Station, a worker wearing a respirator and special protecting clothing is monitored by a health physicist worker, similarly equipped, who holds a radiation meter against the coupling.

The considerations upon which nuclear safety will depend in a given case are reviewed with operational factors by the staff groups. In all production plants, deviations from criticality control provisions are investigated, even though, in general, these have been so minor that there have been no instances where the nuclear safety of plant or operation has been seriously compromised.

High level radiation alarms are provided in many plant locations where enriched uranium materials are processed or handled to warn of the occurrence of a nuclear accident, and all employees are provided with neutron-detecting dosimeters consisting of strips of indium foil incorporated in their security badges, to measure any exposure that might result from an accident.

Radiation Protection of the Environment

Protection of the environment to prevent radiation injury to the public in general, and specifically, to safeguard the neighbors of atomic energy installations, depends primarily on the location, the design of plants, and methods of operation, including handling of industrial wastes. In more recent installations, the Commission considers the relationship between site isolation and arrangements to contain releases of radiation. Commission sites which could occasion major potential hazards often are isolated from large centers of population.

Protection against the potential hazard, for example, of a reactor accident is accomplished by built-in safety factors, by expert operation, by monitoring of operations and interlocking controls, by controlling all wastes, by a balance between isolation and physical containers or shells, where these are necessary, designed to capture and hold any leakage of radioactive material (see chapter III, Safety Factors in Reactor Design and Operation).

Protection of the environment against radioactive discharges from various operations—reactors, processing plants, laboratory research—equally depends on design, expertness, operation, and monitoring. To take a single brief example, the research reactor at Brookhaven National Laboratory, like that at Oak Ridge National Laboratory, is so built that the air used to cool the reactor is cleaned both before and after passing through the reactor, and then is discharged through a lofty stack. The height of the discharge, and the prompt mixing and dilution with air of radioactive gases prevent any difficulties. If meteorologists were to find that conditions were such that the gases would not promptly be diluted and dispersed, or would be borne down toward the earth's surface, the reactor would be shut down until conditions improved. It has never proved necessary to shut down the Brookhaven reactor because of weather conditions. A shutdown also would take place if automatic monitoring devices detected an abnormal amount of radiation originating in the stack discharges.

A key activity assuring that the environment is protected once such steps as mentioned earlier have been taken, is the monitoring program to determine the amount and the kinds of radioactivity present in the environment at any given time. The systems established vary from installation to installation, according to the problems present in each case. Water discharged after cooling the production reactors at Hanford is monitored; fish and other water life are tested; the safety of using the water for irrigation of crops is a subject of long experiment. The air discharges are monitored at Brookhaven, at Oak Ridge National Laboratory, at certain of the experimental and working reactors at the National Reactor Testing Station. Again, vegetation, wild life, and domestic animals, are monitored near chemical processing stations to keep accurate check on discharges of radioactive iodine, a process gas, which is a problem at Hanford, Savannah River, Idaho, and Oak Ridge. Test wells are sunk, and certain plants which absorb particular isotopes are used, to trace seepage of radioactive materials through the soil where this is a possibility. Worldwide monitoring is carried on to determine radioactive contamination of the environment as a result of weapons tests.

The environmental monitoring programs which provide an accurate measure of any trend toward an accumulation of radioactive contamination, are in operation at all Commission installations. Many were established in advance of operation to provide data on existing radiation background, since the amount of radiation present naturally from minerals in the soil, or from cosmic rays, varies from place to place. The record of radiation naturally present helps monitors to identify any untoward accumulation of radioactivity ascribable to operations. Advisory boards established at Hanford, Savannah River, and Idaho, for example, assist in many aspects of environmental protection.

Most of these activities remain essentially the same as when reported in detail in the Eighth Semiannual Report (January–June 1950). Where sites opened since 1950 are concerned, or where there have been new developments or advances in control affecting the environment, they are reported here.

Savannah River Plant

The extent of precautions taken by Commission contractors to assure radiation protection of the environment is typified by the preparation made by the contractor du Pont, for operating the Savannah River Plant to produce plutonium.

Surveys. Two years in advance of operations, in 1951, the contractor's health physics section began a systematic study of the natural radioactivity of the environs of the plant on the South Carolina banks of the Savannah River. Water was assayed from wells, creeks, ponds, the river, and nearby municipal systems. The area was found to be generally low in natural radioactivity. The background radiation was attributed principally to the naturally radioactive isotope, potassium 40.

The regional monitoring team of health physicists has continued a routine sampling program of the wells, streams and the Savannah River. Limited biological monitoring of aquatic organisms has indicated that levels of radioactivity are not significantly above the natural background level, and indeed are just detectably so. The levels would have to be many times greater to be a matter of health concern.

Coincident with the early radiological background study, other environmental investigations were made. A micrometeorological study influenced certain design and operational policies, and determined that no continuing meteorological program would be required.

The Academy of Natural Sciences of Philadelphia was engaged to make four quarterly studies and several followup surveys of the Savannah River to determine the general health of river life as indicated by the abundance of plant and animal species. More recent surveys have revealed no biological changes that could be attributed to radiation or other changes associated with this operation. The U. S. Public Health Service, Department of Health Education and Welfare, has made several surveys of the river, as it has of the Columbia River, in Washington and Oregon, that have substantiated generally the findings of the Academy of Sciences and the regional monitoring group. The University of Georgia conducted a study under Atomic Energy Commission contract designed to elaborate on the migratory habits of catfish in the Savannah River and one major local tributary.

The Ground Water Branch of the U. S. Geological Survey, Department of the Interior, made studies of soil formations, pressures and ground water drawdown due to pumping in various plant areas. This information has been analyzed to estimate percolation rates and direction and rate of migration of radioactive materials in the ground. It is generally assumed from these studies that lateral movement is to be expected and that material released or disposed to the surface of the ground will find its way into surface streams.

The Savannah River Advisory Board was organized in 1951 to review regularly the health of the river as related to all industries and developmental projects associated with water usage. This panel composed of representatives of the U. S. Public Health Service, the Corps of Engineers of the U. S. Army, the Geological Survey, the States of South Carolina and Georgia, the du Pont Co. and the Atomic Energy Commission, has convened periodically to review studies of the river and to consider future influences.

Since 1951 continuing ecological studies have been in progress by the Universities of South Carolina and Georgia. This research has been conducted on land, pond and creek habitats of the area—and comprised largely of basic studies in species distribution, abundance, and relationships. Recently programs emphasize investigations into the effects of radiation upon natural communities, and the role of plants in releasing soil-bound radioisotopes to the environment.

Design and operation. The basic design and operational procedures for the Savannah River Plant were originally planned to contain and control very conservatively the release of radioactive materials to the environment. Technical standards were agreed upon that were sufficiently more conservative than the internationally accepted limits to insure against exceeding those standard limits established for public protection.

Continuing release of low-level radioactivity to the environment occurs when separations plant stacks discharge volatile fission products; low-level fission wastes are released to seepage basins where natural clays function in adsorbing and holding fission products by ion exchange; and heat exchanger cooling water from reactor areas carries off, in tremendous dilutions, controlled bleed-off from the storage basins for irradiated materials and from the aqueous thermal shields of the reactor tanks.

Stack release. A great variety of fission isotopes may be detected in the gases released from the stacks of chemical separation plants. The only problems are with those isotopes which continue radioactive and exist in relative abundance several weeks after fuel is discharged from a reactor.

Radioactive iodine is of primary concern at the Savannah River Plant, as at other plants that process used fuel elements. Other radioelements released from the stacks are below a detection level beyond the boundaries of the plant area. Iodine 131 release has been kept to safe levels by delay in processing discharged reactor fuel which permits radioactive decay to take place, and by the application of recently developed technological improvements in processing. Radioiodine levels beyond the plant boundaries, though detectable by sensitive analytical methods, never have approached levels at which radioiodine might become of biological concern.

The second process material that had to be managed is composed of two principal isotopes of ruthenium. Devices introduced to minimize the release of this element have proved effective, and it never approached a level of concern in the environment.

Very accurate measurements are made of iodine and other groups of wastes released from each processing plant stack. Correlation of these data wtih levels detected in the environment, in air, or on vegetation, makes it possible to estimate the significance of continuing rates of release.

Atmospheric radioactivity is monitored by ionization chambers near the stacks and by automatic filter counting at remote locations. Vegetation is sampled on regular routes to distances of 25 miles.

Low-level fission wastes. If the levels of radioactivity are sufficiently low, it is possible to discharge wastes into seepage basins without hazard. These seepage basins are large, open ponds from which the water seeps slowly into the ground. The soil beneath the ponds by its capacity for ion exchange selectively retains radioactive ions with considerable tenacity.

This method of waste disposal is highly attractive because of its economy. However, pending development of more exact knowledge of the soil, the amount of fission products so discharged has been limited. So far, this limitation has been kept below the amount of fission products that actually could be added directly to the Savannah River without exceeding the limits of radioactivity allowable for drinking water. Even so, by judicious selection of wastes permitted to flow into the seepage basins, the contractor is able to achieve safe and economical disposal of large quantities of contaminated water and inactive salts.

A field and laboratory research program is directed toward increasing the knowledge and use of seepage basins for disposal of radioactive wastes. The soil involved is a mixture of clay and sand, and research has determined it has a considerable capacity for adsorption of fission products. Solutions discharged to the seepage basins must percolate vertically about 60 feet to reach the water table. The water then must flow laterally about 2,500 feet before it reaches the surface streams that flow through the plant area to the Savannah River. Solutions require about 1 year to pass through the soil and to reach surface water.

Verification of these facts in field tests will permit safe discharge of increased amounts of radioactivity through the seepage basins. The field tests include the use of monitoring wells around the seepage basins, to permit a close watch on any radioactivity in subsurface water. Routine sampling of more distant wells and of surface streams supplements monitoring near the basins.

Many waste streams from laboratory and other auxiliary operations at Savannah River are so low in radioactivity that it is biologically insignificant. These wastes normally are discharged to surface streams, but are carefully monitored before release and are diverted to seepage basins if significant activity is found.

Cooling water. Basic principles designed into the Savannah River reactors prevent the radioactive contamination of raw river water that serves to carry away the huge heat load. A battery of heat exchangers near each production reactor provides complete separation of the heavy water moderator-coolant and the river water. After passage through the heat exchangers, the thousands of gallons of water used each minute return to natural tributary streams. The water is free from induced radioactivity that would have resulted if design were such that it passed through the neutron flux of the reactor tank.

The warmed water loses most of its heat load while flowing through some miles of natural meandering streams to the Savannah River.

At each reactor, however, there are other minor sources of waterborne radioactivity that is released in a highly diluted state with the used cooling water. A small bleed-off of water from a portion of the reactor shield contains several induced isotopes from contaminants in the metal of the shield. Considerable handling and limited fabrication of irradiated metal occurs in large water-filled storage basins in which irradiated fuel elements cool radioactively before being processed. The water released from these basins contains, principally, isotopes of the corrosion products of steel and aluminum, and their impurities, in which radioactivity has been induced. Isotopes of chromium, iron, cobalt and zinc usually make up a large fraction of the radioactivity. Fission product contamination never has been significant, though it could occur under certain conditions.

Continuous automatic monitoring of streams has seldom shown levels significantly above background radiation even at points within the plant boundaries. Radioactivity has never reached the limits prescribed for drinking water.

Storage of high-level wastes. The major quantity of radioactive waste from chemical separations plants at Savannah River is stored in large underground tanks. Wastes from the process are concentrated by evaporation, neutralized chemically to reduce corrosion, and piped to the storage tanks. High concentration of wastes may be accomplished when long-term storage is planned.

The total quantity of radioactivity from the chemical separations plants is so tremendous that indefinite retention under rigid control is mandatory. Storage in large underground tanks at present is the simplest way of assuring that the radioactivity does not contaminate the environment. The tanks that contain the most active of the high-level wastes have equipment to remove the heat caused by the radioactivity.

Brookhaven National Laboratory

Prior to the start of full-scale operation of the research reactor at Brookhaven National Laboratory a network of 16 monitoring stations was constructed around the laboratory site at varying distances to collect data on the levels of beta and gamma radiation, and radioactivity that might be associated with airborne particulate matter from reactor operations.

These stations were in operation 2 years before the commencement of full power operation of the graphite-moderated, air-cooled reactor. Specially designed equipment recorded data photographically and included such features as moving filter paper collectors for airborne dust, and ionization chambers and dynamic condenser electrometers for gamma measurements.

Several years of full-power operation of the reactor proved that the increase above normal background radiation was so small that outlying monitoring stations no longer were required. Eleven were suspended since the remaining five in operation located on or close to the site provided ample protection. During the earlier years numerous experiments were made to compare the radiation exposure predicted on the basis of meteorological observations with the exposure actually received on the surface from the reactor air discharged from high stacks.

At Brookhaven, periodic samplings of the sewage from various laboratories, of the ground water and of vegetation are carried out. Liquid wastes of sufficiently low activity are discharged to the laboratory sewage system after assay. Multiple checks are used to assure that only low-level, short-lived materials are released, and then only in small quantities in the wastes that are filtered through sand beds and rechecked before discharge.[29]

The National Reactor Testing Station

The National Reactor Testing Station (NRTS) was established by the Commission about 40 miles west of Idaho Falls, Idaho, to further the reactor development program by providing a place for the development, construction and operation of nuclear reactors, reactor fuel recovery plants, and auxiliary establishments. The station provides a unique environment in which advanced experiments can be carried to extreme levels without danger to populous areas. It is located in a sparsely settled portion of the Snake River Plains on a tract of about 430,000 acres, an area half that of the State of Rhode Island.

Since this site was opened in 1949, some 10 reactors have been operated there without exposure of residents of surrounding areas to radiation of any significance in affecting health. In the location of technical plants within the site, reactor power levels, novelty of the

[29] For a detailed report on operation of Brookhaven National Laboratory, sewage system, see pp. 111–113, Eighth Semiannual Report (January–June 1950).

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reactor concept, the purpose and manner in which a reactor will be operated, are all considered from the standpoint of hazard to workers and neighbors.

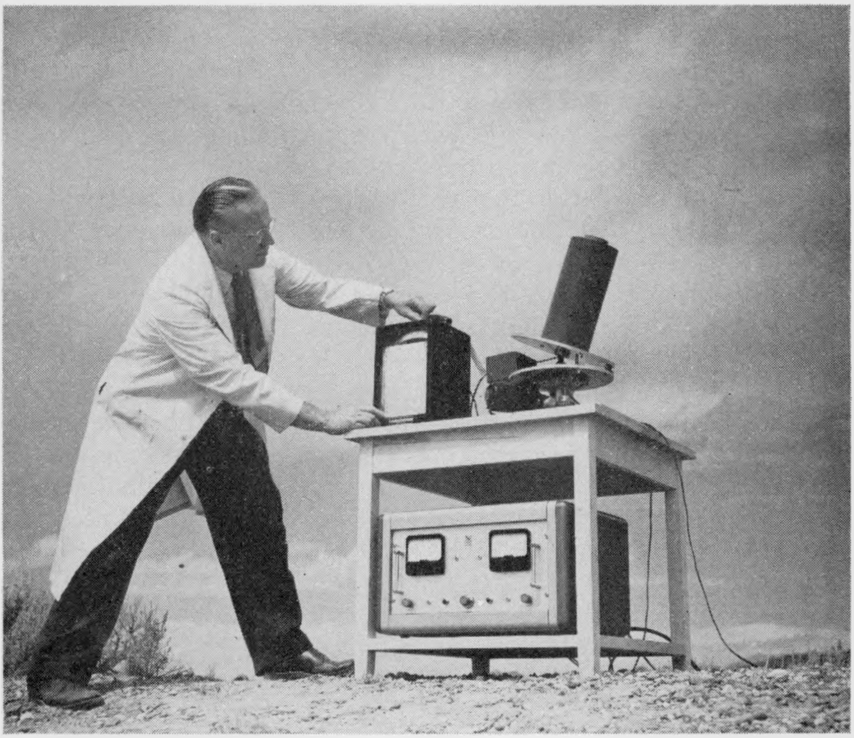
The testing station boundary describes a rough triangle with its hypotenuse to the northwest. The prevailing winds are from the southwest, thus allowing maximum on-site drift of discharged gases. There is no surface water drainage from the station; conversely, three major streams which rise in the mountains to the north and west are soaked up by the porous soils of the area, forming a body of underground water tapped by wells for use in plant areas. It is believed that this water flows underground in a southwesterly direction emerging ultimately in the Thousand Springs area of the Snake River in southern Idaho.

After site choice, patterns of operation control radiation safety. Site analyses of meteorological conditions are made by a Weather Bureau unit attached to the station to provide information that would affect dispersal of stack gases and air filtration. The problem of radioactive stack emissions is reduced by filtering the air used in reactor-cooling systems. The radioactive isotopes produced by the neutron bombardment of air as it passes through the reactor shielding have short half-lives so that dilution in the upper air, and rapid decay to a nonradioactive state, protect the other station installations and the surrounding area.

Gaseous wastes from the chemical processing plant are filtered through fiber glass beds and diluted with ventilating air from the building before being vented to the atmosphere through a 250-foot stack. In the atmosphere, they are further diluted and decay to stable forms. The stack of the chemical processing plant is equipped with a device for heating the gases so that the effluent will rise rapidly and be able to penetrate meteorological inversions—in which heated air blankets cooler air—and not be confined to the lower cooler levels. To check on stack performance, the Health and Safety Division of Idaho Operations Office, which conducts all environmental protection activities at the station, has developed a "Sky Scanner". This instrument, when used in groups of two or more, can trace the form, intensity and direction of air streams containing radioactivity. This is accomplished by triangulating on radiation sources, as radioloops can triangulate and locate a ship or plane by its radio transmission.

When operations are conducted at levels at which radioactivity could be released, its discharge is closely synchronized with meteorological conditions to protect exposure of personnel at the station or the environment against gaseous or particulate fission products. Routine operations are monitored by a network of fixed air-sampling stations, located at a number of points on the station and in the general southeastern Idaho area.

To provide immediate radiation monitoring controls during sensitive experiments, mobile units are utilized.



Sky scanner. An instrument developed by the Idaho Operations Office's Health and Safety Division is used to track radioactivity released from stacks at the National Reactor Testing Station.

To monitor highways or roads where speed is a factor, delivery trucks equipped with two-way radios are used. Should there be a sudden release of airborne radioactive material, their prime function is to detect radiation quickly and determine the extent of areas affected. These trucks are equipped with an array of four Geiger-Mueller tubes arranged in series on the front of the truck close to the roadway. Their sensitivity allows a rapid evaluation of a large area.

Where terrain does not permit this type of monitoring, and samples are needed, radio-equipped, four-wheel-drive vehicles are used. In addition to standard field monitoring instruments, these units have electric generator plants to supply power for sample collectors and flood lights. Each is capable of collecting high-volume air samples, and particulates.

Modifications to "Sky Scanners" permit their being mounted in vehicles and operated in transit, or placed in a remote location. Two house trailers have been converted to mobile laboratories. Each has two-way radio, a constant air monitor, sample counter, and back-up equipment for monitoring teams, including microscopes and micro-projectors for determination of particle size, an important factor in estimating hazards from inhaled material. A control station is located at the central facilities of the station where telephone and radio liaison is maintained with the Idaho Operations Office management, the experiment area, the U. S. Weather Bureau Unit assigned to the station and all monitoring units.

Progress of an experiment, meteorological advice, and field monitoring data are relayed continuously to responsible personnel at the control station who coordinate the placement of monitoring units and keep management informed of developments. Should a radioactive release occur, initial detection can be made at the source, either by the operating group through its normal stack monitors, or by "Sky Scanners" monitoring the stack, or by field survey teams. Normally, two or three monitoring teams are stationed downwind of experimental operations. Under established operating plans, should a radioactive release occur, all sampling equipment is put to work immediately additional teams are dispatched, all groups are alerted, and necessary liaison is established with other station technical areas, if this is indicated.

As a routine precaution, nearly 40 wells south and west of the station, as distant as 140 miles, are sampled monthly for any increase over normal background radioactivity. No deviation from normal has been found.

The Idaho Environmental Advisory Committee was established in 1953 to advise the Idaho manager on aspects of the operation of the NRTS having possible effect on the health and safety of the area, and to act as liaison between the Commission and the public. The committee includes representatives from the State Public Health Department, the State Reclamation Department and includes experts in the fields of meteorology, geology and stack gas.

Hanford

At Hanford, the environmental monitoring program which was reported in detail in the Eighth Semiannual Report (January–July 1950) now encompasses an area of 1,700 square miles immediately surrounding Hanford in which routine monitoring activities are carried out by the contractor. An additional area of some 23,000 square miles is also monitored intermittently. Minute quantities of radio active contamination in air, vegetation, soil, surface water and ground water are detected by radiochemical methods.

Measurement of Hanford wastes as they enter the environs has been refined by the use of advanced monitoring techniques and by the maintenance of complete records of all process waste released to the environment. All radioactive materials routinely detected beyond the plant perimeter are at or below one-tenth of the appropriate maximum permissible limits.

Automatic monitoring devices have been evolved which allow for the prompt detection of the presence of radioactive contamination in reactor cooling water.

Precautions for Weapons Tests

The Atomic Energy Commission has established two testing sites for weapons, one in Nevada and one at Eniwetok in the Pacific. Only relatively small devices are detonated at the Nevada Test Site. Larger shots occur at the Eniwetok Proving Ground with its much larger safety and warning area.

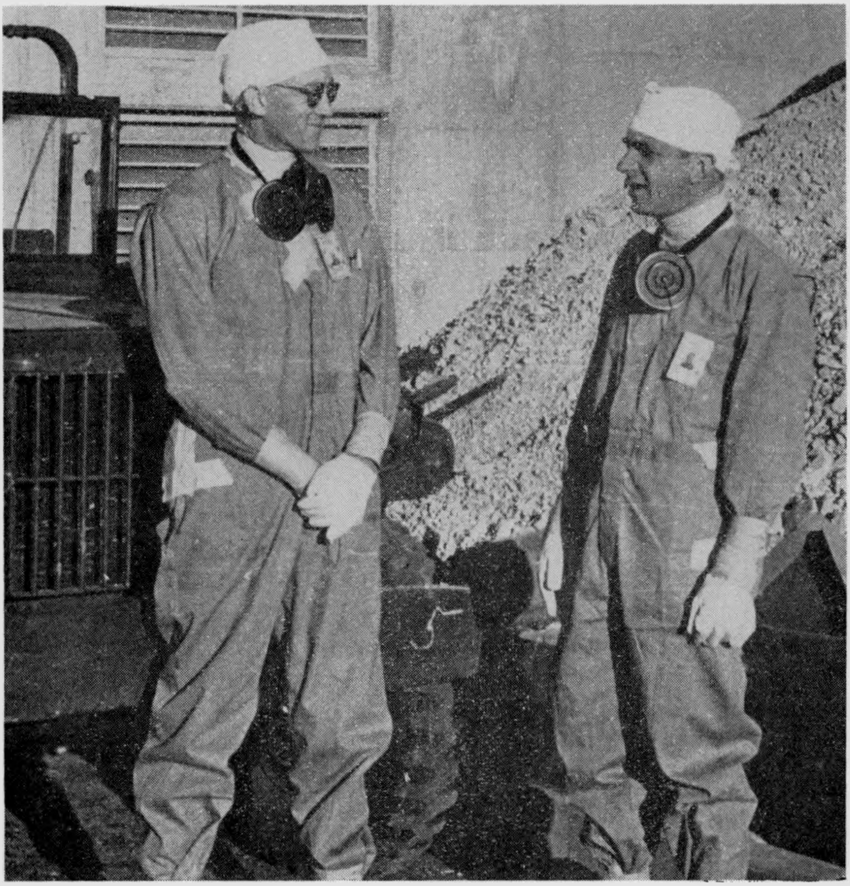
Nevada Test Site. The Nevada Test Site covers an area of about 600 square miles of desert country surrounded by a sparsely populated expanse of land. Adjacent to it is an Air Force Gunnery Range of 4,000 square miles. This large controlled area affords maximum safety conditions. It is closed at all times to the public, not only for security reasons but to prevent possible personal injury.

Only relatively small nuclear devices, carefully evaluated before detonation for their anticipated energy yield, are tested here. Before each detonation, aerial and surface surveys are conducted to assure that no persons or domestic animals have entered the danger area. Announcements of detonation time are made before the tests so that people in surrounding communities have advance warning.

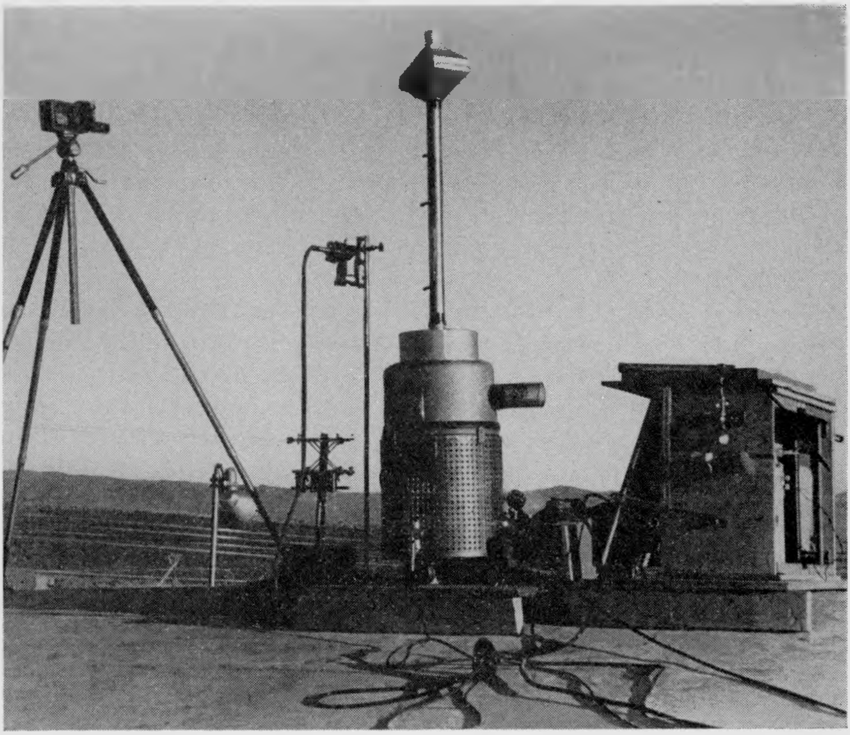
As part of the test organization, an advisory panel of experts in the field of biology and medicine, blast, fall-out, and meteorology meets before each nuclear detonation to consider the advisability of firing the shot. Weather conditions are a prime consideration since they can affect: fall-out pattern; severity of the blast wave in off-site areas, and the cloud cover which has a bearing on operational flights related to the tests. Information on the weather is provided by a complete weather unit at the test site which draws upon data from the U. S. Weather Bureau and the Air Weather Service. In addition, there are six supporting weather stations encircling the area. A shot is not scheduled unless favorable conditions are expected. If unfavorable weather conditions develop a scheduled shot is postponed.

There have been about 80 such postponements related to 17 shots during five past test series in Nevada. The total number of days delayed would be even larger, since each decision to postpone might involve one, two, or more days.

To control the flight of aircraft not connected with the tests in the general test region, or in the predicted path of a radioactive cloud after a blast, an "air space closure" is established by the Civil Aeronautics Administration. Commercial and military aircraft may be advised to avoid temporarily sectors up to several hundred miles away from the detonation point. After each burst, aircraft follow the cloud until it becomes widely dispersed. Other planes follow to track fall-



After tests. Ready to enter test area after weapons detonation, members of the radiological safety group, Los Alamos Scientific Laboratory, Los Alamos, N. Mex., wear canvas boots, surgeon's caps, respirators, rubber gloves. All articles of clothing are securely taped and sealed at wrists and ankles.



After tests. Air-sampling station, one of type established at 15 locations within 200-miles of the test operations at Nevada Proving Ground to guard against possibility of fall-out.

out on the ground near the test site. Additional aircraft are on call to monitor more distant points if necessary.

Precautions also are taken to protect the health of people in nearby communities by a system of monitoring zones, in which the Commission and the U. S. Public Health Service participate jointly. Each zone is under a commander whose duties are to perform routine monitoring activities, i. e., to take radiological measurements and to give advice and information to the people living in the communities in his zone. Mobile units also are on call to be sent to any area, outside the zones, which may require monitoring.

Three additional monitoring programs also are in operation.

a) Unattended, automatic, continuously recording gamma ray monitors aer located adjacent to the Nevada Test Site to document changes over background radiation prior to, during, and after the actual test period. This system has been proved reliable by previous field use and requires a minimum of servicing.

b) Intensive sampling of soil, plants, animals and air for 2 to 4 weeks immediately after a fall-out contamination with special emphasis on occurrence of certain fission products. This study takes place simultaneously in several areas along the mid-line of fall-out to a distance of approximately 300 miles. There is also a continuous sampling program carried on apart from this test activity.

c) Study of the characteristics of extended fall-out patterns by aerial survey.

Eniwetok Proving Ground. Similar precautions are taken during the Pacific tests.[30] Since larger nuclear devices are tested in the Pacific, the warning area covers nearly 400,000 square miles. This area is surveyed by surface ships and aircraft in advance of each test. Any ships that enter it are warned away. Weather and fall-out prediction units function much the same as in Nevada. Nine stations, in addition to the eight that operate regularly, are established for each test series.

Following detonation, aircraft follow the radioactive cloud and others perform surveys over land and sea areas to chart any residual activity. The populated islands of Wotho, Ujelang, and Utirik, were monitored by personnel of the U. S. Public Health Service during Operation Redwing (spring 1956 series). Use is made of a variety of ships, skiffs and buoys containing recording equipment, and large scale marine and land surveys are made to measure any environmental contamination.

Worldwide monitoring. The monitoring programs do not stop at the areas around the test sites. During all test operations, 80 monitoring stations are maintained in the United States and an additional 88 have been maintained in 46 countries and territories throughout the free world through the cooperation of the U. S. Weather Bureau, U. S. Public Health Service, State Health Departments, and the Commission. Other monitoring stations are being added abroad. All these stations collect fall-out particles with gummed paper and send them for counting of radioactive material deposited to the Commission's Health and Safety Laboratory. In addition, about 35 of the Public Health Service and Commission stations in the United States make air collections and some rain analyses. These latter stations are part of a nationwide immediate operative system to supply data on short notice.

Assistance to photographic industry. The Commission, in recognizing the potential operational problems to the photographic industry

[30] A full report on protection methods during Operation Redwing is given in Appendix 9, Twentieth Semiannual Report (January–June 1956).

through a possible contamination or fogging of films from radioactive fall-out due to weapons tests, has furnished information to them since 1951 through the office of the executive secretary of the National Association of Photographic Manufacturers. In order to assist the industry in establishing production schedules, the Commission wherever feasible has provided statements of periods during which no United States tests are planned and advance notice of as much as 4 months of tests which might affect the photographic industry.

During test series frequent forecasts of contaminated areas based on meteorological data have been furnished, enabling processors to take precautions. The Commission has also consulted with the technical Committee on Radioactivity of the Manufacturers' Association on matters of radiation detection, protective measures, transportation, and waste disposal.

Fall-out data. Any nuclear detonation forms immediately about 60 different radioactive substances representing some 35 elements. Most of these substances initiate decay chains consisting of several isotopes so that eventually 170 isotopes may be produced, with radioactive half-lives ranging from a small fraction of a second to many years—that is the time during which about half the atoms in any given quantity of radioactive material undergoes radioactive decay.

If the nuclear detonation occurs high in the air, the radioisotopes become associated with fine particles that settle relatively slowly to the earth, so that the activity of the short-lived isotopes decays and the particulate matter is widely dispersed. Thus, the immediate fall-out will be relatively small. Where the fireball from a nuclear detonation intersects the ground, the radioisotopes will become principally associated with larger particles of matter which fall relatively rapidly, thus producing higher concentrations of radioactivity in nearby areas. Measures to reduce local fall-out include using higher towers and by stabilizing surface soil around the towers.

Another factor which affects the area, the amount, and the timing of the fall-out is, of course, the energy yield of a detonated device. In the kiloton range of bursts, radioactive material will be confined to that section of atmosphere known as the troposphere where winds will mix and dilute materials rapidly, where clouds form, and precipitation will fairly rapidly strip out the radioactive material. Bomb debris in this case may travel around the world but will be confined largely to the approximate degrees of latitude in which the explosion took place.

Radioactive materials driven into the stratosphere from detonations of larger weapons have a different pattern of fall-out from that which is distributed in the troposphere. In the stratosphere, clouds and precipitation are absent, so that finely divided material may remain there for a period of years, to be deposited on the earth only as it drifts downward into the troposphere and becomes subject to its precipitation. Radioactive material that enters the stratosphere may be considered as depositing itself more or less evenly throughout the world.

Several hundred thousand measurements have been made of fall-out in the air, water, soils, and wide variety of biological specimens through the monitoring programs already described. The data have been reported in the open literature and will only be summarized here. In regard to external radiation exposure, the Committee of the National Academy of Sciences—National Research Council in their June 1956 report estimated the average exposure to people in the United States would equal about one-tenth of a roentgen for a total 30-year dose if nuclear weapons tests continued at their present rate (with an uncertainty factor of five). As points of reference, and again concerning external radiation, the estimated average radiation exposure to people in the United States each year from medical uses of X-rays and radioisotopes, and the exposure each year from naturally occurring radioactive sources, are roughly equal to the same amount as 30 years of tests at the present rate would cause—one-tenth of a roentgen. The fall-out outside the United States from weapons tests generally has been even less.

The range in values of maximum possible accumulated gamma doses to date for localities in the United States outside the vicinity of the site is 0.006 to 0.049 roentgen (except three cities, Albuquerque, N. Mex., with 0.11, Grand Junction, Colo., 0.12 and Salt Lake City, Utah, 0.16) while foreign stations range from 0.004 to 0.023 roentgen (except some of the Pacific Islands which range from 0.013 to 0.15).

The highest exposures from fall-out experienced to date in the United States was at a motor court about 100 miles from the Nevada Test Site, where about 15 people might have accumulated approximately a seven to eight-roentgen dose if they continued to live there. The next highest exposure was about four roentgens at Bunkerville, Nev., a community of some 200 people.

Long term exposure. Exposure to radioactive fall-out within a few weeks after a weapons detonation is of interest principally because of the external radiation dose which could be delivered to the body from outside by the mixture of radioisotopes in the surrounding environment. With the passage of time, the radioactivity of many constituents of fall-out will decay to levels which are negligible from the standpoint of external exposure. The focus then shifts to the possibility of internal irradiation from a long-lived radioisotope, strontium 90. For a unique combination of reasons, strontium 90 which enters the body will be deposited in the bones.

Many biochemical and radiological aspects of strontium 90 and its effects are reported in the section on strontium in Chapter VI. The dissemination of strontium 90 from nuclear detonations and of subsequent uptake by humans have been under study by the Commission since 1948.[31]

By 1953 monitoring stations began to record the first detectable deposits of strontium 90 and the sampling and chemical assay procedures of researchers were beginning to detect its distribution in the atmosphere, on the surface of the earth, in food materials, and in the skeletons of animals and humans. In the fall of 1953 a broad program of studies of the distribution and behavior of strontium 90 was initiated and was designated "Project Sunshine".

The principal original participants in Project Sunshine were the Enrico Fermi Institute for Nuclear Studies, University of Chicago; Lamont Geological Observatory, Columbia University; the U. S. Department of Agriculture, the U. S. Weather Bureau, and the Commission's Health and Safety Laboratory. Many other agencies and organizations were represented in planning activities sponsored in the summer of 1953 by The Rand Corp., Santa Monica, Calif. Subsequent participation has included routine chemical analysis of samples by Nuclear Science and Engineering Corp., Pittsburgh, Pa. and by Isotopes, Inc., Westwood, N. J.

The Department of Defense also has engaged in cooperative or related activities. A project for determining the efficiency of scavenging devices to remove fall-out for sample collection is underway at the Armour Research Foundation, Illinois Institute of Technology, Chicago, Ill. General Mills, Inc., Minneapolis, Minn. is participating with a study of relative effectiveness of various methods for collecting radioactive materials in the air. Limited participation, frequently on an informal basis, includes other governmental agencies, agricultural experiment stations, and a number of hospitals and physicians.

While one principal objective of Project Sunshine is to determine directly the relationships between the production of strontium 90 by nuclear detonations and its uptake by humans, in order to provide maximum applicability of general data to conditions of possible interest, the Commission has undertaken to correlate radiostrontium occurrence in and movement through all phases of the environment.

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[31] Certain aspects of radiostrontium research were reported earlier: pp. 115–122, Thirteenth Semiannual Report (July–December 1952); pp. 53–54, Sixteenth Semiannual Report (January–June 1954); Appendix 7, Eighteenth Semiannual Report (January–June 1955); pp. 69–72, Nineteenth Semiannual Report (July–December 1955); pp. 105–106, Twentieth Semiannual Report (January–June 1956).

Sampling patterns have been developed to define relations between quantities of strontium in the stratosphere and rates of fall-out; relations between rainfall and fall-out; occurrence in soil and in plants and animals raised on the soil; uptake from the soil as affected by the nature of the soil; behavior of fall-out reaching vegetation directly from the air; variations in soils, plants, animals, food products, and humans, with location on the earth's surface; and effect of age and diet upon uptake by humans.

Some of these relationships have been studied by sampling within the United States, but many involved extensive sampling on a world-wide basis. The highest concentrations of strontium 90 are found in the general latitudes in which its greatest production in nuclear tests has occurred. The basic facts of all these findings have been reported in the professional literature and by Commission officials.[32]

As the broader outlines of the fall-out problem become better defined, research will attempt to reduce the uncertainties about distribution of fall-out and the physical and chemical behavior of strontium. Some uncertainties arise from physical and geographical factors such as the relative inaccessibility of both the stratosphere and many geographical areas, and difficulties of estimating fall-out into the ocean. Some depend upon the technical difficulties of obtaining and measuring samples. Other uncertainties arise from lack of information about details of nature which affect various aspects of the radio-strontium problem, some of which are being studied perhaps for the first time.

Estimate of the results of detonations of nuclear weapons to date, in terms of both the present and future distribution of strontium 90 in nature and in man, must be considered as tentative to date and to require additional measurements. In the opinion of Commissioner Willard F. Libby and the staff, estimates made by persons actively engaged in Project Sunshine are believed to be generally somewhat conservative and "on the safe side."

In a recent address before the American Association for the Advancement of Science, Washington, D. C., October 12, Commissioner

[32] "Radioactive Strontium Fallout", W. F. Libby, Proc. Nat. Acad. Sci., No. 6, p. 365, June 1956; "Radioactive Fallout in the United States", Merril Eisenbud and John H. Harley, Science, 121, No. 3150, pp. 677–680, May 13, 1955; "Radioactive Fallout through September 1955", Merril Eisenbud and John H. Harley, Science, 124, No. 3215, pp. 251–255, August 10, 1956; "Civil Defense Program", Hearings Before Subcommittee on Civil Defense of the Committee on Armed Services, United States Senate, February 22, 1955; "Health and Safety Problems and Weather Effects Associated with Atomic Explosions", Hearing Before the Joint Committee on Atomic Energy, April 15, 1955; "Civil Defense for National Survival", Hearing before Subcommitee of the Committee on Government Operations, January 31, 1956.

Willard F. Libby has estimated that "a total of about 22 millicuries[33] per square mile of strontium 90 is to be found in the soils of the midwestern United States," and that the concentration is about three quarters of this value in similar latitudes in the rest of the world. "The stratospheric deposition would be expected to continue at the expected rate which at the present is about 1.2 millicuries per year, so that some 15 years from now . . . a maximum additional total stratospheric fall-out of about 6 millicuries per square mile will have occurred. In the meantime, the present 22 millicuries per square mile would have been reduced to 15 by radioactive decay, just about compensating for the stratospheric deposition." From available data relating human uptake to content of the soil, he estimates that "at the moment we would expect that the body burden for children born now in America eventually would amount to between 0.004 MPC units (4 micromicrocuries per gram of calcium) . . . and possibly a figure two or three times higher."

In an address before the Washington Academy of Sciences, Washington, D. C., November 15, Merril Eisenbud, Director of the Atomic Energy Commission Health and Safety Laboratory, New York, stated that his estimates of the deposition of strontium 90 in soils were in good agreement with those of Commissioner Libby. On the basis of current concentrations of strontium 90 in milk in the New York area, Eisenbud estimated that 8 micromicrocuries of strontium 90 per gram of calcium was the upper limit of the foreseeable strontium burden in the skeletons of the population of that area, and that 25 micromicrocuries of strontium 90 per gram of calcium was the highest foreseeable skeletal burden anywhere in the United States from weapon tests already conducted. Eisenbud qualified the estimate with the statement, "This estimate is likely to be reduced as new information about the uptake of strontium 90 eliminates some of the uncertainties which have prompted the use of highly conservative assumptions."

Work is continually being carried out on skeletal radiostrontium burdens. One report on such research, to be published in the near future, indicates that worldwide average radiostrontium burdens resulting from fall-out from weapons already detonated may be somewhat lower than previously estimated.

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[33] For definitions of units of radiation measurements used here, see earlier section on "Standards of Radiation Exposure."

VI

RESEARCH PROGRAMS ON RADIATION EFFECTS AND TREATMENTS

Every year one or more new radioactive or toxic materials emerges in the atomic energy program as extremely important from a health standpoint, either because the material has not previously been handled in sizeable quantities, or because it is encountered in an unfamiliar form or in new circumstances.

Against penetrating radiations from a reactor, an X-ray machine or a high energy particle accelerator protection can be accomplished with relative simplicity once the type of radiation emitted, its energy, rate of emission, and its relative biological effectiveness are known. Shielding, the carefully planned use of distance, time limits on exposure, or these methods in combination, are sufficient.

When radioactive materials are moved around, mined, processed, or machined, as reactor coolants pass them into a river, or as stack gases from processing plants disperses them to the atmosphere, they may be absorbed into living systems. Under such circumstances the problems of protection multiply and precise knowledge is necessary to guard against the toxicity of each form or compound of a given radioisotope if it should accidentally enter the body. The material may be soluble or insoluble, particulate, liquid or gaseous, bound or unbound to specific organic or inorganic matter. If it is in particulate form, the size of the particle is very important in determining its retention if inhaled. If it is in a liquid state it must be known whether it can be absorbed directly through the skin.

Finally, the Commission must be prepared to cope with accidents if the material comes in contact with and enters the body through a cut or abrasion, through the lungs by inhalation, or through the gastrointestinal tract by ingestion. It is then necessary to know where it will go in the body, in what organs it concentrates, and how long it will stay there. Means must be devised for determining how much is in the body at a given time (bioassay methods) and coincidentally methods must be developed for speeding up the removal of a radioelement from the body.

There must be an ever-increasing flow of more exact knowledge concerning the effects of radiation on the body as a whole and on each organ of the body. It must be known how much radiation is delivered to critical body organs by given concentrations of scores of radioisotopes, from tritium at one end of the atomic table to plutonium and other transuranic elements at the other end. The degree and type of injury produced by given amounts of a material deposited at a given site must be ascertained. Research on radiation detection and measurement instruments helps to provide necessary tools, both for research and for monitoring services. These are the sorts of information that the Commission provides through its biological and medical research program for such groups as the National Committee on Radiation Protection and Measurement [34] so that they may develop dependable recommendations concerning maximum permissible exposures to ionizing radiations in all the forms in which they are likely to be encountered.

Fields of Research

Biological and medical research for the Commission encompasses many scientific disciplines, medical, biological, biophysical, biochemical, and agricultural sciences, as well as meteorology, geology, hydrology, and others. It is carried out both in Commission laboratories and under contract for the Commission by many academic, industrial, and other scientific organizations. Categories of research sponsored by the Commission which are important to radiation safety include programs on:

a) Radiation effects on the body, including radiation sickness, life-shortening, sterility, and on immunology, and embryonic development; its effect on various molecules important to bodily health, and the damage it does to blood-forming organs, and to gastro-intestinal and central nervous systems.
b) Biochemical and biomedical methods of combating radiation injuries and of treating injuries.
c) Ways of protecting the environment against radiation, including studies on waste disposal, shielding, weather; kinds and levels of injury resulting from various quantities and kinds of radiation so as to define permissable exposures and concentrations; kinds, volume, and effects of fall-out from weapons tests.
d) Patterns of plant and animal life in the environs of major atomic energy installations, and ecology of total environment, including plant-animal food cycles.
e) Ocean, ocean currents and other related aspects and their effects on waste disposal, marine biology and industrial fisheries products which might be damaged or concentrate radiation.
f) Effects of radiation on genetic inheritance.

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[34] See Chapter V.

g) Chemical and radiation toxicology of various atomic energy products and their different compounds.
h) Cancer, how it is caused by radiation, its diagnosis and treatment.
i) Principles, techniques, and instruments for radiation detection and measurement.
j) Research on radiation detection and measurement instruments.

A Typical Program

Specific research programs usually arise from some actual problem in atomic energy activities. Such are the broad programs, reported later in this chapter, dealing with uranium or plutonium toxicity, or specific problems of waste disposal. Others may arise from research discoveries. An example of the latter type, which might be called the "bone-marrow problem" arose out of efforts to combat the effects of exposure to massive doses of penetrating radiation.

"*The Bone-marrow Problem.*" About 6 years ago, it was discovered through studies at the Argonne National Laboratory and the U. S. National Institutes of Health, that animals exposed to large doses of radiation to the entire body could be kept alive by injecting, within a few hours after exposure, the living blood-forming cells obtained from the bone-marrow of normal animals. The same treatment might prevent the development of leukemia after irradiation. Recent animal studies confirmed that this method provided impressive protection against radiation injury. A mosaic of the research pieces necessary to make a complete picture was developed, and individuals capable of working in the various areas defined were called upon.

It was suggested that the bone-marrow treatment be tried in larger animals, and work with monkeys now is under way.

To develop methods of preserving fresh bone-marrow and critical cells for later use, a contract was executed for research on quick-freeze techniques that have been effective in preserving other types of body tissue.

Some other method than obtaining bone-marrow cells from fresh tissue would be highly desirable, so attempts were made in laboratories to devise a culture for bone-marrow tissue.

A strain of mice was found which continuously produced offspring with a naturally occurring anemia; such a strain was suited for research to test the effectiveness of bone-marrow transplant. The continued availability of this strain of mice had to be assured.

Clinicians were found who were already working on blood and bone-marrow diseases in human beings and were exceedingly interested in trying to help their patients with bone-marrow transplants.

This broad research effort, involving several institutions and scientific disciplines, will test the possibilities of working out those experimental observations to provide a basis for radiation protection practices.

Sites of Research

Much of the Commission's research to support and advance radiation protection in biomedical and related fields is accomplished in Federal laboratories. In many cases, research contracts with universities, hospitals, nonprofit organizations and, in certain instances, industrial organizations are employed. The methods of bringing in such contract groups will vary. Scientific circles may be notified that certain broad areas of research are of interest to the Commission. Personal contacts of Commission staff with the scientific community are used. Research proposals made in these fields are canvassed and those deemed most likely to lead to productive results are selected. In special cases, an individual known to be interested, and qualified to work in a particular field, may be asked to consider making a proposal for research under Commission contract.

At present the Commission has 463 research contracts in biology and medicine, much of it related to radiation effects, treatment, and protection.[35] For this type of research the Commission has a budget of $8.8 million for the year ending June 30, 1957. The Commission supports biology and medicine research at the following laboratories and major Commission projects for which its 1957 budget is $22 million: Argonne National Laboratory (University of Chicago contractor) at Lemont, Ill.; Atomic Bomb Casualty Commission (National Academy of Sciences—National Research Council, contractor) Nagasaki and Hiroshima, Japan; Brookhaven National Laboratory (Associated Universities, Inc., contractor) Upton, Long Island, N. Y.; Eniwetok Marine Biological Laboratory (University of Hawaii, contractor) Marshall Islands; Hanford plant (General Electric Co., contractor) Richland, Wash.; Health and Safety Laboratory (New York Operations Office, Atomic Energy Commission) New York, N. Y.; Knolls Atomic Power Laboratory (General Electric Co., contractor) Schenectady, N. Y.; Los Alamos Scientific Laboratory (University of California, contractor) Los Alamos, N. Mex.; Oak Ridge Institute of Nuclear Studies (contractor) Oak Ridge, Tenn.; Oak Ridge National Laboratory (Union Carbide Nuclear Co. of Union Carbide and Carbon Corp., contractor) Oak Ridge, Tenn.;

[35] See pp. 46–49, Ninth Semiannual Report (July–December 1951) for statement on contract policy.

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University of California Atomic Energy Project (University of California, contractor) Los Angeles, Calif.; University of California Radiation Laboratory (University of California, contractor) Berkeley, Calif.; University of California, Medical Center, Radiological Laboratory (University of California, contractor) San Francisco, Calif.; University of Rochester Atomic Energy Project (University of Rochester, contractor) Rochester, N. Y.; University of Tennessee Atomic Energy Project (University of Tennessee, contractor), Oak Ridge, Tenn.; University of Washington, Applied Fisheries Laboratory (University of Washington, contractor) Seattle, Wash.

Associated with these laboratories and projects are three Commission hospitals which conduct research at University of Chicago, Brookhaven National Laboratories, and Oak Ridge Institute of Nuclear Studies.

Problems of Internal Radiation

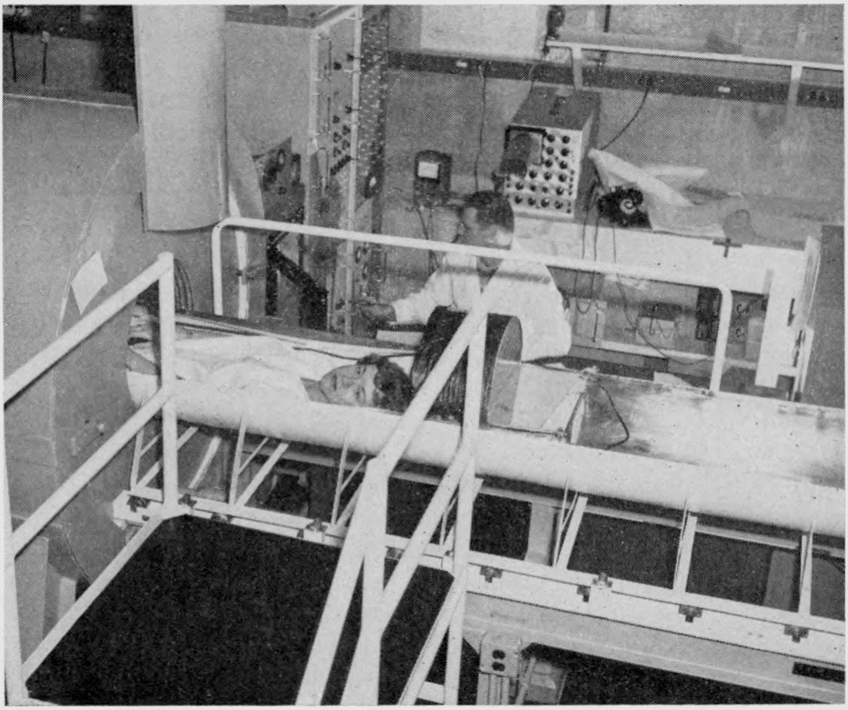
The following sections report on some radioactive elements met with in Commission research and industrial operations, the hazards resulting from them if they metabolize into body tissues, and the present status of knowledge about them. The subject of this section is one in which conclusions may vary over a wide range. In general, what is presented here is a consensus on the present state of knowledge.

When radioisotopes were first manufactured by bombardment of materials in early cyclotrons, radioactive iodine and phosphorus, plus a few other radioisotopes to a slight extent, were used in clinics, but their radiotoxicity was a secondary consideration because of the small amounts that were available. The development of the atomic energy program forced very urgent consideration of the possible internal effects of a whole host of radioactive forms of many elements, most of them rare elements and including some whose biochemistry was undetermined.

Practically all that was known that had direct bearing on radioactive substances within the body was that the effects were much the same as those of external radiation directed to certain tissues; that these effects probably were always damaging when the amounts were great enough to produce noticeable changes, and that cancer was an important end-result and might show itself only after many years. As to exactly how much of an isotope might be expected to produce a serious result, knowledge was limited to the action of radium on persons exposed in industry, or given radium in the years when this element was thought to have curative properties if taken orally or by injection.

Study of such cases seemed to show that human cancer never occurred from taking radium when the person's body had a "burden" of less than one microcurie of radium. Therefore, the assumption was made, using a conventional safety factor, that a permissible body burden of radium of one-tenth of a microcurie would be acceptable. Much more experimental work has been done and many more cases investigated, but this assumption still holds true.

To determine the safe amount of other isotopes, as compared with radium, several types of information were required: first, the physical data must be furnished, the isotope's half-life, its energy, the type of radiation; second, the rate at which it accumulated in the body, or was lost from the body, and the concentrations in various organs and how these changed from time to time. Finally, it was necessary to give animals different doses of the isotopes and to keep them



Detecting internal emitters. A total body counter, at Los Alamos Scientific Laboratory, Los Alamos, N. Mex., is an instrument developed to detect and measure small amounts of radioactive material deposited within the body. The person whose whole body radioactivity is to be measured is placed inside the counter (the woman in the photograph is about to be moved into the counter). The radiations emitted by the body enter a liquid phosphor surrounding the entrance cavity, and the flashes in the liquid caused by radiation are detected by a battery of 108 highly sensitive "electric eyes." The inner mechanism is heavily shielded to exclude background radiation.

throughout their natural lifetimes, observing them, and comparing the effects of the isotopes to those of known substances such as radium.

Besides all this, the question of how to translate to the human body the results of animal experiments was one that concerned investigators since the natural life span of experimental animals limited to a few years the observation of isotope effects. Further, the small size of the animals under observation meant that radiation from one organ might penetrate to and affect other organs much more than in man whose organs are farther apart and larger.

The importance of these questions was foreseen during the early atomic development period at the Metallurgical Laboratory, University of Chicago, since grown into the Argonne National Laboratory. All these problems were studied on rats, mice, rabbits, and dogs, especially with such isotopes as seemed most important at the time: strontium, barium, cesium, yttrium, and plutonium. Animals in the experiments were allowed in large groups to live out their natural lifetime and then were autopsied carefully to detect hidden tumors and other effects. A few dogs that were injected with some of the earlier radiostrontium available still are given periodic physical and X-ray examinations to detect any signs of deterioration due to isotope injections, as well as to old age effects.

At the same time, extensive work was done at the University of California, Berkeley, on the concentration of a large number of isotopes in the various body organs. Most of the isotopes had to be made in the cyclotron and serve as models for the behavior of fission products. At the University of Rochester detailed studies were made on the effects of plutonium, polonium, and radium.

Results from all these laboratories, when collected independently and compared, produced information that has been crucial in determining safe levels of exposure to a great variety of radioactive elements. The value of direct biological investigations was shown. Thus it was found that, in animals, plutonium was many times more toxic than physical calculations had predicted. This was explained by the fact that plutonium gives off its alpha particles in the very parts of the bone that are most active and full of growing cells.

Since that time, other studies of the same type were continued and expanded at these laboratories. Tests on carbon 14, tritium, and several uranium isotopes have been made at Argonne, Hanford, Los Alamos Scientific Laboratory, and Mound Laboratory. At the University of Utah, a large experiment using inbred beagle dogs has been established on the model of earlier experiments with smaller animals, so as to sharpen knowledge of the action of plutonium, radium, and mesothorium. Another large experiment of the same sort to yield more information about radiostrontium has been initiated at the

University of California, Davis Campus. Extensive research on various aspects of radiostrontium is being carried out at a number of universities and Commission laboratories (see later section on that material), and special features of the effects of some other elements are being studied at the cancer and medical research hospitals operated for the Commission at Brookhaven National Laboratory, Oak Ridge Institute of Nuclear Studies, and the University of Chicago.

Radon and Radon-Daughter Problems

Although uranium ores were discovered in this country in 1881, their domestic production remained low for many years, especially after high grade uranium ore became available from the Belgian Congo in 1923. However, the development of the atomic energy program, and the discovery of new deposits during the late 1940's led to tremendous expansion of uranium mining and milling operations.

Radon in mines. The major source of exposure to radioactivity in uranium mines is the presence of radon gas in the atmosphere. Radon is the heaviest gas in existence, seven times denser than air, and is inert, reacting with no other materials. Radon originates in ores which contain, in addition to uranium, all the other members of its radioactive family including radium, which at one stage decays into radon gas. Radon is radioactive, with a half-life of about four days, and decays into two important radioactive products, radium-A and radium-C^1. All three elements emit alpha particles.

Radon diffuses through rocks or is carried into the mine by ground water, and disperses into the mine atmosphere. Some radon gas is inhaled, enters the blood stream and is distributed throughout the body. The radon in the mine atmosphere also decays to produce the solid daughter products which attach themselves to dust and water droplets. If these are inhaled a fraction of the materials also is retained in the lung.

Other radon hazards. Radon exposure may also exist in ore processing plants and uranium refineries, up to the point where radium is separated from uranium, as well as in the handling, shipping and storage of residues containing radium.

Since in none of these operations is there enough radon to produce an acute illness in workers, the most important problem is how much radon can be breathed over long periods of time without producing injury. In 1927 it was demonstrated that 50 to 75 percent of deaths among the miners in the Erz Mountains region of Bohemia and Saxony were from lung cancer. These mines had been worked since the

16th century for silver, cobalt, nickel, bismuth, arsenic, and later, radium. The precise causative factor in these lung cancers remains in dispute, but the probability is that the disease was produced either by radioactivity alone, or by radioactivity acting in combination with dusts containing a great variety of chemical elements. A review of early crude estimates of radon concentrations in those mines was the basis for the present permissible levels of 100 micromicrocuries of radon per liter of air in plants or mines.

Pattern of research. The ultimate target of much research in this field has been to obtain a more precise figure for the maximum permissible concentration of radon. To begin with, several major problems had to be solved, including: development of better analytical methods for radon; estimates of retention and persistence in the lung of radon decay products; rates and sites of distribution of radon in various body tissues; and development of suitable indicators on the basis of which the magnitude of exposure to radon could be calculated.

By 1951 it became apparent to research workers at the Atomic Energy Project at the University of Rochester, Rochester, N. Y., that under the conditions of exposure, the radiation dose to the lungs from filtered, solid, radon-decay products was more important than that from radon gas itself. This finding shifted the emphasis of research toward defining what happened to inhaled dust in the lung.

It was found that test animals on the average retained 25 percent of the amount of radon daughter-products in ordinary dusty atmospheres. In specially cleaned air, although the concentration of the poisonous materials in the air was less, the retention rate was three times higher. In cleaned air the radon daughter-products were unattached to dust particles and were free to move about much more rapidly, and consequently a higher percentage of the amount of materials available would strike and stick to the walls of the air passages.

Studies at the University of Rochester and the Naval Radiological Defense Laboratory with mice, rats and dogs demonstrated that the radiation dose from the radon-daughter products is 10 times higher on the lining of the air passages of the lung than in its deeper portion, the air sacs. Once the material is deposited, the rate of removal from the lung by physiological processes is not sufficiently rapid to modify the radiation dose to the lung itself.

It has also been found that inhaled radon gas diffuses into the blood and is largely taken up by body fat. As the radon gas decays into the various radio elements in its natural decay chain, it is eventually converted to radioactive lead 210, which has a relatively long half-life. Lead 210 does not have an affinity for fat deposits, is ejected and carried in the blood stream to the skeleton where it accumulates.

Lead 210 in turn decays slowly to polonium 210, which does not have an affinity for bone, and is excreted in the urine at a rate proportional to the radon inhaled. Thus the amount of polonium 210 which appears in the urine is a useful index of cumulative exposure to radon.

Great improvement in the analytical methods used for studies of radon and its decay products has taken place in the last 10 years. These were in large measure the result of the emphasis of the atomic energy program on developing radiation detection instruments. Satisfactory techniques for measuring radon and its decay products were developed at the Argonne National Laboratory and the Health and Safety Laboratory.

Although much information has been accumulated about radon hazards, a number of problems remains to be solved. Important among these is the basic question of establishing more precise definitions of the health hazard from protracted exposure. Long-term animal studies at the University of Rochester, and the epidemiological field work being carried out among uranium miners by the U. S. Public Health Service in cooperation with the Commission are expected ultimately to provide the answers.

Uranium Toxicity

The atomic energy program is founded upon the heavy metal, uranium, No. 92 in the table of elements. One of the wartime program's earliest industrial problems was to produce uranium of extremely high purity in large quantities and in various chemical compounds. Uranium now is mined in various areas in this country and abroad, concentrated, and processed into either a gaseous compound for the government's huge gaseous diffusion plants, or into metal to fuel nuclear reactors. Used reactor fuel elements are passed through chemical plants to separate the plutonium from the uranium, part of which was transmuted into plutonium in the nuclear reactors.

From the beginning, detailed knowledge about uranium as a health hazard was vital. The scientists, engineers, and administrators needed to know the answers to such questions as: How toxic were various uranium compounds? How much uranium dust could be permitted in the air of factory or laboratory rooms without injury to the men working there? What respiratory protective devices could be certified to filter uranium dust and fumes from the air? How much of a soluble uranium compound would be absorbed through the intact skin from a spilled solution? What methods should be used to tell the toxic effects on men if they were unavoidably exposed to uranium? How should uranium poisoning be treated?

One of the most important questions arose because uranium is radioactive. Tragic experiences resulted from working with a radioactive material during the first world war. Women employed to paint aircraft dials with a radium-containing material had pointed the paintbrushes with their lips and swallowed traces of the material. A number of these women died years later from severe anemia or from bone cancer. Deaths had been associated with the presence of as little as a millionth of a gram (one microgram) of radium in the whole body. The question for atomic energy administrators was: Will uranium also be deposited in the skeleton and, because of its radioactivity, constitute a radium-like hazard?

Studies on Inhalation. Typical of the vigorous attacks made on such problems of toxicity in the atomic energy program was the extensive program of research on inhalation exposures undertaken at the University of Rochester. Groups of dogs, cats, rabbits, guinea pigs, and mice were allowed to breathe for 30 days various concentrations of uranium dusts and fumes. A total of 46 one-month studies was made. In addition, 13 one-year studies were carried out on representative compounds: uranium nitrate; uranium tetrachloride; uranyl fluoride; the brown oxide, uranium dioxide; and the green salt, uranium tetrafluoride. A two-year exposure study was made in which some animals at the end of each one-year study were placed for a second year in an atmosphere containing uranium nitrate dust.

Based on evidence from these studies, the principal injurious effect of soluble uranium salt was found not to result from radiation at all, but from a chemical poisoning chiefly affecting the kidney. A level of 50 one-millionths of a gram (50 micrograms) per cubic meter of soluble uranium compounds now has been set as the maximum acceptable concentration (MAC).[36] This recommendation in effect predicts that inhalation of such an atmospheric concentration will not cause kidney injury.

It was not possible, however, simply to apply to insoluble compounds the standards established for soluble compounds. Insoluble compounds originally were classed as of lesser toxicity, and research proved this was correct insofar as chemical poisoning of the kidney was concerned. However, with very high dust concentrations, such as 10,000 micrograms per cubic meter, experiments showed that the deposition in dog lung was 950 micrograms per gram of lung. This was an astonishing buildup. The pulmonary lymph nodes accumulated considerably more. These concentrations could well constitute

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[36] MAC, or Maximum Acceptable Concentration, is a term applied to materials in which chemical toxicity is the controlling factor in setting concentration levels, as contrasted with MPC or Maximum Permissible Concentration for materials in which radioactivity is the controlling factor.

a radiological hazard, thus the problem of the lung buildup of an insoluble dust emerged as the chief radiation problem with uranium compounds. Twenty-five micrograms of uranium per gram of tissue would deliver approximately the maximum dose of radiation which tissue could withstand. The dog lung tissue contained nearly 40 times this amount.

A level of 100 micrograms per cubic meter of air was then recommended for insoluble uranium compounds but because of the difficulty of distinguishing in a dusty atmosphere between soluble and insoluble uranium compounds where both were present a single limit was selected—50 micrograms per cubic meter.

A still further problem of dealing with uranium involved its deposition in bones. Rough calculation indicated the radioactive hazard of skeletal uranium could be temporarily disregarded. Uranium is about one four-millionth as radioactive as radium. Thus, nearly 4,000,000 micrograms (4 grams) of uranium would have to be deposited in the skeleton to produce the effects of one microgram of radium. If the level were set at 150 micrograms per cubic meter of air, and if a man breathed 10 cubic meters a day and actually retained and deposited in his bones all the uranium dust inhaled, it would still take over 5 years at this rate to build up a total of 3.8 grams. The 150-microgram level was the one set early in the program.

Other research results. The levels set in the program for uranium have been justified by the test of use. There are no known chronic uranium poisoning cases despite the fact that thousands of people have handled tens of thousands of tons of uranium.

The research to determine safe radiological and toxicological operating levels for uranium as reported here is only a part of that conducted during the early months and years of the atomic energy program. Further studies along the paths of basic biochemical research not only led to a method of treating acute uranium poisoning, but also to major advances in knowledge about cellular metabolism of carbohydrates—a basic knowledge that may assist understanding of other diseases, notably diabetes.

One key problem that had to be solved early was development of an analytical method of sufficient precision to trace uranium in the body and measure its concentrations in various body fluids. The method eventually perfected at both the Commission's Health and Safety Laboratory and the University of Rochester gives extremely high sensitivity. Under ultraviolet light, sodium fluoride glass will fluoresce if it contains uranium. In certain uranium concentration ranges, the fluorescence is directly proportional to the amount of uranium present. By irradiating the glass with ultraviolet light of an appropriate wave length, and by filtering the fluorescent light which results, so that only the characteristic emission wave length reaches a photo cell, it is possible to measure with high precision one two-billionth of a gram of uranium. Subsequent improvements increased the sensitivity of this test by at least 10 times.

Using this analytic method scientists at the University of Rochester traced uranium after its entrance into the body and determined that an hour after absorption, about a third of the uranium is in the bone, another third is in the urine, and the balance in the kidney and other soft tissues of the body. When uranium concentrates in the urine, a reaction between the uranium and the cells lining the kidney tubules injures the cells. If the dose is large enough, the cells die and the debris, including protein and several enzymes, is discharged in the urine. Studies on the functional nature of the kidney damage indicated specific injury occurred only in that portion of the tubular system largely responsible for the control of sugar excretion. This explained why increased amounts of sugar were excreted in the urine as a result of kidney damage by uranium.

Further studies sought to explain why uranium poisoned the kidney tubular cells. Working with yeast cells, experimenters demonstrated that uranium blocked sugar metabolism, and that the uranium was bound to the surface layer of the cell where it interfered with a series of enzymes responsible for the uptake of glucose. Uranium binds complex phosphate compounds in the cell wall, replacing the element magnesium and forming a compound that does not allow the first reaction in the metabolism of glucose to take place.

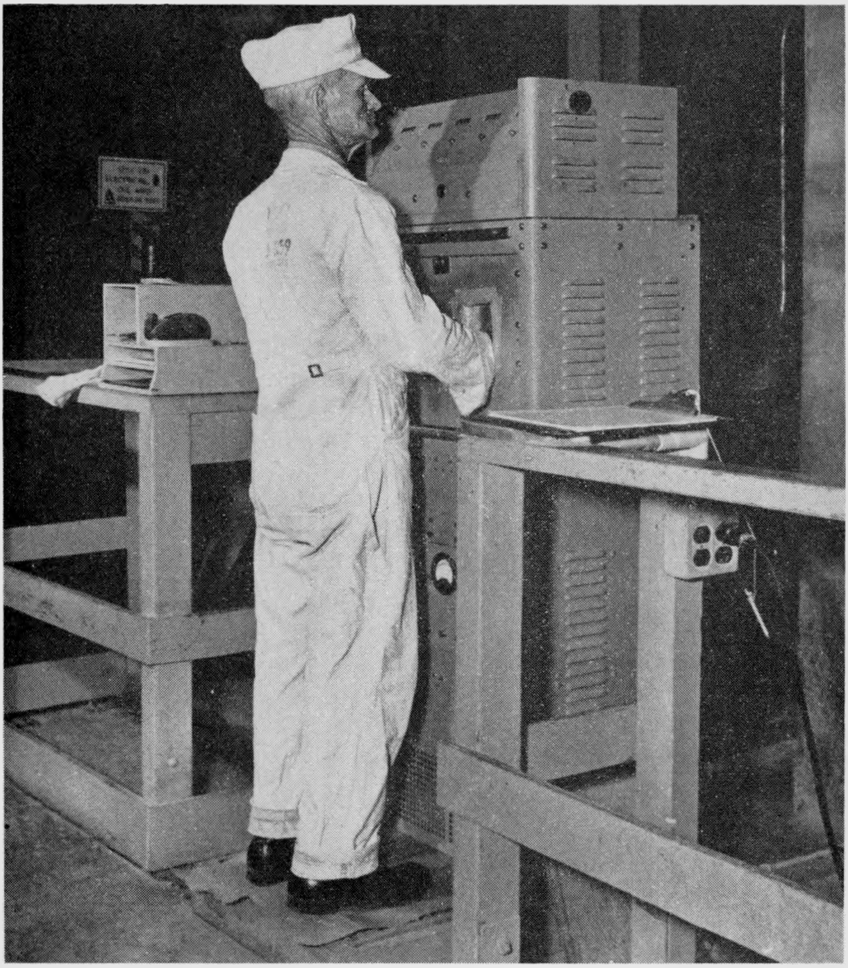
This discovery led to development of a method for treating acute uranium poisoning. Similar complex phosphate compounds are used which, when injected into the blood, react with the uranium before it has a chance to poison the cell. Later studies demonstrated that some of the versenes, a chelating agent of the kind that renders a material chemically inert, are more potent as antidotes for acute poisoning and are recommended for intravenous human therapy.

The story of uranium research, insofar as defining the hazard, engineering against it, and developing an antidote for acute kidney poisoning, is about finished. There are a few long-term experiments yet to be completed at the University of Rochester and Jefferson Medical College. Meanwhile, the scientists who worked on the uranium problem are already engaged in other researches.

Plutonium Toxicity: Estimating Body Burdens of Radioisotopes

The fissionable material plutonium 239 is not found in nature, and is produced in atomic reactors by neutron-capture transmutation of uranium 238. Plutonium has a half-life of 24 thousand years, emits alpha particles, and, gram for gram, is some 200,000 times more radioactive than uranium. Because of its radioactivity, plutonium, like radium, is dangerous within the body in amounts far less than would produce a chemical hazard.

Once plutonium is extracted from reactor fuel elements or reactor blankets, it is carried through a series of compounds into metallic form and then cast or machined into the desired shape. In these activities, exposure hazards exist potentially from skin and wound



Checking on contamination. A standard hand-and-foot counter used in atomic energy operations wherever hands and feet are apt to pick up contamination, this one at Oak Ridge National Laboratory, Oak Ridge, Tenn. If either hands or feet contain even as much contamination as on the dial of a night-visible watch, the counter will flash a warning light and sound a buzzer.

contamination, and accidental ingestion, but primarily from inhalation of dust or fumes.

Plutonium was first produced in 1942, and soon was recognized as dangerous to man in a manner similar to radium. The accepted permissible body burden of radium is one-tenth of a microgram. With allowances made for differences in the rate of radioactive decay, and the energy of the radiations and specific biological effects, it was calculated that it would take about 45 times as much plutonium, or 4.5 micrograms, to equal the damaging effects of one-tenth of a microgram of radium. To be on the safe side, the tolerance dose for plutonium was set below these levels at one microgram (one millionth of a gram), or 10 times the radium tolerance level.

Preliminary studies at the University of Chicago Metallurgical Laboratory on the urinary excretion of plutonium by rabbits indicated a fairly constant rate of elimination was reached about 2 or 3 weeks after the initial entry of plutonium into the body. To measure rates of excretion it became necessary to develop methods of detecting the presence of plutonium in quantities as low as one-hundredth of a millionth part of a gram per cubic centimeter of urine. Scientists at Hanford, Los Alamos Scientific Laboratory, Oak Ridge National Laboratory, and the University of Chicago, all had a hand in perfecting a technique that made it possible to detect in the urine quantities of plutonium that represented something less than that expected if the subject's body had a maximum allowable amount. Excretion was found to be approximately 0.01 percent per day of the body burden.

Further studies, however, on a variety of species indicated that the excretion rate varied considerably, and studies on human beings became necessary. During the first 15 days after plutonium was administered to human volunteers at several sites where plutonium was handled, there was less than a 10 percent variation among the daily urinary plutonium excretion. By these tests, it was determined that urinary plutonium excretion rates were about 0.01 percent per day of the body burden for subacute concentrations of plutonium in human beings.

Following the very extensive studies on plutonium toxicity at Argonne National Laboratory, the University of Utah is working in this field. Hanford is studying the absorption and metabolism of plutonium. The Los Alamos Scientific Laboratory is conducting a comparison study of the metabolism of plutonium, strontium and calcium. At the University of Rochester, the biological effects of inhaled radioactive material, including plutonium, are under study.

Other applications. Using analysis of excreta to estimate the amount of internally deposited radioactive isotopes—the "body burden" of an isotope—is applicable to a number of other radioelements besides plutonium. For convenience in predicting amounts of radioactivity deposited in the body, mathematical formulations have been attempted to express patterns of excretion. The concept of a biological half-life of isotopes in the body is useful in certain instances. This concept assumes that, once a radioactive material enters the body, it is retained in a single "compartment" of the body (blood, tissue fluids, thyroid gland, etc.), or that the rate of elimination from one or all compartments controls the total excretion rate. In the case of radioiodine, numerical values have been calculated for the rates of transfer between "compartments" with the use of a specially designed analogue computer. In many instances experimental data indicate that these assumptions, although not strictly accurate, are usable for practical purposes. They also provide a basis for calculating maximum permissible levels of exposure.

Urinary excretion does not, of course, directly measure unabsorbed radioactive material deposited in the lung. It can reflect only that amount of the material which has been dissolved into the blood from the lung and deposited in tissues. Much research has been devoted to obtaining quantitive data on the rates at which each isotope of practical importance is removed from the lung. Particles inhaled and deposited in the bronchial or upper air passages are swept out in a matter of several hours by tiny hairs (cilia) covering the inner wall of these tubes. The particles are swept upward to the throat and then swallowed. This fact led to estimating the magnitude of an accidental exposure to radioactive material by measuring radioactivity in the feces.

The rates of solution and passage of particles from the lung into the blood have been studied, as have the rates at which particles are engulfed by scavenger cells and transported in lymphatic channels to the lung roots. Measurements were made by scientists at the Universities of California, Berkeley and Los Angeles, and the University of Rochester, of the patterns of unequal deposition of dust in the various lobes of the lung so as to estimate radiation dosage delivered by retained dust particles. New techniques developed at New York University have recently been utilized to increase knowledge about the relationship between particle size of dust in the atmosphere and the amount and site of retention in the lung. Elaborate radiation detection systems, developed at Los Alamos and Argonne laboratories and used in cases of accidental exposures of humans to radioactive dust, have provided much needed data on the rates of removal of radium and other radioelements from the lung and from the body in general.

Tumor formation. The permissible concentration of radioactive dusts in the atmosphere is set at that level—the same as that for the whole body—which will prevent accumulation of sufficient radioactive dust in the lung to inflict a radiation dose in excess of a "permissible" level. However, when scattered radioactive particles are deposited in the lung the radiation dose to tissues near the particles is very much higher than to other tissues. Thus the average dose to the lung as a whole may be at the "permissible" level but bits of tissues may receive much higher radiation doses.

Because of this fact, another large area of Commission research is concerned with tumor production by radiation. Experiments were undertaken to determine the cancer-producing properties of various radioactive materials, the majority of which were "bone-seekers." A large portion of these materials that reach the circulatory system is deposited in the skeleton, as are radium, uranium, strontium, yttrium, plutonium and, to a lesser extent, cesium. The chemical form of the radioactive element influences the site of its deposition and consequently the location of any tumor that may be formed. Radioelements lodged in the skin in very insoluble form may produce tumors only at the site of injection. Feeding insoluble radioelements to test animals has resulted in tumors of the large bowel.

Numerous studies indicate that the probabilities for development of cancer are directly related to the size of the radiation dose. With smaller dosages, very few tumors occur, and the numbers of animals required to get a statistically valid estimate of true tumor incidence becomes very large. This fact is directly related to human problems. For example, if only ten individuals were exposed to a given dose of radiation, and the incidence of radiation-induced tumors at that dose was only one-tenth of 1 percent, the risk to the group as a whole would be relatively low. On the other hand, if several hundred thousand persons were exposed, the risks for each individual would remain the same but the probability would be that many cases of cancer would occur because the group was large enough for statistical averages to take effect. The evidence still is incomplete on the relationship of radiation dose to the risk of cancer production and the matter is under continuing and intensive study. However, permissible exposures have been established on the basis of a consensus of the best scientific opinion.

Other studies of tumor induction by radiation have been directed toward determining the relationship between single large doses and repeated smaller doses in producing cancer. The problem is extremely complex but at the present time the evidence indicates that repeated smaller doses tend to be somewhat more effective in producing cancer.

The effect of radiation during the "latent period" between overexposure to radiation and cancer occurrence is being studied. The question still to be answered is whether this period of delay is increased as radiation doses become smaller. Because the emitted radiation and the physiological affinities to various tissues differ greatly among the radioelements, it is necessary to study the relative effectiveness of each one in producing cancer.

Removing poisons from the body. Study of methods of treating radioactive element poisoning has been concerned in most cases with the treatment of poisoning by radioactive metals. These are the radioisotopes of greatest danger since they possess long radioactive lives and stay in the body for a long time. A number of basic factors in the treatment of radioactive poisoning require experimental studies; for example, the chemical nature of the radioelement following its initial deposition in the body; the time required for transfer from the initial site of deposition into the blood; rates of deposition in organs of higher affinity; and excretion.

The first objective of treatment is to minimize absorption of the poison into the blood stream. After absorption has taken place, efforts can be made to increase the rate of excretion from the body. Research in this field has led especially to defining the biochemistry of bone metabolism since many of the poisons are deposited in the bone.

A considerable body of information was available through studies on lead poisoning. Attempts had been made to remove skeletal lead by upsetting the normal pattern of calcium metabolism so that the bones tended to become demineralized. To a limited extent, this worked. Experimental attempts to eliminate radioactive bone-seeking isotopes by this method have had small success. Massachusetts Institute of Technology currently is utilizing an artificial kidney to learn more about the limiting factors in the demineralization process and to develop a method of treatment which, although drastic, might be effective in cases of massive exposure.

In recent years the class of compounds with the capacity of rendering certain types of elements chemically inert, the "chelating agent," was developed. "British Anti-Lewisite," used successfully against poisoning by arsenic, mercury, and bismuth, has the capacity of combining with the heavy metal in the blood and tissues and rendering it chemically harmless. Working on this principle, researchers have found new chelating agents the most outstanding of which is ethylenediaminetetraacetic acid, better known as EDTA and developed originally as a boiler cleaner. This compound has a relatively low toxicity and forms chelates which are water soluble, easily diffusible, and hence readily excreted from the body.

EDTA is especially useful against a class of radioelements known as the "rare earths," which have come into prominence since the beginning of the atomic age, as well as the man-made elements heavier than uranium. Its administration following an accidental exposure to plutonium has resulted in a striking increase in plutonium excretion, and EDTA is now an important therapeutic tool.

Another interesting development in treatment of radioelement poisoning has been the use at the Argonne National Laboratory of zirconium salts against plutonium poisoning. The injected zirconium is carried in the blood stream in tiny aggregates which selectively bind whatever plutonium happens to be circulating in the blood stream at the same time, and deposits them in certain cells of the liver and spleen. The fact that zirconium salts block plutonium deposition in the bone permits EDTA treatment to divert the poison toward the kidney where the plutonium will be excreted.

These treatments are of real use only in the early stages of poisoning. When radioelements have been allowed to remain in the bone for extended periods, they are incorporated into the older portions of the skeleton, and are inaccessible to present methods of treatment. The problem of how to treat such individuals remains the subject of intensive study, much of which is on basic bone metabolism.

Hazards at Radiochemical Plants: Iodine, Strontium, Tritium

Fuel elements irradiated in nuclear reactors, besides uranium and plutonium, contain the highly radioactive fission fragments of uranium. When the fuel element slugs are processed in the radiochemical separation plants, the irradiated slugs contain millions of curies of radioactivity. The transfer of the slugs from their shipping containers into the dissolving tanks and the transfer of solutions from one vat to the next is accomplished by remote control from behind heavy concrete barriers.

The hazards encountered in these operations stem from the possible release of these materials into working areas, and into the environment of the plant. The fission products are to all intents and purposes radioactive wastes and must be disposed of in some safe way (see Chapter IV, Radioactive Wastes). Research on two of the radioactive fission products that contribute especial problems—radioiodine and radiostrontium—are reported on here, as is research on tritium (radiohydrogen).

Radioiodine. Most fission product wastes appear as radioelements combined as salts in solution. A few form gases and are readily released into the atmosphere. A major potential hazard arises from the gas, radioiodine (iodine 131), a beta and gamma-emitter with a half-life of 8 days. Elaborate scrubbing and filtering devices, linked to the tall venting stacks of processing plants, make it possible to prevent release into the atmosphere of excessively large amounts.

Inasmuch as it was almost impossible to prevent some iodine 131 from escaping from the stacks, Hanford scientists undertook to determine how much of the gas released would precipitate on vegetation and be eaten by grazing animals. In addition, they had to determine how much radioiodine the animals could eat without harm.

Earlier medical research on the metabolism of iodine in humans proved invaluable as a basis for the animal researches. At Hanford, sheep were fed graded doses of iodine 131 for long periods and the effects of the radiation were assessed by examination. It has been possible to establish tentatively the minimum doses, either from single or from multiple exposure, which will lead to demonstrable changes in the thyroid itself or in other tissues of the body. These studies still are under way and are being supplemented by observation in humans at the Oak Ridge Institute of Nuclear Studies, Argonne Cancer Research Hospital, and Brookhaven National Laboratory.

Research with radioiodine has contributed valuable information on important factors related to the hazards from radioiodine encountered in industrial operations. For example, it has been a source of much knowledge about absorption from the intestinal tract, the amounts deposited in the thyroid gland under different conditions, and the effects on the thyroid gland at different dosage levels. The use of tracer amounts of radioiodine has provided the most sensitive technique for detecting radiation damage of the thyroid gland even at relatively low dosage levels, and biochemical studies on anti-thyroid drugs have given valuable data on methods for blocking the deposition of radioiodine in the thyroid gland in case of accidental exposure.

Studies of radioiodine hazards are parallelled by a tremendous amount of work done in clinical medicine. Radioiodine has provided an extremely sensitive means for measuring thyroid gland function and has been a useful tool in treating excessive thyroid activity and thyroid cancer. Radioiodine has been used to reduce thyroid activity as a palliative measure in the treatment of selected cases of heart disease, particularly of angina pectoris and certain pulmonary conditions. Extensive biochemical work has been done on the detailed chemical mechanisms of iodine binding by the thyroid gland and its conversion into the thyroid hormone, effects of various drugs on iodine uptake into the thyroid gland and hormonal relationships

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between the thyroid and pituitary glands. Exploratory studies have been carried out at the University of California, Berkeley, on the potential usefulness of a related radioelement, astatine 211, which is also taken up by the thyroid gland. Since astatine emits alpha particles whereas iodine 131 emits beta radiation, a comparison of the two isotopes has yielded data on the relative effectiveness of alpha and beta radiation on cellular function.

The long-term follow-up of patients treated with radioiodine is expected to reveal something about the potential cancer hazard associated with radiation of the thyroid gland. The observation of an unusually high incidence of thyroid cancer in young adults who as infants received X-ray treatment to the neck has been an important contribution. An extensive body of data from experiments in a variety of animals has been accumulated on the cancer-inducing properties of radioiodine. The results indicate a comparatively low susceptibility of this gland to cancer induced by radioiodine. The University of California is studying induction of thyroid cancer.

Studies of thyroid metabolism and radioiodine uptake in plants, animals and humans are under way at the Iowa State College, Massachusetts General Hospital, University of Missouri, State University of New York, Research Foundation, Western Reserve University, University of Tennessee, and the University of Kansas, in addition to special studies at Commission laboratories. Among these the University of California Radiation Laboratory, Berkeley, the University of Tennessee School of Medicine, and the Oak Ridge Institute of Nuclear Studies, are making a study of iodine 131 fall-out and radioiodine incorporation in animals and humans; the University of Washington Applied Fisheries Laboratory is studying the uptake of radioiodine in marine crustaceans, and Hanford is studying the biological effects of iodine 131 and its absorption in plants.

Strontium. Radiostrontium is a most hazarodus radioelement present in the fission product waste materials and in atomic bomb debris. The hazard derives from the fact that (a) it is one of the more abundant and long-lived, a beta-particle emitter with a radiological half-life of 28 years, and (b) it is closely related chemically to calcium and so becomes incorporated into bone where, in sufficient amounts it can damage the bone-marrow and induce cancer.

Commission scientists are studying problems associated with the presence of radiostrontium in the environment, water supplies, agricultural and grazing lands, and in the oceans. It has been discovered, for example, that plants take up less strontium when calcium is plentiful in the soil. Data have been obtained on the fraction of radiostrontium taken up by vegetation and later by dairy cattle which is deposited in the skeleton and secreted into the milk. On the basis of these studies, it is becoming possible to calculate with increasing accuracy the amounts of radiostrontium which are transmitted from the soil through the food chain and hence the degree to which it constitutes a source of exposure for humans.

Similar research is being carried out in marine laboratories on the food cycles of the ocean where fission products are initially concentrated by minute marine life called plankton, transmitted to fish which eat the plankton and then to humans who eat the fish. These studies are applicable both to waste disposal problems of chemical separations plants and to the fall-out of fission products following nuclear explosions.

Research involving strontium metabolism in animals and in humans has been undertaken to compare these toxicity data with information on other important "bone-seekers," radium and plutonium. It has been demonstrated that, to a very large extent, strontium behaves like calcium in the body, which depends in the individual on the state of his calcium metabolism. On a molecular scale it is probable that strontium is located in "solid solutions" within the bone crystals, again essentially like calcium. On the microscopic scale, numerous studies have shown by photographic measurement of radioactivity (called autoradiography) that calcium and strontium deposit essentially in the same areas of bone. The initial deposition has been found to be very pronounced at the growing portions of the bone, in a portion of bones known as the epiphyseal plate, under the bone sheath (the periosteum), and in spots throughout the shaft of the bone.

Studies at the University of Rochester and elsewhere show that, as time progresses, these sites of initial deposition are reworked by the metabolic processes of the bone, but the strontium is merely relocated within the skeleton. The result is a progressively more homogeneous distribution of radioactivity and a more nearly uniform radiation dosage throughout the skeleton. The magnitude of radiation dosages in spotty deposits is of significance because of the cancer hazard. Dose rate in spots may be five to ten times higher than for the rest of the bone. Some bones may take up two to three times as much radiostrontium as do others. When radiostrontium is taken in more or less continuously by ingestion, the distribution within the skeleton would become fairly uniform.

Work done on experimental animals at Argonne National Laboratory to determine the radiotoxicity of radiostrontium as compared with radium, led to the general conclusions that, curie for curie, radium is ten times more dangerous.

The recently available cyclotron-produced isotope, strontium 85, which emits penetrating gamma rays rather than beta particles, has permitted studies in humans. Much useful data on absorption and excretion has been obtained with it.

Presently at the University of Utah and at the University of California, Davis Campus, among other places, a series of lifetime experiments is being undertaken in dogs to determine with a greater degree of precision the relative toxicity of radiostrontium and radium. Studies of radiostrontium uptake and metabolism in soils, crops and plants are being made by the University of Arizona, Michigan State University, the United States Department of Agriculture and at Hanford. Strontium deposition in animals and humans is under study at the University of Tennessee, University of Kansas, Massachusetts General Hospital, Montfiore Hospital, New York City, University of North Carolina, Marquette University, the University of Utah, the University of California Radiation Laboratory, University of Rochester, Argonne National Laboratory, and the Los Alamos Scientific Laboratory. Studies of marine plants and organisms are conducted by the Woods Hole Oceanographic Institution, Columbia University Lamont Geological Observatory, the University of Hawaii, the U. S. Department of the Interior, and the University of Washington Applied Fisheries Laboratory. Idaho State College is working on the development of analytical methods for the determination of small amounts of strontium, in addition to other materials.

In addition to these studies, the Commission supports an extensive study of the occurrence, on a worldwide basis, of strontium 90 in air, water, soils, plants, animals, and humans. (For further details, see earlier section on Precautions for Weapons Tests.)

Tritium is an isotope of hydrogen, as is deuterium; the latter is better known as heavy hydrogen, a constituent of heavy water. However, tritium is even heavier than deuterium, and in addition is radioactive, emitting very low energy beta particles with a half-life of about 12 years. It is generated by neutron bombardment of heavy water used as a moderator in a reactor. The possible release of tritium in maintenance operations on heavy-water reactors poses potential health hazards.

Tritium combines with oxygen to form water, because its chemical behavior is identical to that of normal hydrogen. Tritium also exists in the purely gaseous form, again like hydrogen. This raises questions of the comparative hazard of the two forms, the effect of the relative heaviness of tritium water on its distribution in the body. and the effect of the incorporation of tritium into some of the body's essential molecular structures.

A considerable body of knowledge about estimating and controlling the hazards from this radioisotope has been accumulated because of its extensive use in medical research in Commission and other medical centers. It has been an invaluable tool for the study of water metabolism in normal and diseased states, for example, in endocrine disturbances, heart failure, liver disease and the metabolic responses to surgery. The problem of removing excessive water accumulation in heart failure and liver disease has had an important application to the treatment of tritium overexposure in man.

In addition to these indirect contributions, experiments with human volunteers were carried out at Los Alamos Scientific Laboratory. The experiments were safe because the required amounts of tritium were very small due to development of extremely sensitive detection methods. These studies have included estimates of the rate of absorption into the body from the lung following inhalation; the rates of absorption through the skin and from immersion of an extremity into tritium water.

Collateral studies have been carried out at Los Alamos and Hanford Production Works on small animals to obtain information in greater detail on these factors. The patterns of excretion in urine have been determined in man with mathematical analyses to determine the number of body "compartments" into which the tritium water goes. Estimates of absorption by various routes provide the necessary data for calculating permissible concentrations of tritium in drinking water and in the air. In addition, studies have been carried out for evaluating the effectiveness of various procedures which accelerate the removal of tritium water from the body; for example, by forced feeding of fluids and by the use of drugs for increasing the excretion of urine.

Of all the important radioisotopes, tritium is the one which has been studied in the greatest detail so that the current needs for the estimation of body burden and the treatment of exposure are well satisfied. This is due in large measure to the previous accumulation of background information on water metabolism, the inherent simplicity of the problem; and the applicability of tritium to direct study in humans. Only a small research effort is presently in progress on tritium toxicity.

Effects of External Radiation

An important aspect of the hazard associated with atomic energy activities is exposure to penetrating ionizing radiation striking the body from outside. There are many sources of radioactive exposure over which the Commission has no control—general medical or industrial use of X-rays or radium, for example—and for which it bears no responsibility. Radiation emanates from naturally radioactive elements in soil, air and water—such elements as uranium and radium, potassium 40, as well as carbon 14 and tritium formed in the upper atmosphere by cosmic rays. The cosmic rays themselves, from outer space, strike us continually, and add to this natural background radiation. In addition, man has been exposing himself to radiation from X-rays and radium in increasing amounts for the past 60 years.

In the following sections, reports are given on the effects of penetrating radiation, and the treatment of injuries. The subject of this section is one in which conclusions may vary over a wide range. In general what is presented here is a consensus on the present state of knowledge.

Detecting Biological Radiation Effects

The effects of external radiation from X-rays, gamma rays, and neutrons depend on their initial energy and hence the depth in the body to which they can penetrate. The concepts and values for the permissible exposure to highly penetrating radiation originally was evolved on the basis of experience with relatively few X-ray workers. At the very beginning of the atomic energy program, therefore, the question was raised as to whether or not exposure to external radiation within the tolerances established for the program could produce detectable body changes.

The adverse effects that could be produced by radiation upon the blood-forming tissue and the reflection of such effects in the circulating blood were well recognized. The available experimental data, however, were confined to animal studies in which lethal or near-lethal doses of externally applied X-rays and gamma-rays or fast neutrons were given either to a part of the body, or the whole body, in one acute dose or in closely spaced divided doses.

The purely clinical data were limited almost entirely to reports on the effects of therapeutic doses of these same radiations given to local areas of the body and in relatively large single or divided doses. No deliberate studies in animals or man had been reported in which chronic exposure to ionizing radiations was within the estimated tolerance range. A few reports indicated that as far as whole body chronic exposure was concerned, the constituents of the blood were the most sensitive indicators of radiation effect.

A vigorous combined program of animal and human study was initiated in the early days of the atomic energy project. After much work at Argonne National Laboratory and the National Institutes of Health, it was demonstrated that the reduction in lymphocytes (one kind of white blood cells) was the most sensitive indicator of both acute and chronic exposure. No hematologic effects, however, were noted in mice, rabbits and guinea pigs with daily exposures in the tolerance range to penetrating radiations from external sources for periods up to 3 years. The blood tissues of human beings subjected to X-rays at relatively high levels showed about the same sensitivity as those of the guinea pig and dog. It was also demonstrated that the white blood cells were not affected in humans exposed for considerable periods of time to low levels of external radiation. This was good supporting evidence for the permissible radiation doses in use.

Biological indicators of exposure may have certain advantages over monitoring devices. This is particularly true of indicators which utilize changes in the body of one who works with radiation, and which react to low exposures likely to be classed as inherently safe for such work. The advantages of biological monitoring are especially pertinent to the medico-legal and morale problems which arise during the operation of health programs for radiation workers, but few biological processes are as prompt or as sensitive as physical measuring instruments.

In 1952 at the University of Rochester four physicists, present in a cyclotron building at the University of Rochester while certain adjustments were being made at the control panel, received a slight exposure to the beam. Blood studies were performed daily on these men during the ensuing two weeks. For the first time, these studies of irradiated persons revealed the presence of lymphocytes with nuclei abnormally shaped in the form of an hourglass. Subsequent detailed blood studies of laboratory personnel clinically exposed to levels of radiation well within the accepted maximum permissible level of 0.3 roentgen per week showed a measurable increase in these double-nucleated lymphocytes. Thus, a biological change was demonstrable after very small doses of radiation. Use of this method, however, is extremely tedious and time-consuming and consequently has not yet found general application.

Another observation of considerable practical and theoretical interest was made following two fatal injuries in accidents at Los Alamos in 1945 and 1946. Studies at Argonne National Laboratory of the urine chemistry of the exposed persons showed a striking rise in the amounts of urinary amino acids. These acids are the fundamental building blocks for the body's proteins. Subsequent study after another accidental exposure confirmed this initial finding as did a number of animal investigations. The effect is demonstrable as an early and very sensitive indicator of radiation exposure.

The reason for its occurrence has not yet been worked out. It could be the result of increased tissue breakdown, or a diminished utilization of amino acids by the liver and other tissues; it could be a direct radiation effect or possibly a secondary effect to a hormonal change resulting from stress. These questions are incompletely resolved.

Another very sensitive measure of exposure to radiation has been found in the diminished rate of incorporation of iron into hemoglobin by the blood-forming tissues as determined by radioisotope tracer methods.

Neither of these two observations has had wide applicability to practical situations and work is going on at the University of California Radiation Laboratory and at the Naval Radiological Defense Laboratory to gain more basic information on radiation effects and possibly to obtain a more practical variant of the approach.

Treatment of Biological Effects

Another question recognized early as an urgent atomic energy problem was: What should be the treatment for massive exposure to radiation? The experimental approach to a solution followed two main paths. The first was to define the changes which occurred following acute radiation exposure; second, to try out reasonable measures on the basis of the observed changes.

The major information on massive exposure in humans came from the detailed medical investigations following the atomic bombings of two Japanese cities, and also from studies of the few accidents which have occurred in the atomic energy program in this country. Penetrating radiation passing through the body in sufficient amount will damage many tissues according to their inherent sensitivity to radiation. This injury to sensitive tissues produces a collection of signs and symptoms which in combination have been called "syndrome of acute radiation injury." Actually, a sudden assimilation of sufficient quantity of radioactive elements distributed throughout the body may produce a variety of clinical signs and symptoms which correspond to this syndrome. The severity and time of their appearance, however, are conditioned by the degree of exposure and the sensitivity of the individual.

In general, the effects include weakness, diarrhea, nausea, and vomiting, hemorrhage into the bowel and skin, ulceration of the mucous membranes of the mouth, loss of hair, and fever. An enormous amount of research work has been devoted to this problem. It is impossible to summarize adequately this extensive field, but a number of salient points can be made clear.

Radiation deaths. There are three different major mechanisms of radiation death, due respectively to injury to the nervous system, intestines, and bone-marrow, following high-level, whole-body irradiation.

The neurological type of death is produced by many thousands of roentgens and occurs within minutes to hours following a variety of manifestations of nerve disorder.

The gastrointestinal type occurs after doses of around 1,000 roentgens[37] and is characterized by nausea, vomiting, diarrhea with severe dehydration, and death in 3 to 6 days.

The bone-marrow type is produced by dosages of 300 to 1,000 roentgens, with death occurring in one to eight or more weeks from hemorrhage, infection, and anemia. For practical purposes it is this last syndrome with which study is most concerned, since the doses necessary to produce the neurological and gastrointestinal syndromes are, almost by definition, supralethal doses.

The sequence of changes in the bone marrow has been well worked out in studies at the Argonne National Laboratory, the Naval Medical Research Institute, the Naval Radiological Defense Laboratory, and the National Institutes of Health. There is a rapid and marked suppression of red and white blood cell production. This results in a relatively rapid drop in the white cells of the circulating blood and the more gradual development of anemia.

It has been demonstrated at Oak Ridge National Laboratory that a contributing factor to anemia, in addition to the suppression of red-cell production in bone-marrows, is the leakage of red cells out of the blood stream into the lymphatic system, where they are destroyed. Hemorrhage is generally a factor in acute radiation sickness and its pathogenesis has received considerable attention. The bleeding characteristically appears after a severe reduction in the blood stream of the numbers of the blood platelets, factors which assist clotting. Current opinion is that the loss of these elements from the circulating blood is the most important factor in the development of hemorrhage. Work to substantiate this was accomplished several years ago at Oak Ridge National Laboratory and the Naval Research Institute. Studies on other possibilities such as a direct damaging effect on the blood vessels themselves, and the various factors in the blood which are important in clot formation, have not led to convincing evidence of their importance in post-irradiation bleeding.

Some treatments. A wide variety of treatments of severe irradiation has been tried. The use of repeated transfusions of fresh blood proved of some value, especially in cases with severe anemia.

The reduction in the level of circulating white blood cells has been shown to be an important factor in the increased susceptibility to infection. The replacement of fresh cells from the transfusion is of slight but definite benefit. Because of the impossibility of adequate

[37] See earlier section on "Standards of Radiation Exposure" for definitions of radioactive units of measurement.

replacement of the white blood cells by transfusion, considerable effort has been made to collect the cells from whole blood and preserve them for time of need, but their inherent fragility has prevented any real success.

Since the platelets whose numbers are drastically reduced by severe irradiation, have an even briefer life span than the white cells, there has been a parallel effort to achieve satisfactory methods for their collection and preservation. Investigators have studied the various normal functions of the platelets in hope of isolating and even eventually synthesizing the factors responsible for their effectiveness in the control of bleeding. The problem of replacement of platelets is not limited to treatment of radiation sickness but extends to other disease where cessation of platelet formation is a complication. Platelets have been concentrated and transfused with good results. Some promising research is under way on the fractionation of platelets into more effective components which may eventually lead to their long-term economical storage. The normal functions of platelets in the control of bleeding is a tremendously complex field and is currently the subject of intense medical research.

As might be expected, a host of agents which play a role in blood formation, including folic acid, liver extract, pyridoxine, and penta-nucleotide, has been tried in an attempt to stimulate the radiation-damaged bone-marrow cells. Various hormones and compounds known to support the integrity of small blood vessels have been employed. None has proved very successful.

A major accomplishment in the problem of understanding and controlling suppression of bone-marrow function by radiation was a discovery at Argonne National Laboratory that considerable protection is accomplished during whole body irradiation by shielding the spleen. The most striking protective effects of spleen shielding on mortality and recovery of blood-forming tissues have been seen in mice. Test animals of different species, age, and strains show differences in benefits. Embryo spleen transplants and injections of the pulped organ also are highly effective in promoting recovery of blood-forming tissues, and enhance survival when given during the first day or two after irradiation. Biological factors such as age, strain and species are operative here also.

Further studies at the National Institutes of Health and later at Oak Ridge National Laboratory have shown that normal bone-marrow from the same species of animal is equally effective, while marrow from a different species of animal may have supportive effect. For example, an irradiated mouse can be kept alive for a time by bone-marrow from a normal rat, but the foreign bone-marrow does not keep all irradiated animals alive indefinitely.

Bone-marrow or spleen taken from a normal animal can be kept in tissue culture for short periods, or preserved for several days by cooling to very low temperatures. The preserved blood-forming tissues will keep lethally irradiated animals alive for several weeks and, in some instances, for much longer periods of time.

Toxicity from Radiation Effects

Radiation of one part of an animal was found to give rise to effects in other parts. Thus it was reasonable to assume that a toxic material formed in irradiated tissue and then was transferred by blood or lymph systems to other tissues. An indication of the presence of such a circulating toxic factor has been found at the Brookhaven National Laboratory.

Mice with their adrenal glands surgically removed were given blood plasma from irradiated rats similarly operated upon and were found to die sooner than did mice given plasma from adrenalectomized rats which had not been irradiated.

The plasma was found to have its maximum effect about 48 hours after irradiation. Its toxic activity was destroyed by heat or by exposure to room temperature for 30 minutes but was preserved for some time at zero degrees centigrade. The nature of the toxic material and the extent of its contribution to radiation damage has not yet been clarified.

A separate series of experiments designed to remove any hypothetical radiotoxic substance by passing test animals' blood through the filtration membranes of an artificial kidney were carried out in irradiated dogs at Western Reserve University. These animals were given 500 roentgens of X-ray and their blood was passed through an artificial kidney to remove the toxic material if it were filterable.

Cross-transfusions also were performed in dogs similarly irradiated by attaching the circulatory system of an irradiated dog to a nonirradiated partner. The supposition was that the toxic materials from the irradiated dog might be destroyed by blood factors of its nonirradiated mate. Studies with such parabiont animals have not demonstrated the presence of a toxic factor when only one of the two interconnected animals has been irradiated. Painstaking studies at the New England Deaconess Hospital in Boston failed to demonstrate any deleterious effect on the organs of the nonirradiated animal.

Neither parabiosis nor artificial kidney technique so far has shown positive results. The importance of the toxic factor is not clear.

Prevention of Biological Effects

A major advance in modification of irradiation effects stemmed from an understanding of the basic chemical changes induced by irradiation, namely, the transient production of strong oxidizing and reducing agents in water within living cells.

Removal of oxygen before irradiation was found to protect cells against many kinds of radiobiological damage in organisms that could tolerate low oxygen concentrations. The dose required to cause a given amount of chromosomal aberration in plants can be nearly tripled by reducing oxygen content. Protection of a similar magnitude has been obtained for bacterial killing, recessive lethal mutations and translocations of genes in fruit flies.

Scientists at University of California at Los Angeles found that rats kept in an atmosphere of 5 percent oxygen instead of the approximate 20 percent of the normal atmosphere have approximately twice the normal resistance to the acute effects of irradiation. Removal of oxygen is not, in general, a practical procedure for man, but these findings were of great theoretical importance because they clearly demonstrated how widespread the effects of strong oxidizing substances were as a mechanism of biological damage resulting from penetrating radiation.

A number of chemical compounds given before irradiation have been found to protect mice. A series of studies with bacteria have demonstrated some of the ways in which such compounds act. Some, notably sodium hydrosulfite, remove oxygen from a cell and its environs by chemical combination. Others, such as glycol, glucose, succinate, and alcohols, cause the cell to remove oxygen metabolically.

The sulfur-hydrogen compounds, such as cysteine demonstrated at Argonne National Laboratory in 1949, and 2-mercaptoethylamine experimented with in Belgium, may remove oxygen, but their protective action cannot be explained entirely in this way. By using 2-mercaptoethylamine, the effectiveness of a given dose of radiation can be reduced in bacteria by a factor of 12, indicating the very great protection obtained under favorable circumstances.

Of the large number of compounds tested for protection of mammals, three seem promising, namely, cysteine, 2-mercaptoethylamine, and 2-mercaptoethylguanadine (MEG). The last was discovered at the Oak Ridge National Laboratory in a large-scale research program in which a variety of substances was given to mice which then were exposed to a dose of radiation that would kill untreated mice.

Extensive studies established that the latter two compounds approximately doubled mice's resistance to radiation and were effective when administered orally, intramuscularly, intraperitoneally, or subcutaneously prior to radiation. Mice so protected have lived, so far, more than a year after receiving what would otherwise have been a lethal dose of radiation.

In addition, by combined treatment of the mice with MEG before irradiation, and with bone-marrow from the same inbred line afterward, it has been possible nearly to triple the survival rate of the test animals. Studies of more than 50 structural variants in these compounds have demonstrated a relationship between protective activity and structure. The structure essential for maximum activity of these compounds has been defined.

Radiation and Infection

An infection often plays an important part in death from acute radiation injury. The effects of irradiation on immune response and on susceptibility to infection have been investigated intensively. Bacteriological studies on irradiated animals have indicated that the septicemia, or generalized infection following irradiation, is caused by bacterial organisms which reside in the intestine and penetrate into the blood stream after damage to the intestinal wall. Various antibiotics have proved of definite value in combating this effect. Septicemia is relatively unimportant in early death following massive irradiation.

A number of studies support the theory, however, that irradiated animals are more susceptible to injected bacteria, viruses, and toxins, and that irradiation may stimulate a latent disease infection, such as typhus, to renewed activity. Basic research on the effects which radiation has on antibody formation has produced some very striking results. It has been demonstrated that the formation of antibodies (protein molecules that circulate in the blood and are vital to defense against bacterial infection) may be divided into a radiosensitive and radio-resistant phase.

The initial phase persists for about 12 hours following a stimulus to antibody formation and is concerned with the initiation of antibody formation or, in a sense, the organization of the necessary machinery for its subsequent production. It is this phase which is sensitive to radiation, since once the production of antibodies has begun the mechanism is quite resistant to radiation. Some recent work has indicated that extracts of yeast and certain types of bacteria are capable of blocking this immediate effect of radiation during the sensitive phase of antibody production. This has great theoretical possibilities, since it suggests that the radiation damage is limited to a specific link in the production system which can be replaced by these administered substances.

Radiation Preaging and Life Shortening Effects

About a decade ago, laboratory workers observed that animals which appeared to recover completely from radiation sickness, tended nevertheless to die prematurely. In other words, a correlation was made between exposure to radiation on the one hand, and shortening of the life span on the other.

The studies revealed that irradiated animals somehow grew old faster, and that when they died the causes and conditions of their death appeared to be the usual causes and conditions. The animals tended to develop at an early age the usual diseases associated with their particular species or strain. With further study, impressions were gained that natural aging and radiation-induced aging might well be the same so far as the body was concerned, and that aging by the two processes is at least partly additive.

Not very much is known about the quantitative relations between exposure to radiation and shortening of life. One hypothesis is that life shortening is proportional to the total dose of radiation received, and is independent of the time interval over which the dose accrued. More recent data suggest that the interval over which a given dose accrues does affect the results, and that the shorter the time over which the dose is given, the more severe are the consequences. The National Academy of Sciences-National Research Council Report cited studies of a group of radiologists,[38] some of whom may have received as much as 1,000 roentgens of X-ray exposure, which showed on the average a life-span of 5 years less than that of other physicians.

Research has been chiefly concerned with the effects of large quantities of radiation, and the results of continued radiation at low levels so far have given inconclusive results. The "Summary Reports" of the National Academy of Sciences-National Research Council,[39] states on this point, "The shortening of life correlates roughly with doses of radiation but has not yet been demonstrated at low losses." Elsewhere, in the NAS–NRC, "A Report to the Public," [39] the Academy survey states, "Doses up to 100 roentgens, when spread over years, have not been shown to shorten human life. On the other hand, we cannot yet say that there is a minimum amount below which the effect does not take place."

The Commission's research indicates that the aging effect is not necessarily preceded by radiation sickness. When low intensity dosages are used, and exposures are protracted, preaging and earlier death may appear without any evidence of the acute radiation sick-

[38] "Longevity and Causes of Death From Irradiation in Physicians," pp. 464–68; "Journal of the American Medical Association," Sept. 29, 1956, by Dr. Shields Warren.

[39] P. 84 and p. 20, respectively, of the indicated volumes of "The Biological Effects of Atomic Radiation," Washington 1956.

ness syndrome—a finding which suggests that acute sickness and more rapid aging are manifestations of different kinds of effects.

The means by which ionizing radiations accelerated aging still are not defined, as is true of the means by which "natural" aging takes place. Inherent are questions about the possible role of natural earth and cosmic radiations as factors influencing or determining length of life. Questions also arise as to why the average length of life is different in different species of organisms, and why living things grow old at all since they have, as a particular attribute, the ability to repair and reconstitute themselves.

The large number of research projects on radiologically induced aging going forward at national laboratories and under Commission contracts, testifies to the importance placed on this subject. At Brookhaven National Laboratory the degree of radiation-induced aging is being measured by determining the ability of animals to cope with an added burden of infectious agents in known amounts. At the University of Rochester, mathematical formulations have been developed to characterize the process of physiologic aging and these are being tested against findings from animal experimentation. At Argonne National Laboratory, through the use of special gamma ray sources, survival and performance ability are being determined for animals exposed continuously to radiation throughout their life span. At Oak Ridge and at various other laboratories, studies are being made of the influence of bone-marrow transplants and chemical protection as a possible means of counteracting the life-shortening effects of irradiation.

At Los Alamos Scientific Laboratory, the relative biological effectiveness of different nuclear radiations in life-shortening is being determined. At the University of California, Berkeley, data are being accumulated not only on the life-shortening effects of radiation, but also on diseases and other noxious agents, on industrial hazards, and on stimulants taken commonly by people in different population groups; these findings then are being correlated with age-specific death rates of different countries and territories.

At the Naval Radiological Defense Laboratory, precise methods are being developed for measuring performance and physical and mental ability at different times after exposure to radiations, and information is being obtained about the levels of radiation that may constitute a hazard to life. Studies of the graying of hair, of cataracts, of burns, of tumors, of mutations, of developmental anomalies, and the like, induced by ionizing radiations, also yield information about radiation-induced aging, inasmuch as the residual potential of tissues determines the amount of functional capacity in vital organs and thereby the amount of the natural life which remains to the organism.

Neutron-Induced Cataracts

Although radiation cataracts have not proved a serious problem in atomic energy activities, the appearance of radiation cataracts in some early cyclotron workers and among Japanese survivors at Hiroshima and Nagasaki stimulated a program of research into the mechanism of this damage, which has been given assistance by the National Research Council Committee on Radiation Cataracts. Gamma rays can cause cataracts, but not nearly to the extent that neutrons can. A much better understanding of the amount of fast and slow neutron exposure required to produce changes in the lens of the eye has been gained through work at the Los Alamos Scientific Laboratory, the University of Iowa, the University of Pittsburgh, and the Massachusetts Eye and Ear Infirmary, as well as observations made by Oak Ridge National Laboratory on mice at the weapons test designated "Operation Greenhouse," plus studies by the U. S. Air Force. The work has also led to a better understanding of how these changes result from the death of epithelial cells on the surface of the lens which eventually migrate to form opacities at the posterior pole. At the Kresge Eye Institute in Detroit continuing studies are in progress of the complex biochemical changes induced in the lens by ionizing radiation.

Effects on Embryos

Recent studies on the irradiation of mice in various stages of pregnancy at Oak Ridge National Laboratory and the New England Deaconess Hospital have shown that the effect on the young is closely correlated with the stage of embryonic development at which they were irradiated. Irradiation during the first 5 days, i. e., prior to the embryo's implantation into the uterus, leads to all-or-none effects: there is a high incidence of death shortly after irradiation, but those embryos which survive appear normal. Irradiation during the next 8 days, when most of the major organ formation is under way, will permit survival of most embryos, but almost all are born abnormal. The exact type of malformation depends closely on the exact stage the embryo has reached at the time of irradiation.

By equating human and mouse gestation periods developmentally, it is thought possible to predict when the most sensitive period occurs in humans for the production of any given abnormality determined in the mouse. By this reasoning, the human embryo during the second through the seventh week of a human pregnancy is potentially the most sensitive to radiation. Since pregnancy still may be unsuspected at such early times, it has been recommended that, whenever possible pelvic irradiation of women of child-bearing age should be restricted to the first 2 weeks following a menstrual period. This recommendation applies particularly to medical (diagnostic) irradiation. On the other hand, the present permissible weekly dose of irradiation which may be received in industry does not constitute a measurable hazard at any stage of pregnancy.

Genetic Effects of Radiation Exposure

At the inception of the United States atomic energy program, the fact that radiation caused hereditary changes was well understood. Adequate information about the exact amount of hereditary change, or genetic effect, that would result from definite amounts of radiation, however, was known essentially only about fruit flies, and it chiefly concerned the effects of X-rays on mature male sperm cells. Knowledge about radiation effects on other species indicated the broad general applicability of the fruit fly results, but more precise information was needed to estimate the genetic risks to humans from an increased exposure to atomic energy radiation. Genetic studies were initiated by the Manhattan District and greatly expanded as a major part of the Commission's research program in biology. In addition to Commission-sponsored programs, the recent heightened interest in radiation effects has stimulated work in genetics throughout the world.

Studies during the last 10 years make it increasingly apparent that the genetic effects of radiation differ in quantity between species, between stages in development within a species, and between physiological states of otherwise similar reproductive cells.[40] Though subsequent studies have made it necessary to qualify somewhat certain broad generalizations about genetic effects that had been adopted earlier, most of these findings still are essentially valid:

a) To the best of the present knowledge, the frequency with which radiation-induced mutations, or inheritable changes, occur is roughly proportional to the accumulated dose received by the reproductive germ cells (the male sperm and female egg cells, and the cells from which they have been derived) throughout the individual's life prior to procreation from all sources, including natural, background radiation.

b) Whether the radiation is received in a single large exposure or in many smaller exposures, there is no known reason, either from experiment or theory, to assume that any finite quantity of radiation is too small to have some chance of causing a mutation.

[40] Certain important current findings in this area, resulting from Commission-sponsored studies, are reported on pp. 81–83.

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o) Most mutations, whether radiation-induced or occurring naturally, are to some extent deleterious to individuals inheriting them.

Geneticists' estimates. During the last year, committees of geneticists have collated the information currently available, and have attempted to make estimates of expected effects on human populations of exposure to increased amounts of radiation. The results of these surveys make up major parts of reports issued in June 1956 by the U. S. National Academy of Sciences-National Research Council, and by the United Kingdom's Medical Research Council.[41]

The two groups of geneticists, working independently, reached substantially the same conclusions regarding human risks of radiation exposure: Any increased radiation exposure will be to some extent harmful to future generations of human populations. The reassuring inference, that exposure of an individual to fairly appreciable amounts of additional radiation probably should not greatly increase the chance of having a child with a recognizable genetic defect, is equally valid. The reports recognized the limitations imposed by the insufficiency of information relating directly to humans, by the uncertainties of projecting results of experiments with other species into predictions for man, and by inadequate experimental data in some areas, but felt that the limitations were not sufficiently great to negate the validity of the estimates.

Roughly 4 or 5 percent of all infants born alive in the United States at present have some easily recognizable congenital handicap, such as hematological, neuromuscular and mental defects, congenital malformations, and defects in the gastrointestinal and urinogenital tracts. Perhaps half these handicaps, something like 20 out of 1,000 live births, may have genetic causes, and the other half arise from disease or other nongenetic causes, according to the Academy of Sciences' report. The frequency with which genetically handicapped individuals are born is directly related to the total frequency at which deleterious genes occur in the population. (Genes are chemical entities in reproductive cells that transmit inheritable factors.) Many deleterious genes which now are present in the population have been inherited from previous generations. Since individuals affected by these deleterious genes are somewhat less likely to marry and have children than are unaffected individuals, deleterious genes have less chance than favorable genes of being transmitted to succeeding generations. Loss to the population of deleterious genes in each generation is, however, counterbalanced by new mutations which occur "naturally". If more new mutations occur—as a result, for example, of radiation exposure—this would increase somewhat the total fre-

[41] Op. cit. and "The Hazards to Man of Nuclear and Allied Radiations," London, England, 1956.

quency of deleterious genes in the population and, hence, the number of individuals in later generations affected adversely by this inheritance.

On the basis of a number of considerations, the Academy report estimated that if the rate at which new mutations of genes occurred were doubled, it would cause about a 10 percent increase in the number of genetically handicapped individuals in the first following generation—about 22 handicapped persons per thousand live births instead of 20.

If the higher mutation rate were maintained throughout subsequent generations, there would be an increased number of affected individuals in each succeeding generation. The increase would be somewhat smaller in each new generation because of the loss of deleterious genes. After very many generations, the frequency of affected individuals would double and reach about 40 per 1,000 live births.

If the doubled rate of new mutations occurred for a single generation only, followed by a return to the original rate, the greatest effect would persist for a single generation, and would be followed by a decline through loss of deleterious genes until, eventually, the original frequency of affected individuals would again occur.

Calculating a "doubling-dose". Only rather vague limits now can be set for the amount of radiation necessary to double the mutation rate in man. The human race has always been exposed to "normal background radiation" from radioactive materials and from cosmic rays which can cause mutations. However, there are other possible causes of mutations, and the natural mutation rate of the species used in experiments is greater than could be accounted for by natural radiation. Therefore, the radiation necessary to double the existing mutation rate in man (i. e., the "doubling dose") would have to be greater than double the amount of radiation now ordinarily received by people between conception and the average procreation age of 30 years. The minimum cumulated exposure to radiation over 30 years which could possibly double mutation frequency has been calculated at 5 roentgens in the U. S. Academy report, whereas the U. K. report suggests the minimum possibility is more likely 15 roentgens. For a number of reasons, the conclusion reached in both reports is that the doubling dose is probably not greater than 150 roentgens; that the most probable doubling dose for man lies somewhere between 30 and 80 roentgens of X-rays or gamma rays, or an amount of neutrons which is mutationally equivalent (the total cumulative dose to the gonads prior to procreation).

In summary, any cumulated radiation exposure to one parent above the amount received from natural background up to the age of 30 increases the average chance of having a genetically handicapped child, but not to a very great extent. Based on the present estimated range for the doubling dose range it would require an exposure of 150 to 400 roentgens prior to conception to increase an individual's chance of having a genetically handicapped child from 1 in 50 (20 per 1,000 live births) to 1 in 40 (25 per 1,000 live births). Therefore, at the "permissible" levels of exposure for individuals—not more than 50 roentgens through age 30 as recommended in both U. S. and U. K. reports, and not to exceed an additional 50 roentgens during the next 10 years—there should be little genetic risk to an individual's own descendants unless the actual doubling dose is much less than now seems probable.

The much lower limits on total radiation exposure recommended as permissible for large populations (10 roentgens cumulative to age 30 above natural radiation as recommended in the U. S. report) are based on several considerations that do not apply so directly to individuals. In general, the recommendation assumes that both parents would be exposed, and thus the genetic risk from a given level of radiation would be twice that which would exist if only one parent were irradiated. Secondly, where large populations are concerned, a relatively small increase in the rate at which genetically handicapped individuals were born would mean a large increase in the total number of handicapped. For example, among the 100,000,000 children expected to be born to persons now living in the United States, the effect of a "doubling dose" would be about 10 percent increase in the rate of births of handicapped children. This would mean an increase of some 200,000 in the number of genetically handicapped children in that generation. A comparable dose to 100,000 persons would produce similarly 200 additional defective children.

Finally, there is known to be a genetic component in such things as individual life span and susceptibility to disease. This genetic effect cannot be identified in individuals, but it is detectable by statistical methods when large numbers of individuals are involved.

The National Academy of Sciences' report [42] in estimating levels of exposure in the United States, made this statement: "At present, the United States population is exposed to radiation from (a) the natural background, (b) medical and dental X-rays, (c) fallout from atomic weapons testing. The 30-year dose to the gonads received by the average person from each of these sources is estimated as follows:

a) background—about 4.3 roentgens
b) X-rays and fluoroscopy—about 3 roentgens

[42] P. 4, op. cit. "A Report to the Public."

c) weapons tests—if continued at the rate of the past 5 years would give a probable 30-year dose of about 0.1 roentgens. This figure may be off by a factor of 5, i. e., the possible range is from 0.02 to 0.5 roentgens. If tests were conducted at the rate of the two most active years (1952 and 1954) the 30-year dose would be about twice as great as that just stated."

Japanese studies. The results of genetic studies carried out during 1946–1955 by the Atomic Bomb Casualty Commission at Hiroshima and Nagasaki have now been analyzed at the University of Michigan [43] and reported at the First International Congress of Human Genetics in Copenhagen in August 1956, and at the International Genetics Symposia in Tokyo in September 1956. Among more than 30,000 births to parents exposed to atomic bomb radiations, and an equivalent number of births to unexposed parents, studies were made of the frequencies of congenital malformations, of stillbirths and deaths soon after birth, of the sex ratio, weight at birth, growth rates and body measurements. Because the exposed parents differed from the unexposed parents in a number of ways known to be related to evaluating the results of the studies, it was necessary to undertake an extensive investigation of the influence upon the characteristics under investigation of a large number of genetic and nongenetic factors other than radiation exposure.

This is the most thorough and extensive study of the genetic effects of radiation on humans so far undertaken, and contributes greatly to our knowledge of human populations, but the results do not give a clear-cut answer concerning the extent of the genetic damage resulting from exposure to atomic radiation.

The statistical problems raised by the data are extremely complex but unavoidable in a study of this nature. It was recognized from the very beginning of the study that the results might be inconclusive, in the sense that while certain types of genetic effects might be excluded, it would be impossible either to exclude or confirm certain other possibilities. This is precisely what has happened. The data indicate that the effect of the amount of radiation received by the more heavily exposed persons was not so large as to result in an actual doubling in the total incidence of malformations, or to cause an increase of as much as 80 percent in the total incidence of stillbirths and deaths shortly after birth.

On the basis of the studies in Japan, however, it is now relatively certain that the genetic effects of atomic radiation on human popula-

[43] "The Effect of Exposure to the Atomic Bombs on Pregnancy Termination in Hiroshima and Nagasaki"—by J. V. Neel and W. J. Schull, obtainable from the National Academy of Sciences—National Research Council, Washington 25, D. C.

tions cannot be appreciably greater than would be surmised on the basis of animal experimentation. On the other hand, some smaller changes in the frequency of malformations, stillbirths, and early deaths—changes indicative of important genetic damage—may have gone undetected under the conditions in Japan. In other words, the data, which fail to show a clear difference between the children of exposed parents and those of unexposed parents, are sufficient to exclude the possibility of extensive genetic effects but still are compatible with the range of effects observed in mice and fruit flies.

The net result of this study is to make an important contribution towards specifying the range within which the effect of radiation on human inheritance lies, but to leave, within that range, considerable room for uncertainty. By combining the findings of this study with those of other studies, such as those dealing with the characteristics of children born to parents who have received therapeutic irradiation,[44] continuing clarification of the question of the genetic risks of irradiation to man is to be anticipated.

Some of the factors tending to obscure results are:

a) Relatively few surviving individuals of child-bearing age were heavily exposed to radiation, so that the total number of children born to them was small.

b) The more heavily exposed mothers were, on the average, older than those less exposed, and especially older than the average of those not exposed at all. Hence, since congenital malformations are relatively more frequent among children of older mothers, nongenetic causes of malformation are not equally distributed among the different exposure categories.

c) A similar nongenetic bias results from the greater proportion of first births, and births of the seventh and eighth child, to mothers more heavily exposed than to those less exposed. The frequencies of stillbirths and deaths shortly after birth are normally disproportionately high among first births and births following a number of previous children.

d) The proportions of congenitial malformations, stillbirths and deaths soon after birth which ordinarily result from genetic causes, as contrasted to nongenetic causes, is not known.

e) The unexposed parents at both Nagasaki and Hiroshima are largely persons moving into the cities after the bombings and may not be strictly comparable in a number of influential respects to the exposed parents.

f) Radiation exposures of parents, especially the amount of radiation reaching the germ cells, is not known with any great accuracy.

[44] Turpin, R. et J. Lejeune: "Etude de la descendance de sujets traités par radiothérapie pelvienne." The First International Congress of Human Genetics, Copenhagen, August 1–6, 1956: Book of Abstracts, pp. 4–5.

Support of genetic research. Although present estimates of the total genetic effect of radiation on humans are still unsatisfactory, they are better than would have been possible 10 years ago, when much less information was available. They will improve in accuracy as more information is obtained. During the last 10 years, the Commission's support to genetics studies has grown until now there are 58 offsite research projects supported in the 1957 fiscal year at an annual level of $873,000 in addition to genetic studies at Argonne, Brookhaven, and Oak Ridge National Laboratories at a level of $1.1 million. Present emphasis is upon gaining knowledge of the extent of the genetic component in a number of human characteristics; improving methods for direct comparisons between human and other species; and more precise and more extensive experimental data concerning other species.

Instruments for Radiation Safety

Since unaided human senses cannot detect nuclear radiation, an indispensable part of all nuclear research and utilization is the detection instrument. The development of many instruments and their use—not only to detect, but also to measure radiation—has been reported throughout the chapters on various aspects of radiation protection. There are many instruments specifically designed for radiation measurement problems inherent in all atomic energy programs, and the Commission has a program for the development of new instruments, or improvement of old instruments. Most of the work is done by private industry, either on its own initiative, or under Commission contract or incentives.

At the beginning of the Manhattan Engineer District project, only five companies manufactured instruments for radiation measurements. Their limited production in types and numbers could not meet the requirements. For that reason, and to maintain necessary secrecy about atomic energy efforts, most of the instrumentation requirements of the period were met by designing and fabricating the equipment within the atomic energy project. At the close of the war, the Government essentially declassified instrumentation and initiated a program for development of commercial supplies. This program was continued by the Commission and there now are over 100 companies producing more than 1,000 different instruments or assessories used for the detection of radiations. In all areas of radiation safety adequate instruments now are commercially available. From time to time, new specialized requirements emerge and, if sufficiently large, are met by normal expansion of industry.

In the past 10 years, progress in developing radiation safety instrumentation has been primarily in technological improvements rather than by the innovation of basic detection principles. The principal instruments are the ionization chamber, the proportional counter, the Geiger-Mueller counter and the film badge. However, today's instruments are immeasurably improved, the emphasis in technological advancement having been upon portability, reliability and accuracy. These developments have been made possible in general by advances in electronic theory and techniques, and by improvements in such instrument components as Geiger-Mueller counter tubes, insulating materials, electrometer amplifying tubes, long-lived batteries, and transistors. The progress resulted from cooperation between Government laboratories and industry to which the special talents and facilities of each have contributed.

The only basically new instrument since 1948 has been the scintillation counter which has demonstrated its versatility in most areas of nuclear radiation detection. Its great sensitivity limits its usefulness in radiation safety surveys, however, principally to measuring airborne radioactive particulates and other such analyses of low-level radioactivity as measuring radioisotopic content of urine and breath samples.

One principal developmental trend in recent years has been stimulated by the increasing use of high energy accelerators, with the possible hazard of fast neutrons. Three instruments involving different approaches to the detection of fast neutrons have been developed specifically for this purpose. One is a proportional counter utilizing, as the detecting mechanism, the recoil of the ionized hydrogen nucleus, the proton, from the fast neutrons in a chamber having a high proportion of hydrogen both in the walls and gas filling. The second approach makes use of the same nuclear reaction but the proton recoil is detected by a scintillating material used in conjunction with a scintillation counter. The third instrument has broader applications in that it can assess the physiological effect of gamma rays and slow neutrons as well as those of fast neutrons. This equipment has an ionization chamber with plastic walls that have proportionately the same atomic composition as tissue and is filled with hydrogenous gas. In consequence, the effects of radiation on the chamber can be correlated directly with their effect on tissue.

The development in the technology of radiation detection necessary for the radiation safety program cannot be isolated from its development in other areas where the measurement of these nuclear rays is equally essential. As earlier sections of the report made clear, basic nuclear research, radio-chemical analysis, process instrumentation and nuclear reactor control all have basically analogous radiation problems, as do radioisotope tracer techniques in the physical and life sciences, particularly in medicine. It is for this reason that the Commission sponsors its continuing program in research and improvement of basic detecting elements and specialized components both through contracts and in Commission installations.

For the fiscal year ending June 30, 1957, the Commission has budgeted nearly $1.3 million for research assisting in instrument development. Of the $615,000 funds for contracts in this field, $160,000 is allocated to the development of new and improved photomultiplier tubes required for the rapidly expanding scintillation counter techniques. The Radio Corporation of America, and the Allen B. DuMont Laboratories are the principal contractors in this development program, and the University of Notre Dame is conducting a small research project to study the basic phenomena associated with photoelectric emission.

In addition to photomultiplier tubes, the scintillation counter method depends equally on the characteristics of the scintillating material. Approximately $120,000 is funded for scintillator development projects at Levinthal Electronic Products Co., Redwood City, Calif., the University of Louisville, Ky., the Engineering Research and Development Laboratory, Ft. Belvoir, Va., The Borden Co., Philadelphia, Pa., and Pilot Chemicals Inc., Waltham, Mass.

In the field of radiation dosimetry, the utilization of quartz fiber techniques and improved insulator materials are being studied under a research program at St. Procopius College. Additional projects in various aspects of dosimetric instrumentation are being conducted at New York University, New England Center Hospital, and the National Bureau of Standards.

Instrumentation programs at Commission installations, conducted in support of basic research in radiation safety and in biomedical effects and beneficial uses of radiation amount to $664,000 for the 1957 fiscal year. Of particular interest are projects for the development of airborne radiological monitoring equipment for the determination of fallout, the development of automatic sample counting equipment for measurement of radioactive samples obtained in the world-wide fallout program, the development of germanium crystal fast neutron detectors and chemical dosimeters for both gamma and neutron measurements.

An even larger portion of Commission radiation instrument activities is an integral part of programmatic research and plant operations and costs are associated with the sponsoring program, not broken out specifically as instrumentation items. Based on a 1953 survey, it is estimated that an additional $9 to 10 million in Commission funds is devoted to this type of instrumentation development. Approximately half this amount is allocated to the research and development required to instrument primary programs such as reactor development, accelerator and nuclear research, plant and processing operations, raw material exploration and isotope utilization. About 25 percent is used for the procurement of commercial instruments, as compared with 5 percent for on-site fabrication of equipment. The remaining 20 percent is for repair and maintenance of equipment.

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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.
	John von Neumann.
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	William Mitchell.
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, Divison 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	WESLEY M. JOHNSON.
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	ALLAN C. JOHNSON.
New York (N. Y.) Operations Office	MERRIL EISENBUD.
Brookhaven (Long Island, N. Y.) Area.	E. L. VAN HORN.
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.
Los Angeles (Calif.) Area	RICHARD G. CAVANAUGH.

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).
Vacancy.
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).
Vacancy.
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.
Rear Adm. COURTNEY SHANDS, 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, dean of physical sciences, University of Chicago, Chicago, Ill., Chairman.
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. Y.
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.
Dr. EDWARD TELLER, associate director, University of California Radiation Laboratory, Berkeley, Calif.
Dr. J. C. WARNER, president, Carnegie Institute of Technology, Pittsburgh, Pa.
Dr. EUGENE P. WIGNER, professor of physics, Princeton University, Princeton, N. J.
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, University of California at Los Angeles, 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.

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. WARREN C. JOHNSON, *chairman;* dean of physical sciences, University of Chicago, Chicago, Ill.
Dr. THOMAS B. DREW, head, department of chemical engineering, Columbia University, New York, N. Y.
Dr. ALVIN C. GRAVES, J division leader, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
Dr. JOHN P. HOWE, section chief, reactor materials, Atomics International, North American Aviation, Inc., Downey, Calif.
Dr. WINSTON M. MANNING, director, chemistry division, Argonne National Laboratory, Lemont, Ill.
Dr. J. R. RICHARDSON, professor of physics, University of California at Los Angeles, Calif.

ADVISORY 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. JOHN C. BUGHER, director, medical education & 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. SHIELDS WARREN, vice chairman; pathologist, New England Deaconess Hospital, Boston, Mass.

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, appraises technological developments within the national atomic energy program and makes recommendations which serve as guides in the formulation of information-for-industry policy.

E. E. THUM, chairman; editor, *Metal Progress*, American Society for Metals, Cleveland, Ohio.

S. A. TUCKER, vice chairman; publications manager, American Society of Mechanical Engineers, New York, N. Y.

Dr. ALLAN 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.

Dr. ELMER HUTCHISSON, editor, *Journal of Applied Physics*, American Institute of Physics, 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., Chicago, Ill.

Dr. WALTER J. MURPHY, editorial director, Applied Publications, American Chemical Society, Washington, D. C.

FREDERICK A. PAWLEY, research secretary, American Institute of Architects, Washington, D. C.

EDWARD H. ROBIE, secretary emeritus, American Institute of Mining and Metallurgical Engineers, New York, N. Y.

KARL T. SCHWARTZWALDER, The American Ceramic Society, Inc., Columbus, Ohio.

GEORGE F. SULLIVAN, editor, *The Iron Age*, Chilton Publication, Inc., Philadelphia, Pa.

Dr. ALBERTO F. THOMPSON, chief, office of scientific information, National Science Foundation, Washington, D. C.

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OLIVER H. TOWNSEND, secretary, Atomic Industrial Forum, Inc., New York, N. Y.

F. J. VAN ANTWERPEN, editor, *Chemical Engineering Progress*, American Institute of Chemical Engineers, New York, N. Y.

BERNARD M. FRY, secretary; assistant director for technical information service, division of information services, AEC, Washington, D. C.

EDWARD J. BRUNENKANT, assistant secretary; chief, industrial information branch, division of information services, AEC, Washington, D. C.

Advisory Committee on Isotope Distribution

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

Dr. REYNOLDS F. BROWN, department of radiology, University of California Medical School, San Francisco, Calif.

Dr. JOHN A. D. COOPER, assistant dean, Northwestern University Medical School, Chicago, Ill.

Dr. DONALD S. CHILDS, Jr., department of radiology, Mayo Clinic, Rochester, Minn.

Dr. JOHN E. CHRISTIAN, associate professor, department of pharmaceutical chemistry, Purdue University, Lafayette, Ind.

Dr. HENRY J. GOMBERG, assistant director, Phoenix Memorial Laboratory, University of Michigan, Ann Arbor, Mich.

Dr. H. R. NELSON, department of physics, Battelle Memorial Institute, Columbus, Ohio.

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

Dr. JOHN E. WILLARD, professor of chemistry, University of Wisconsin, Madison, Wis.

Dr. PAUL C. AEBERSOLD, secretary; director, isotopes extension, division of civilian application, AEC, Oak Ridge, Tenn.

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, AEC, Washington, D. C.

Dr. MANSON BENEDICT, professor of chemical engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Dr. WILLARD P. CONNER, manager, physics 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.

Dr. I. B. JOHNS, Monsanto Chemical Co., Everett, Mass.

Dr. MARK H. 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, director, department of research, engineering and loss control, the Travelers Insurance Cos. of Hartford, Conn.

Dr. ABEL WOLMAN, head, department of sanitary engineering and water resources, The Johns Hopkins University, Baltimore, Md.

Dr. HARRY WEXLER, director of meteorological research, U. S. Weather Bureau, Department of Commerce, Washington, D. C.

J. Z. HOLLAND, secretary; AEC, Washington, D. C.

Advisory Committee of State Officials

This committee was established by the Commission in September 1955 as a means of obtaining the views and advice of State regulatory agencies in connection with the Atomic Energy Commission's regulatory activities in the field of public health and safety.

Dr. DANIEL BERGSMA, commissioner of health, Trenton, N. J.

A. C. BLACKMAN, chief, division of industrial safety, California Department of Industrial Relations, San Francisco, Calif.

Dr. ROY L. CLEERE, executive director, Colorado State Department of Public Health, Denver, Colo.

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.

CLARENCE I. STERLING, Jr., chief sanitary engineer, division of sanitation, Department of Public Health of Massachusetts, Boston, Mass.

Dr. IRVING TABERSHAW, director, division of industrial hygiene, New York State Department of Labor, New York, N. Y.

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 Company of America, New Kensington, Pa.

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

ERNEST H. ROSE, project director, metallurgy, Materials Advisory Board, National Research Council, Washington, D. C.
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 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; AEC, Washington, D. C.
Dr. MACK 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, AEC, 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, AEC, 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, AEC, Washington, D. C.

Dr. CARROLL W. ZABEL, secretary; department of physics, 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.

WILLIAM H. DAVIS; Davis, Hoxie & Faithfull, New York, N. Y.

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

CASPER W. OOMS, firm of Casper W. Ooms, Chicago, Ill.

Personnel Security Review Board

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

GANSON PURCELL, chairman; Purcell & Nelson, Washington, D. C.

Dr. PAUL E. KLOPSTEG, associate director, National Science Foundation, Washington, D. C.

Vacancy.

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. 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, atomic power division, 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, AEC, 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. WILLIAM M. BROBECK, assistant director, University of California Radiation Laboratory, Berkeley, Calif.
Dr. LYMAN SPITZER, Jr., Forrestal Research Center, Princeton University, Princeton, N. J.
Dr. EDWARD TELLER, associate director, University of California Radiation Laboratory, Berkeley, Calif.

Dr. James L. Tuck, technical director, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

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 directed by individual members and by individual consulting advice to the various Commission installations.

Dr. Abel Wolman, chairman; head, department of sanitary engineering and water resources, The Johns Hopkins University, Baltimore, Md.

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, AEC, 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, AEC, Washington, D. C.

Dr. William P. Yant, director of research and development, Mine Safety Appliances Co., Pittsburgh, Pa.

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	Vacant
Deputy Director (Acting Director)	Dr. Norman Hilberry
Business Manager	John H. McKinley
Assistant Director, 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
- 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
Assistant Director	Dr. ROBERT A. PATTERSON
Assistant Director	WILLIAM H. FIELDS

The participating institutions are:
- Columbia University
- Cornell University
- Harvard University
- The Johns Hopkins University
- Massachusetts Institute of Technology
- Princeton University
- Yale University
- University of Pennsylvania
- University of Rochester

Knolls Atomic Power Laboratory (General Electric Co., contractor), Schenectady, N. Y.

General Manager	F. E. CREVER
Manager, 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
Laboratory Director	EDWARD C. McCARTHY

Oak Ridge Institute of Nuclear Studies (contractor), Oak Ridge, Tenn.

Chairman of Council	Dr. MARTEN TEN HOOR
Vice Chairman of Council	Dr. H. M. PHILLIPS
President of Institute	Dr. PAUL M. GROSS
Vice President of Institute	Dr. W. C. JOHNSON
Scientific and Educational Consultant	Dr. GEORGE B. PEGRAM
Executive Director of Institute	Dr. WILLIAM G. POLLARD

The sponsoring universities of the Institute are:

Agricultural and Mechanical college of Texas
Alabama Polytechnic Institute
Catholic University of America
Clemson Agricultural College
Duke University
Emory University
Florida State University
Georgia Institute of Technology
Louisiana State University
Meharry Medical College
Mississippi State College
North Carolina State College
North Texas State College
Rice Institute
Southern Methodist University
Tulane University of Louisiana
Tuskegee Institute
Vanderbilt University
Virginia Polytechnic Institute
University of Alabama
University of Arkansas
University of Florida
University of Georgia
University of Kentucky
University of Louisville
University of Maryland
University of Miami
University of Mississippi
University of North Carolina
University of Oklahoma
University of Puerto Rico
University of South Carolina
University of Tennessee
University of Texas
University of Virginia

Oak Ridge National Laboratory (Union Carbide Nuclear Co. of Union Carbide & Carbon 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. E. D. SHIPLEY
Assistant Laboratory Director	Dr. R. W. JOHNSON
Assistant Laboratory Director	Dr. C. E. WINTERS
Assistant Laboratory Director	Dr. 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, 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. Seaborg
Associate Director	Dr. Edward Teller
Associate Director	Dr. Herbert F. York
Assistant Director	William M. Brobeck
Director, Crocker Laboratory Medical Physics	Dr. Joseph G. Hamilton
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–Nov. 30, 1956		Jan. 1, 1956–Nov. 30, 1956		Total to Nov. 30, 1956	
	Activity (Curies)	Shipments	Activity (Curies)	Shipments	Activity (Curies)	Shipments
Iodine 131	3,240	28,700	681	4,297	3,921	32,997
Phosphorus 32	918	16,965	152	2,245	1,070	19,210
Carbon 14	39	2,385	9	261	48	2,646
Tritium	1,101	329	3,381	110	6,482	439
Strontium 89, 90	392	932	21	135	413	1,067
Cobalt 60	96,389	1,191	74,158	217	170,547	1,408
Cesium 137	2,410	636	2,852	119	5,262	455
Iridium 192	4,760	193	5,528	120	10,288	313
Irridiated Units [2]	11,930	11,608	1,625	1,611	13,555	13,219
Others	430	13,874	3	3,481	433	17,355
Total	109,679	76,813	88,785	12,596	198,464	89,409
Shipments to AEC installations		9,463		1,109		10,572

[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, 1956–Nov. 30, 1956]

States and Territories	Medical Institutes and Physicians	Colleges and Universities	Industrial Firms	Federal and State Laboratories	Foundations and Institutes	Other	Total
Alaska							
Alabama	2		4				6
Arizona	2		2				4
Arkansas	3		3				6
California	38	1	17	3	1	3	63
Colorado	3		1				4
Connecticut	3		8		1		12
Delaware			1	1			2
District of Columbia	1						1
Florida	8		3			1	12
Georgia	4		3				7
Hawaii	1			1			2
Idaho	2		2				4
Illinois	17	5	14	2			38
Indiana	8	1	3				12
Iowa	10						10
Kansas	9		1				10
Kentucky	2		1	1			4
Louisiana	4		4			1	9
Maine			4			1	5
Maryland	4		4	1		1	10
Massachusetts	4	1	12	1			18
Michigan	15	1	7	1			24
Minnesota	8	2	3				13
Mississippi	2	2	1				5
Missouri	15		1				16
Montana	2		1				2
Nebraska	2		1				3
Nevada							
New Hampshire	1						1
New Jersey	10		20				30
New Mexico	1		3				4
New York	48	1	26	5	2	1	83
North Carolina	4		2				6
North Dakota	2						2
Ohio	21		11			1	33
Oklahoma	6		4				10
Oregon	2		1				3
Panama							
Pennsylvania	10		15	1			26

LOCATION AND TYPE OF NEW USERS—Continued

[Jan. 1, 1956–Nov. 30, 1956]

States and Territories	Medical Institutes and Physicians	Colleges and Universities	Industrial Firms	Federal and State Laboratories	Foundations and Institutes	Other	Total
Puerto Rico	2						2
Rhode Island	2		1				3
South Carolina	1		3				4
South Dakota	1						1
Tennessee	7	1	4			1	13
Texas	21	1	20	1			43
Utah	1						1
Vermont	1						1
Virginia	6		6				12
Washington	5	2	1				8
West Virginia	8		1				9
Wisconsin	7		1		1		9
Wyoming	1		1				2
Total	337	18	220	18	5	10	608

LOCATION AND TYPE OF ALL USERS

[Aug. 2, 1946–Nov. 30, 1956]

States and Territories	Medical Institutes and Physicians	Colleges and Universities	Industrial Firms	Federal and State Laboratories	Foundations and Institutes	Other	Total
Alaska	1	1		1			3
Alabama	12	3	18	4	2		39
Arizona	9	1	4	2			16
Arkansas	14	1	8	1			24
California	178	17	151	46	11	7	410
Colorado	32	3	12	4	2	3	56
Connecticut	17	5	52	2	1		77
Delaware	2	1	10	2	1		16
District of Columbia	15	3	6	17		1	42
Florida	31	6	8	4		2	51
Georgia	17	5	12	7			41
Hawaii	6	1	1	3	2		13
Idaho	5	1	5			1	12
Illinois	93	14	101	15	5	2	230
Indiana	28	4	32			1	65
Iowa	20	4	9				33
Kansas	24	4	6				34
Kentucky	11	3	13	3	1	2	33
Louisiana	21	5	18	3		1	48
Maine	5	3	17	1		1	27
Maryland	21	5	25	17		2	70
Massachusetts	45	17	100	12	3	3	180
Michigan	50	8	43	3		1	105
Minnesota	22	9	12	1			44
Mississippi	6	3	8	3			20
Missouri	53	5	14	1		1	74
Montana	9	1		1	1		12
Nebraska	14	3	1	3			21
Nevada	4		3	1			8
New Hampshire	3	2	3	2			10
New Jersey	45	4	116	7	6	1	179
New Mexico	10	3	4	3			20
New York	214	28	178	28	10	7	465
North Carolina	20	6	14	7		1	48
North Dakota	8	2		1			11
Ohio	80	9	107	10	3	2	211
Oklahoma	25	1	27	1	3		57
Oregon	14	3	4	5		1	27
Panama	1			1			2
Pennsylvania	73	11	130	12	4	1	231
Puerto Rico	7	1		2			10
Rhode Island	6	2	13	1			22
South Carolina	5	3	5	2			15
South Dakota	8	2					10
Tennessee	29	5	14	6		2	56
Texas	95	7	91	8	4	1	206
Utah	8	3	5	2			18
Vermont	4	1	2				7
Virginia	18	4	22	8			52
Washington	19	6	12	7			44
West Virginia	19	2	8	2			31
Wisconsin	30	3	41	4	2		80
Wyoming	3	1	1	1	1		8
Total	1,509	245	1,486	277	62	45	3,624

SHIPMENTS OF RADIOACTIVE ISOTOPES TO FOREIGN COUNTRIES

Country	Jan. 1, 1956–Nov. 30, 1956	Total January 1947 to Nov. 30, 1956	Country	Jan. 1, 1956–Nov. 30, 1956	Total January 1947 to Nov. 30, 1956
Argentina	1	126	Ireland	0	0
Australia	1	111	Israel	5	14
Austria	1	2	Italy	8	50
Belgian Congo	0	3	Japan	92	496
Belgium	15	176	Korea [1]	0	0
Bermuda	0	16	Lebanon	1	7
Bolivia [1]	0	0	Mexico	61	200
Brazil	109	477	Netherlands	9	81
British West Africa	0	1	New Zealand	1	13
Canada	389	1,296	Nicaragua [1]	0	0
Chile	31	156	Norway	19	64
Colombia	17	34	Pakistan	3	10
Costa Rica	1	2	Paraguay [1]	0	0
Cuba	103	445	Peru	30	66
Denmark	9	236	Philippines	1	7
Dominican Republic	0	1	Portugal	3	11
Egypt	0	2	Republic of China	1	2
El Salvador	1	1	Spain	5	15
England	11	174	Sweden	36	243
Federal Republic of Germany	16	51	Switzerland	12	84
Finland	6	20	Syria	2	2
France	29	152	Thailand	1	2
Gold Coast	0	1	Trieste	1	4
Greece	0	1	Turkey	0	5
Guatemala	10	35	Union of South Africa	6	37
Honduras	0	1	Uruguay	0	11
Iceland	0	5	Venezuela	38	68
India	12	41	Yugoslavia	1	2
Indonesia	0	3	Total	1,099	5,064
Iran	1	1			

[1] Authorized to receive isotopes; no shipments made.

Kind of Isotope	Jan. 1, 1956–Nov. 30, 1956	Total January 1947 to Nov. 30, 1956	Kind of Isotope	Jan. 1, 1956–Nov. 30, 1956	Total January 1947 to Nov. 30, 1956
Phosphorus 32	81	1,021	Strontium 89, 90	37	144
Iodine 131	483	1,779	Calcium 45	17	137
Carbon 14	46	395	Other	292	954
Sulfur 35	11	140			
Iron 55, 59	64	211	Total	1,099	5,064
Cobalt 60	68	283			

APPENDIX 5

COMMISSION-OWNED PATENTS

PATENTS ISSUED TO THE COMMISSION WHICH ARE AVAILABLE FOR LICENSING[1]

The following 111 United States Letters Patents owned by the United States Government as represented by the Atomic Energy Commission are in addition to patents listed in semiannual reports. The patents listed have been made available for licensing at periodic intervals. Licenses are granted on a nonexclusive, royalty-free basis.

Patent No.	Title	Patentee
2,748,710	Heat-Exchanger Pump	L. B. Vandenberg, Sharon Springs, N. Y.
2,749,520	Directional Coupling Means for Transmission Lines.	B. J. Bittner, Sandia Base, N. Mex.
2,750,254	Process of RecoveringUranium From Its Ores.	R. A. Blake, Leadville, Colo.
2,750,500	Linear Pulse Integrator	W. R Aiken, Berkeley, Calif.
2,750,520	Electrostatic Measuring Device	A. S. Langsdorf, Jr., Roselle, Ill.
2,751,229	Releaseable Gripper for Holding an Article Suspended.	A. B. Schultz, Western Springs, Ill.
2,751,273	Particle Trajectory Plotter	B. H. Rankin, Berkeley, Calif.
2,751,344	Electropolisher	C. A. Kienberger, R. E. Greene, I. C. Flanders and A. R. Flynn, Oak Ridge, Tenn.
2,751,505	Neutronic Reactor Device	H. L. Anderson, Chicago, Ill.
2,751,662	Method of Making an Electronic Grid	W. E. Glenn and W. E. Hostetter, Berkeley, Calif.
2,751,780	Leakage Testing Apparatus	R. F. Plott, Chicago, Ill.
2,752,309	Process for Water Decontamination	A. H. Emmons, Ann Arbor, Mich.; R. A. Lauderdale, Jr., Cambridge, Mass.
2,752,508	Counting-Rate Meter	B. V. Zito, Jersey City, N. J.
2,753,250	Solvent Extraction of Zirconium Values	H. A. Wilhelm, Ames, Iowa; K. A. Walsh, Los Alamos, N. Mex.; J. V. Kerrigan, Chicago, Ill.
2,753,462	Neutron Flux Measuring Device	J. W. Moyer and H. Hurwitz, Jr., Schenectady, N. Y.
2,754,179	Mixer-Settler	M. E. Whatley, Oak Ridge, Tenn.
2,754,422	Source of Highly Stripped Ions	E. J. Lofgren, Albany, and W. W. Eukel, El Cerrito, Calif.
2,754,423	Calutrons of the Multiple Ion Beam Type	E. O. Lawrence, Berkeley, Calif.
2,755,253	Neutron Scintillation Detector	C. O. Muelhause, Brookhaven, N. Y.; C. E. Thomas, Naperville, Ill.
2,755,387	Ground Indicator for Calutrons	C. C. Waugh, Oak Ridge, Tenn.
2,755,391	Ionization Chamber	J. J. Keyes, Jr., Newark, Del.
2,755,441	Counting Rate Meter	H. D. Gulnac, Santa Cruz, N. Mex.
2,755,853	Denitration Apparatus	R. S. Edgett, Pittsburgh, and A. O. Olson, Indiana Township, Pa.
2,756,122	Process for Recovering Uranium and Vanadium From Ores.	D. C. McLean, Watertown, Mass.
2,756,123	Uranium-Vanadium Recovery and Purification Process.	R. H. Bailes, Walnut Creek, and R. S. Long, Vallejo, Calif.
2,756,124	Uranium Chlorination Process	J. L. Patterson, Oak Ridge, and A. Bell, Kingsport, Tenn.
2,756,138	Process of Vacuum Refining Uranium	G. Meister, Newark, N. J.
2,756,489	Metal Alloy	H. E. Morris, Chicago, Ill.
2,756,857	Positioning Device	W. H. McCorkle, Chicago, Ill.
2,756,858	Fuel Charging Machine	K. Kasschau, Oak Ridge, Tenn.
2,756,925	Centrifuge Systems	R. H. Selkirk, New Brunswick, N. J.
2,756,930	Computing Device	G. T. Pelsor, Albuquerque, N. Mex.; H. S. Sack, Ithaca, N. Y.
2,757,072	Recovery of Free and Combined Nitric Acid From Metal Nitrate Liquors.	N. M. Kapp, Swarthmore, and W. W. Weinrich, Wallingford, Pa.
2,757,799	Automatic Filtration Equipment	C. F. Ritchie, University City, Mo.
2,758,006	Isotope Enrichment Process	J. M. Carter, Pasadena, and M. D. Kamen, Berkeley, Calif.
2,758,007	Ether Extraction of Uranium Salt From Solutions.	A. E. Ballard, Rochester, N. Y.
2,758,023	Method of Purifying Liquid Fuels of Nuclear Reactors.	D. W. Bareis, Brookhaven, N. Y.
2,758,024	Method of Dissolving Binary Alloys	H. M. Feder and R. P. Larson, Forest Park; H. B. Evans, Chicago, Ill.
2,758,213	Calutron Receiver	B. Peters, Berkeley, Calif.
2,758,214	Time-of-Flight Mass Spectrometer	W. E. Glenn, Jr., Schenectady, N. Y.

[1] Patents listed as of December 18, 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 [1]—con.

Patent No.	Title	Patentee
2,758,706	Inspection Conveying Apparatus	F. B. Quinlan, Richland, Wash.
2,758,950	Process for Producing Steel by Electroforming and Carburization.	J. F. Lakner, Los Alamos, N. Mex.
2,758,963	Electrodeposition of Plutonium Fluoride	M. Kahn, Berkeley, Calif.
2,759,175	Leak Detector for Pipe Joint	T. R. Spalding, Spencerville, Ind.
2,759,788	Purification of Materials Containing Chlorides.	L. Spiegler, Woodbury, N. J.
2,759,789	Uranium Products and Methods of Using	L. Spiegler, Woodbury, N. J.
2,759,790	Purification of Materials Containing Fluorides.	L. Spiegler, Woodbury, N. J.
2,759,791	Purification of Materials Containing Chlorides.	L. Spiegler, Woodbury, N. J.
2,759,801	Solvent Extraction Apparatus Using Jet Mixers.	J. M. Yeager and K. S. Eckberg, St. Louis, Mo.
2,759,886	Process of Treating Steel	H. F. Priest, New York, N. Y.
2,760,064	Pulse Analyser	P. R. Bell, Oak Ridge, Tenn.
2,760,076	Arrangement for Minimizing Negative Signals.	J. T. Dalton, Knoxville, and R. H. Stevens, Oak Ridge, Tenn.
2,760,158	Method and Apparatus for Measuring Electrical Current.	Q. A. Kerns, Berkeley, Calif.
2,760,655	Remote Handling Apparatus	H. E. Foskuhl, Waynesville, Ohio.
2,761,063	Electrostatic Memory System	J. H. Bigelow, Princeton, N. J.
2,761,071	Fast Neutron Dosimeter	G. S. Hurst, Oak Ridge, Tenn.
2,761,756	Process for Production of Uranium Hexafluoride.	H. F. Priest, New York, N. Y.
2,761,757	Processes of Recovering Uranium	M. D. Kamen, Berkeley, Calif.; A. DeHaan, Jr., Oak Ridge, Tenn.
2,761,758	Process for Recovery of Uranium	R. S. Long, Vallejo; R. H. Bailes, Walnut Creek; E. S. DeHaven, Concord, Calif.
2,762,941	Positive Ion Electrostatic Accelerator	C. M. Turner, Stony Brook, N. Y.
2,763,570	Wetting of Heat Transfer Surfaces With Liquefied Metal Heat Transfer Media.	O. C. Shepard, Stanford, and E. P. Franch, Granada Hills, Calif.
2,763,611	Method of Preventing Corrosion of Iron Metals.	C. R. Breden, La Grange, Ill.
2,763,816	Spark Gap	W. R. Baker, Berkeley, Calif.
2,764,301	Remote Control Manipulator	R. C. Goertz, Lemont, Ill.; R. G. Schmitt, Ft. Worth, Tex.; R. A. Olsen, Lemont, Ill.
2,764,470	Purification of Uranium	C. L. Richardson, Salem; S. B. Smith, Woodstown; and G. B. Robbins, Pennsgrove, N. J.
2,764,471	Recovery of Uranium from Dilute Solutions by a Precipitation.	G. W. Kinzer, Columbus, and R. D. Morin, Grandview Heights, Ohio.
2,764,689	Pulsed Oscillator	W. C. Struven, Berkeley, Calif.
2,764,707	Ion Source	R. B. Crawford, Walnut Creek; J. D. Gow, W. G. Pon, and L. Ruby, Berkeley, Calif.
2,766,032	Impregnated Crucible	G. Meister, Newark, N. J.
2,766,110	Method of Refining Uranium	G. Meister, Newark, N. J.
2,766,204	Method for Decontamination of Radioactively Contained Aqueous Solution.	C. S. Lowe, Niagara Falls, N. Y.
2,766,442	Leak Detection Apparatus	W. H. Meyer, Jr., W. Mifflin, Pa.
2,767,044	Plutonium Recovery Process	O. F. Hill, Champaign, Ill.; S. G. Thompson, Richmond, Calif.
2,767,047	Process of Separating Tantalum and Niobium Values From Each Other.	H. A. Wilhelm, Ames, Iowa; J. V. Kerrigan, Chicago, Ill.
2,768,059	Process for Recovery of Uranium and the Upgrading of Alkali-Uranium Fluoride Precipitates.	R. H. Bailes, Walnut Creek; R. C. Lindblom; and R. R. Grinstead, Concord, Calif.
2,768,134	Testing Material in a Neutronic Reactor	E. Fermi (Deceased); H. L. Anderson, Hartford, Conn.
2,768,433	Metallic Bond and Method	T. J. O'Donnell, Chicago, Ill.
2,768,813	Heat Exchangers	R. Q. Boyer, Berkeley, Calif.
2,768,871	Process Using Carbonate Precipitation	H. S. Brown and O. F. Hill, Oak Ridge, Tenn.; A. H. Jaffey, Chicago, Ill.
2,768,872	Manufacture of Uranium Tetrafluoride	D. X. Klein, Wilmington, and H. B. Gage, Edge Moor Terrace, Del.
2,768,873	Method of Purifying Uranium	N. C. Beese, Verona, N. Y.
2,769,094	Time-of-Flight Neutron Spectrometer	W. I. Linlor, Richmond, and B. Ragent, Concord, Calif.
2,769,776	Method of Making a Product Containing Uranium 237.	A. F. Reid, New York, N. Y.
2,769,780	Precipitation Process	W. E. Clifford, San Francisco, Calif.; R. E. Burns, Richland, Wash.
2,769,903	Pulse Forming Network	G. D. Paxson, El Cerrito, Calif.
2,770,128	Electronic Pressure Differential Wind Direction Indicator.	H. Moses, Park Forest, Ill.
2,770,520	Recovery of Uranium From Phosphoric Acid and Phosphate Solutions by Ion Exchange.	R. S. Long, Solano, and R. H. Bailes, Walnut Creek, Calif.
2,770,521	Separation of Uranium from Mixtures	L. Spiegler, Woodbury, N. J.
2,770,522	Method of Purifying and Recovering Vanadium From Phosphate-Containing Solutions.	R. H. Bailes, Walnut Creek, Calif.; R. R. Grinstead, Concord, Calif.

PATENTS ISSUED TO THE COMMISSION WHICH ARE AVAILABLE FOR LICENSING [1]—con.

Patent No.	Title	Patentee
2,770,590	Reactor Circulating System	J. T. Serduke, El Cerrito, Calif.
2,770,591	Heavy Water Moderated Neutronic Reactor	E. P. Wigner, Princeton, N. J.; L. A. Ohlinger and G. J. Young, Chicago, Ill.; A. M. Weinberg, Oak Ridge, Tenn.
2,770,684	Limited Amplifier	R. E. Thomas, Walnut Creek, Calif.
2,770,775	Linear Accelerator	M. L. Good, Berkeley, Calif.
2,770,776	Automatic Beam Stabilization	R. J. Klein, Downers Grove, Ill.
2,770,856	Crucible and Stopper Therefor	A. W. Becker, Oxford, Ohio; A. W. Woker, St. Louis, Mo.
2,771,199	Remote Control Manipulator	D. G. Jelatis, Red Wing, Minn.
2,771,338	Manufacture of Uranium Peroxide	L. Spiegler, Woodbury, N. J.
2,771,339	Processes for the Purification and Recovery of Uranium.	R. Q. Boyer, Berkeley, Calif.
2,771,340	Improved Uranium Recovery and Purification Processes.	M. D. Kamen, Berkeley, Calif.; A. DeHaan, Jr., Oak Ridge, Tenn.
2,771,357	Method of Melting Metal Powder in Vacuo	D. Wroughton, Verona, N. J.
2,771,582	Phase Meter	C. N. Winningstad, San Lorenzo; Q. A. Kerns, Berkeley, Calif.
2,771,999	Filtering Apparatus	R. Q. Boyer, Berkeley, Calif.
2,772,142	Processes of Reclaiming Uranium From Solutions.	R. Cummings, Berkeley, Calif.
2,773,195	Beam Regulator	E. O. Lawrence and Q. A. Kerns, Berkeley, Calif.
2,773,386	Level Indicator	E. O. Swickard, Jr., Los Alamos, N. Mex.
2,773,820	Electrolytic Process of Salvaging Uranium	R. Q. Boyer and S. B. Kilner, Berkeley, Calif.
2,773,823	Safety Device for a Neutronic Reactor	J. J. Goett (deceased).
2,773,824	Electrolytic Cells	R. Q. Boyer and S. B. Kilner, Berkeley, Calif.
2,773,825	Electrolysis Apparatus	F. A. Newcombe, Nutley, N. J.
2,773,826	Electrolytic Apparatus for the Recovery of Rare Refractory Metals.	N. C. Beese, Verona, and J. W. Marden, E. Orange, N. J.
2,774,488	Remote-Control Manipulator	R. C. Goertz, Downers Grove, and R. B. Wehrle, Lemont, Ill.; R. G. Schmitt, Jr., Ft. Worth, Tex.; R. A. Olsen, Chicago, Ill.

APPENDIX 6

REGULATIONS OF THE U. S. ATOMIC ENERGY COMMISSION[1]

PART 2—RULES OF PRACTICE

MISCELLANEOUS AMENDMENTS

The following rules are designed to carry out the Commission's responsibility under Section 181 of the Atomic Energy Act of 1954 (68 Stat. 953) to provide "such parallel procedures as will effectively safeguard and prevent disclosure of Restricted Data * * * to unauthorized persons with minimum impairment of the procedural rights which would be available if Restricted Data * * * were not involved." Discharge of this responsibility requires the framing of novel procedures, and a delicate balancing of the need to provide adequate protection for Restricted Data with the importance of providing parties and the public with access to the records of administrative proceedings before the Commission and information relating thereto.

Because they may be needed in pending proceedings, the Atomic Energy Commission has found that good cause exists why the regulations in this part should be made effective soon after expiration of a 15-day period of notice of proposed rule making, without the customary 30-day period of notice. The Commission will, however, continue its study of the problems involved in the rules with a view to making such further changes as may from time to time appear to be desirable. Members of the bar and others are invited to subject these rules and the manner of their administration to extended study and to submit any further comments and suggestions they may have to the Commission.

Pursuant to the Administrative Procedure Act, Public Law 404, 79th Congress, 2d Session, the following rules are published as a document subject to codification, effective upon publication in the FEDERAL REGISTER.

1. The following paragraph is added to § 2.790:

(d) Matters of official record in any proceedings subject to this part, which are classified as Restricted Data and are within a category specified in Appendix "A", Part 25 of this chapter, will be made available for inspection by access permittees in accordance with the regulations in Parts 25 and 95 of this chapter.

2. The following subpart is added:

SUBPART H—SPECIAL PROCEDURES APPLICABLE TO ADJUDICIARY PROCEEDINGS INVOLVING RESTRICTED DATA

Sec.
2.800 Purpose.
2.801 Scope.
2.802 Definitions.
2.803 Protection of Restricted Data in proceedings under this subpart.
2.804 Classification assistance.
2.805 Access to Restricted Data for parties—*security clearances.*
2.806 Obligations of parties to avoid introduction of Restricted Data.
2.807 Notice of intent to introduce Restricted Data.
2.808 Contents of notice of intent to introduce Restricted Data.
2.809 Rearrangement of suspension of proceedings.
2.810 Unclassified statements required.
2.811 Admissibility of Restricted Data.
2.812 Weight to be attached to classified evidence.
2.813 Review of Restricted Data received in evidence.
2.814 Access under Part 25 of this chapter not affected.

AUTHORITY: §§ 2.800 to 2.814 issued under sec. 161, 68 Stat. 948; 42 U. S. C. 2201. Interpret or apply sec. 181, 68 Stat. 953; 42 U. S. C. 2231.

§ 2.800 *Purpose.* The regulations in this subpart are issued pursuant to section 181 of the Atomic Energy Act of

[1] Policies and regulations of the U. S. Atomic Energy Commission announced prior to December 1956 can be found in the Federal Register and in the following semiannual reports: Fifth, Sixth, Ninth, Tenth, Eleventh, Twelfth, Thirteenth, Fourteenth, Fifteenth, Sixteenth, Seventeenth, Nineteenth and Twentieth.

1954 (63 Stat. 919) to provide such parallel procedures in adjudicatory proceedings subject to this part as will effectively safeguard and prevent disclosure of Restricted Data to persons not authorized to receive it, with minimum impairment of the procedural rights which would otherwise be available to the parties if such information were not involved.

§ 2.801 *Scope.* The provisions of this subpart apply to all proceedings under this part involving adjudication as that term is used in the Administrative Procedure Act, except that §§ 2.807 to 2.814, inclusive, apply to such proceedings only upon the service of a notice of hearing pursuant to § 2.735.

§ 2.802 *Definitions.* As used in this subpart,

(a) "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;

(b) "Interested party" means a party having an interest in the issue or issues to which particular Restricted Data is relevant. Normally the interest of a party in an issue may be determined by examination of the notice of hearing, the answers and replies;

(c) The phrase "introduced into a proceeding" refers to the introduction or incorporation of testimony or documentary matter into any part of the official record of a proceeding subject to this subpart;

(d) "Person" means (1) any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, Government agency other than the Commission, any State or any political subdivision of, or any political entity within a State, or other entity; and (2) any legal successor, representative, agent, or agency of the foregoing;

(e) "Restricted Data" means all data concerning (1) design, manufacture, or utilization of atomic weapons; (2) the production of special nuclear material; or (3) the use of special nuclear material in the production of energy, but shall not include data declassified or removed from the Restricted Data category pursuant to section 142.

§ 2.803 *Protection of Restricted Data in proceedings under this subpart.* Nothing contained in this subpart shall relieve any person from safeguarding Restricted Data in accordance with all applicable provisions of laws of the United States and rules, regulations or orders of any Government agency.

§ 2.804 *Classification assistance.* Upon request of any party or of the presiding officer, AEC will designate a representative to advise and assist the presiding officer and the parties with respect to security classification of information and the safeguards to be observed.

§ 2.805 *Access to Restricted Data for parties—Security clearances*—(a) *Access to Restricted Data introduced into proceedings.* (1) Restricted Data which is within a category specified in Appendix "A", Part 25 of this chapter, and which is introduced into a proceeding subject to this subpart, will be made available to any party to the proceeding who has an appropriate security clearance, to appropriately cleared counsel for a party, and to such other appropriately cleared individuals (including employees of a party) as a party intends to use in connection with the preparation or presentation of his case.

(2) Other Restricted Data introduced into a proceeding subject to this subpart will be made available to any interested party having an appropriate security clearance; to appropriately cleared counsel for an interested party; and to such additional appropriately cleared persons (including employees of a party) as the AEC or the presiding officer determines are needed by such interested party for adequate preparation or presentation of his case. Where the interest

of the party will not be prejudiced, action upon an application for access under this subparagraph may be postponed until after a notice of hearing, answers and replies have been served pursuant to §§ 2.735 to 2.737, inclusive.

(3) Any party desiring access to Restricted Data introduced into the record of a proceeding subject to this subpart should submit an application for order granting access pursuant to this section.

(b) *Access to Restricted Data not introduced into proceedings.* (1) Upon application showing that access to Restricted Data may be required for the preparation of a party's case, and except as provided in paragraph (h) of this section, the AEC (or the presiding officer if one has been appointed) will issue an order granting access to such Restricted Data to the party upon his obtaining an appropriate security clearance, to appropriately cleared counsel for the party and to such other appropriately cleared individuals as may be needed by the party for the preparation of his case.

(2) Where the interest of the party applying for access will not be prejudiced, the AEC or presiding officer may postpone action upon an application pursuant to this paragraph until after a notice of hearing, answers and replies have been served pursuant to §§ 2.735 to 2.737.

(c) The AEC will process requests for appropriate security clearances in reasonable numbers pursuant to this section. No charge will be made by the AEC for costs of security clearance pursuant to this section.

(d) The presiding officer may certify to the Commission for its consideration and determination any questions relating to access to Restricted Data arising under this section. Notwithstanding the provisions of § 2.748, any party affected by a determination or order of the AEC or the presiding officer under this section respecting access to or the safeguarding of Restricted Data, may appeal forthwith to the Commission from such determination or order. The filing by AEC of an appeal from an order of a presiding officer granting access to Restricted Data shall stay such order pending determination of such appeal by the Commission.

(e) Applications under this section for orders granting access to Restricted Data within a category specified in Appendix "A", Part 25 of this chapter, will normally be acted upon by the presiding officer, if one has been appointed, or by the General Manager. Applications for orders granting access to Restricted Data which is not within such a category will be acted upon by the Commission.

(f) To the extent practicable, each application for order granting access under this section shall describe the subjects of Restricted Data to which access is desired and the level of classification (e. g. Confidential, Secret) of such information; the reasons why access to such information is requested; the names of individuals for whom clearances are requested; and the reasons why security clearances will be requested for such individuals.

(g) Upon the conclusion of a proceeding, the AEC will terminate all orders issued in the proceeding for access to Rrestricted Data and all security clearances granted pursuant to such orders; and may issue such orders requiring the disposal of classified matter received pursuant to such access orders or requiring the observance of other procedures to safeguard such classified matter as it deems necessary to protect Restricted Data.

(h) There may be incorporated in any order issued pursuant to this section such requirements, conditions and limitations as are deemed necessary to protect Restricted Data.

(i) The Commission may refuse to grant access to Restricted Data which is not within a category specified in Appendix "A" to Part 25 of this chapter upon a determination that the granting of such access will be inimical to the common defense and security.

NOTE: Procedures for granting security clearances are not contained in this part. Criteria, procedures and methods for resolving questions concerning the eligibility of an individual for security clearance are contained in Part 4 of this chapter.

§ 2.806 *Obligation of parties to avoid introduction of Restricted Data.* It shall be the obligation of all parties in a proceeding subject to this subpart to avoid, insofar as is practicable, the introduction of Restricted Data into the proceeding. This obligation shall rest upon each party whether or not all other parties have appropriate security clearances.

§ 2.807 *Notice of intent to introduce Restricted Data.* (a) If, at the time of service of a notice of formal hearing pursuant to § 2.735, it appears to the AEC that it will be impracticable for the AEC to avoid the introduction of Restricted Data into the proceeding, the AEC will include in the notice of hearing a notice of intent to introduce Restricted Data.

(b) If, at the time of service of an answer pursuant to § 2.736, it appears to the party serving the answer that it will be impracticable for the party to avoid the introduction of Restricted Data into the proceeding, the party shall include in the answer a notice of intent to introduce Restricted Data into the proceeding.

(c) If, at any later stage of a proceeding subject to this subpart, it appears to any party that it will be impracticable for the party to avoid the introduction of Restricted Data into the proceeding, the party shall give prompt notice of intent to introduce Restricted Data into the proceeding.

(d) Restricted Data shall not be introduced into a proceeding after the service of a notice of hearing unless a notice of intent has been served and filed in accordance with § 2.808 except that in the discretion of the presiding officer Restricted Data may be introduced without the service and filing of such notice where it is clear that no party will be prejudiced by such introduction.

§ 2.808 *Contents of notice of intent to introduce Restricted Data.* (a) A notice of intent to introduce Restricted Data shall be filed with the AEC and copies served upon all parties to the proceeding. Such notice shall be unclassified and, to the extent consistent with classification requirements, shall contain the following information:

(1) The subject matter of the Restricted Data which it is anticipated will be involved;

(2) The level of classification of such information (e. g., Confidential, Secret);

(3) The stage of the proceeding at which he anticipates a need to introduce such information; and

(4) The relevance and materiality of such information.

(b) In the discretion of the presiding officer, such notice, when required by § 2.807 (c), may be given orally.

§ 2.809 *Rearrangement or suspension of proceedings.* In any proceeding where a party gives notice of intent to introduce Restricted Data, and the presiding officer determines that any other interested party does not have appropriate security clearances, the presiding officer may in his discretion:

(a) Rearrange the normal order of the proceeding in such a manner as to give such interested parties opportunity to obtain appropriate security clearances with minimum delay in completion of the proceeding; or

(b) Suspend the proceeding or any portion thereof until all interested parties have had opportunity to obtain appropriate security clearances: *Provided,* That no proceeding shall be suspended for such reason for more than 100 days except with the consent of all parties or upon a determination by the presiding officer that further suspension of the proceeding would not be contrary to the public interest; or

(c) Take such other action as he determines to be appropriate.

§ 2.810 *Unclassified statements required.* (a) Whenever Restricted Data is offered in evidence at a formal hearing, the party offering such information shall submit to the presiding officer and to all parties to the proceeding an unclassified statement setting forth the in-

formation contained in the classified matter as accurately and completely as possible.

(b) In accordance with such procedures as may be agreed upon between the parties or prescribed by the presiding officer, and after notice to all parties and opportunity to be heard thereon, the presiding officer shall determine whether the unclassified statement or any portion thereof, together with any appropriate modifications suggested by any party, may be substituted for the classified matter or any portion thereof without prejudice to the interest of any party or to the public interest.

(c) If the presiding officer determines that the unclassified statement, together with such unclassified modifications as he finds are necessary or appropriate to protect the interest of other parties and the public interest, adequately sets forth the relevant and material information contained in the classified matter, he shall direct that the classified matter be excluded from the record of the proceeding and such determination will be considered by the Commission as a part of the decision in the case where appropriate exceptions are filed to the presiding officer's determination.

(d) If the presiding officer determines that an unclassified statement does not adequately present the relevant and material information contained in the classified matter, he shall include his reasons therefor in his determination. Said determination shall be included as a part of the record and will be considered by the Commission in reviewing the case.

(e) The presiding officer may in his discretion postpone all or part of the procedures established in this section until the reception of evidence has been completed: *Provided*, That service of the statement required in paragraph (a) of this section shall not be postponed where any party does not have access to the Restricted Data.

§ 2.811 *Admissibility of Restricted Data.* Presiding officers shall not receive any Restricted Data in evidence unless:

(a) The relevance, materiality and competence of such information is clearly established; and

(b) The exclusion of such information would prejudice the interests of a party or the public interest.

§ 2.812 *Weight to be attached to classified evidence.* In considering the weight and effect of any Restricted Data received in evidence to which an interested party has not had opportunity to receive access, the presiding officer and the Commission shall give to such evidence such weight as, under the circumstances, is appropriate, taking into consideration any lack of opportunity for such parties to rebut or impeach the evidence.

§ 2.813 *Review of Restricted Data received in evidence.* At the close of the reception of evidence, the presiding officer shall review the record and shall direct that any Restricted Data therein be expunged from the record where such expunction would not prejudice the interests of a party or the public interest. Such directions by the presiding officer will be considered by the Commission in reviewing the case where appropriate exceptions are filed to the directions.

§ 2.814 *Access under Part 25 of this chapter not affected.* Nothing contained in this subpart or any order issued pursuant hereto shall be deemed to abridge access to Restricted Data to which any person may be entitled under the regulations in Part 25 of this chapter.

Dated at Washington, D. C., this 4th day of December 1956.

K. E. Fields,
General Manager.

Part 4—Security Clearance Procedures

CRITERIA AND PROCEDURES FOR DETERMINING ELIGIBILITY FOR SECURITY CLEARANCE

Effective upon publication in the Federal Register the following amendments are made to Part 4, Title 10, CFR, "Criteria and Procedures for Determining Eligibility for Security Clearance."

1. There is added a new section designated as § 4.5 reading as follows:

§ 4.5 *Definitions.* As used in this part:

(a) "Personnel Security Board" means an advisory board appointed by the Manager of Operations and consisting of four members, one of whom shall be a non-voting member who shall act as counsel to the Board;

(b) "Board" means the three voting members of the Personnel Security Board.

2. The introductory text of paragraph (d) of § 4.10 is amended to read as follows:

(d) In resolving a question concerning the eligibility of an individual for security clearance, the following principles shall be applied by the Board:

3. The heading and paragraphs (a), (c), (e), (f), (g) and (h) of § 4.25 are amended to read as follows:

§ 4.25 *Appointment of Personnel Security Boards.* (a) Upon receipt from the individual of his written answer to the notification letter, signifying his desire to appear before a Personnel Security Board, the Manager shall forthwith appoint a Personnel Security Board consisting of four members, one of whom shall be a nonvoting member who shall act as counsel to the Board in accordance with the provisions of §§ 4.26 and 4.27. One member of the Board shall be designated as the Chairman of the Personnel Security Board;

(c) The personnel of the Board shall be selected from a panel of individuals possessing the highest degree of integrity, ability, and good judgment. Such panels may include employees of the AEC or its contractors but no AEC employee shall serve as a voting member of a Personnel Security Board hearing the case of an AEC employee, or applicant for AEC employment, and no employee of an AEC contractor shall serve as a voting member of a Personnel Security Board hearing the case of an employee of, or an applicant for employment with, that contractor;

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(e) No person shall serve as a member of a Personnel Security Board who has prejudged the case to be heard; who possesses information that would make it embarrassing to render impartial recommendations or advice; or who for bias or prejudice generated for any reason would be unable to render fair and impartial recommendations or advice;

(f) Immediately upon the appointment of a Personnel Security Board, the Manager will notify the individual of the identity of the members of the Personnel Security Board and of his right to challenge any member for cause, such challenge or challenges, accompanied by the reasons therefor, to be submitted to the Manager within seventy-two hours of the receipt of the notice;

(g) In the event that the individual challenges a member or members of the Personnel Security Board, the justification of the action of the individual shall be determined by the Manager. Where the challenge of the individual is sustained, the Manager shall forthwith appoint such new members as required to constitute a full Personnel Security Board and notify the individual. The individual shall have the right to challenge such new members for cause and such challenge shall be dealt with in the same manner as an original challenge. The Manager shall also notify the individual of his rejection of any challenge. The Personnel Security Board shall convene as soon as is reasonably practicable;

(h) The Manager of Operations shall notify the individual in writing, at least one week in advance, of the date, hour, and place the Personnel Security Board will convene. In the event the individual fails to appear at the time and place specified, a recommendation as to the final action to be taken shall be made by the Manager of Operations to the General Manager on the basis of the existing record. However, the Manager of Operations may for good cause, at the request of the individual, permit the individual to appear before a Personnel Security Board at a newly scheduled date, hour, and place.

4. The heading and paragraphs (a) and (b) of § 4.26 are amended to read as follows:

§ 4.26 *Appointment of Counsel to the Boards.* (a) Managers of Operations shall appoint an attorney as a non-voting member of the Personnel Security Board to serve as counsel to the Board; such attorney shall possess the highest degree of integrity, ability and good judgment and shall have an AEC "Q" clearance. Counsel to the Board may be an employee of the AEC, or he may be an attorney specifically retained to serve as Counsel to the Board;

(b) Counsel to the Board shall not participate in the deliberations of the Board, and shall express no opinion to the Board concerning the merits of the case. He shall advise the Board concerning the meaning and application of the procedures. He shall also advise the individual of his rights under these procedures when the individual is not represented by counsel of his own choosing.

5. Paragraph (a) of § 4.27 is amended to read as follows:

(a) The proceedings shall be presided over by the Chairman of the Personnel Security Board and shall be conducted in an orderly and decorous manner with every effort made to protect the interests of the Government and of the individual and to arrive at the truth. In no case will undue delay be tolerated nor will the individual be hampered by unduly restricting the time necessary for proper preparation and presentation. In performing their duties, the members of the Board shall avoid the attitude of a prosecutor and shall always bear in mind and make clear to all concerned that the proceeding is an administrative hearing and not a trial.

6. Paragraph (b) (1) of § 4.29 is amended to read as follows:

(1) Refer the matter to the Personnel Security Board which had been appointed in the individual's case when the Manager of Operations has not yet forwarded his recommendation to the General Manager. The Board receiving the application for the presentation of new evidence shall determine the form in which it shall be received, whether by testimony before the Personnel Security Board, by deposition or by affidavit.

7. Paragraph (g) of § 4.22 is amended to read as follows:

(g) That the individual will have the right to appear personally before a Personnel Security Board and present evidence in his own behalf, through witnesses, or by documents, or both, and subject to the limitations set forth in § 4.27 (f) and (m), be present during the entire hearing and be represented by counsel of his own choosing.

(Sec. 161, 68 Stat. 948; 42 U. S. C. 2201)

Dated at Washington, D. C., this 12th day of September 1956.

K. E. FIELDS,
General Manager.

PART 9—PUBLIC RECORDS

Notice is hereby given that the Atomic Energy Commission has adopted the following rules. Because these rules may be needed in pending proceedings, the Atomic Energy Commission has found that good cause exists that the rules should be made effective upon publication without the customary 30-day period provided by section 4 (c) of the Administrative Procedure Act, Public Law 404, 79th Congress, 2d Session.

AUTHORITY: §§ 9.1 to 9.7 issued under sec. 161, 68 Stat. 948; 42 U. S. C. 2201. Interpret or apply sec. 3, 60 Stat. 238, 5 U. S. C. 1002.

§ 9.1 *Scope.* This part prescribes the rules governing the Atomic Energy Commission's public records which relate to any proceeding subject to Part 2 and Part 25 of this chapter.

§ 9.2 *Definitions.* As used in this part:

(a) "Public records" means those documents in the custody of the AEC which are available for public inspection.

(b) "Filings" means:

(1) Applications or other documents seeking Commission action, notices, orders, motions, answers, replies, objections, stipulations, exceptions, proofs of service briefs, transcripts of hearings, exhibits received in evidence, decisions, licenses, permits, rules, and regulations.

(2) Exhibits, attachments and appendices to, amendments and corrections of, supplements to, and transmittals and withdrawals of any of the foregoing.

(c) "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.

(d) "Commission" means the commission of five members or a quorum thereof sitting as a body, as provided by section 21 of the Atomic Energy Act of 1954.

(e) "AEC" means the agency established by the Atomic Energy Act of 1954, comprising the members of the Commission and all officers, employees, and representatives authorized to act in the case or matter whether clothed with final authority or not.

(f) "AEC personnel" means employee, consultants, and members of advisory boards of the AEC.

§ 9.3 *Inclusions.* Except as excluded by § 2.403 of this chapter, the following matters are included in the public records:

(a) All filings in proceedings.

(b) All correspondence or portions of correspondence to and from AEC regarding the issuance, amendment, transfer, renewal, modification, suspension or revocation of a license or permit or regarding a rule-making proceeding subject to Part 2 of this chapter.

(c) All correspondence or portions of correspondence to and from AEC as to the interpretation or applicability of any statute, rule, regulation, order, license, or permit; and letters of opinion as to such matters signed by the General Counsel.

(d) All filings in court proceedings to which the AEC is a party and all correspondence with the courts or clerks of the court.

§ 9.4 *Exceptions.* The following are not included in the public records:

(a) Documents withheld in accordance with the provisions of § 2.790 (b) and (c) of this chapter.

(b) Documents relating to personnel matters and medical and other personal information, which, under general governmental personnel practices, are not normally made public.

(c) Intra-agency and inter-agency communications, including memoranda, reports, correspondence, and staff papers prepared by members of the Commission, AEC personnel, or by any other Government agency for use within the AEC or within the executive branch of the Government.

(d) Transcript or other records of Commission meetings except those Commission meetings which constitute public hearings.

(e) Correspondence between the AEC and any foreign government.

(f) Records and reports of investigations.

(g) Documents classified as Restricted Data under the Atomic Energy Act of 1954 or classified under Executive Order No. 10501, except that documents classified as Restricted Data which would otherwise be public records defined in § 9.3 and not excepted by this part will be made available in accordance with Part 25 of this chapter or will be made available to members of Congress upon authorization by the Commission.

(h) Correspondence received in confidence by the AEC relating to an alleged or possible violation of any statute, rule, regulation, order, license or permit.

(i) Correspondence with members of Congress or congressional committees, unless and until such correspondence is released by the member of Congress or congressional committee concerned.

(j) Any other documents involving matters of internal agency management.

§ 9.5 *Location.* Public records normally will be made available for inspection in the Public Document Room located at 1717 H Street NW., Washington, D. C.

§ 9.6 *Copies.* Copies of public records, not available elsewhere, will be made available upon request and payment of any charges for reproduction.

§ 9.7 *Production or disclosure.* (a) AEC personnel shall not produce or disclose the contents of any material that falls within the scope of § 9.4, except as provided in paragraph (b) of this section.

(b) AEC personnel served with the subpoena requiring the production or disclosure of any material that falls within the scope of § 9.4 shall appear in response thereto and shall respectfully decline to produce or disclose the material called for, basing refusal upon this section: *Provided, however,* That the Commission or the General Manager may authorize the production or disclosure of any material that falls within the scope of § 9.4 if it is deemed that such disclosure is not contrary to the public interest. Any person who is served with such a subpoena shall promptly advise the AEC thereof and of any relevant facts and the Commission or the General Manager will give such instructions as it is deemed advisable.

Dated at Washington, D. C., this 4th day of December 1956.

K. E. FIELDS,
General Manager.

PART 30—LICENSING OF BYPRODUCT MATERIAL

MISCELLANEOUS AMENDMENTS

This amendment to 10 CFR, Part 30, Licensing of Byproduct Material, is published for the purpose of adding to § 30.71, Schedule A, three classes of devices which may be possessed and used under the general license contained in § 30.21 (a) (1) when such devices are manufactured, tested and labeled in accordance with the specifications contained in a specific license issued to the manufacturer under these regulations; and to add small quantities of beta and/or gamma emitting byproduct material to the list of byproduct materials generally licensed pursuant to §§ 30.21 (a) (2) and 30.72. Inasmuch as this amendment is intended to relieve from, rather than to impose, restrictions, the Atomic Energy Commission has found that general notice of proposed rule-making and public procedure are unnecessary and that good cause exists why the regulations should be made effective without the customary period of notice.

Part 30, *Title 10, CFR,* Licensing of Byproduct Material, is hereby amended in the following respects:

1. Section 30.71 *Schedule A* is amended to read as follows:

§ 30.71 *Schedule A.* The following devices and equipment incorporating byproduct material, when manufactured, tested and labeled by the manufacturer in accordance with the specifications contained in a specific license issued to him pursuant to the regulations in this part, are placed under a general license pursuant to § 30.21 (a) (1).

(a) *Static elimination device.* Devices designed for use as static eliminators which contain, as a sealed source or sources, byproduct material consisting of a total of not more than 500 microcuries of Polonium 210 per device.

(b) *Spark gap and electronic tubes.* Spark gap tubes and electronic tubes which contain byproduct material consisting of not more than 5 microcuries per tube of Cesium 137, or Nickel 63, or Krypton 85 gas, or not more than one microcurie per tube of Cobalt 60.

(c) *Light meter.* Devices designed for use in measuring or determining light intensity which contain, as a sealed source or sources, byproduct material consisting of a total of not more than 200 microcuries of Strontium 90 per device.

(d) *Ion generating tube.* Devices designed for ionization of air which contain, as a sealed source or sources, byproduct material consisting of a total of not more than 500 microcuries of Polonium 210 per device.

2. Section 30.72 *Schedule B* is amended as follows:

a. The abbreviation for Cesium-Barium 137 is corrected to read "(CsBa 137)."

b. The following is inserted at the end of the presently scheduled byproduct materials, immediately under Zinc 65:

	Column No. I Not as a sealed source (microcuries)	Column No. II As a sealed source (microcuries)
Beta and/or Gamma emitting byproduct material not listed above	1	10

(Sec. 161, 68 Stat. 948; 42 U. S. C. 2201)

Dated at Washington, D. C., this 27th day of September 1956.

For the Atomic Energy Commission.

K. E. FIELDS,
General Manager.

PART 30—LICENSING OF BYPRODUCT MATERIAL

APPLICATIONS FOR SPECIFIC LICENSES; ELIMINATION OF REQUIREMENT FOR SIGNATURE UNDER OATH OR AFFIRMATION

This amendment to Title 10, Part 30, Licensing of Byproduct Material, eliminates the requirement that applications for specific licenses must be signed under oath or affirmation. Because this amendment merely eliminates a present procedural requirement, the Atomic Energy Commission has found that general notice of proposed rule making and public procedure thereon are unnecessary and would be contrary to the public interest; and that good cause exists why this amendment should be made effective without the customary 30-day period of notice.

Paragraph (c) of § 30.22 is amended by deleting the words "under oath or affirmation."

(Sec. 161, 68 Stat. 948; 42 U.S.C. 2201)

Dated at Washington, D. C., this 17th day of September 1956.

For the Atomic Energy Commission.

K. E. FIELDS,
General Manager.

PART 25—ACCESS TO RESTRICTED DATA

CONTROLLED THERMONUCLEAR PROCESSES

The following amendments to Title 10, CFR, Part 25, Access to Restricted Data, establish special requirements for access to Secret Restricted Data in Category C–20 *Controlled Thermonuclear Processes.* Because these amendments are required in the interests of the common defense and security, the Commission has concluded that they should be effective without a prior period of notice.

1. Add the following sentence at the end of 25.11 (b) (7): "In addition, if access to Secret Restricted Data in category C–20 *Controlled Thermonuclear Processes* is requested, the application should also include sufficient information to satisfy the requirements of 25.15 (b) (2).

2. Paragraph (b) of 25.15 is amended by adding "(1)" after "(b)" and adding the following subparagraph at the end thereof:

(2) An application for access to Secret Restricted Data in category C–20 *Controlled Thermonuclear Processes* will be approved only if the application demonstrates also that the applicant,

(i) Is engaged in a substantial effort to develop, design, build or operate a fission power reactor that is planned for construction; or

(ii) Possesses qualifications demonstrating that he is capable of making a significant contribution to research and development in the controlled thermonuclear field.

Dated at Washington, D. C., this 30th day of July 1956.

K. E. FIELDS,
General Manager.

(Sec. 161, 68 Stat. 948; 42 U.S.C. 2201)

PART 50—LICENSING OF PRODUCTION AND UTILIZATION FACILITIES

EFFECT OF FINDING OF PRACTICAL VALUE UPON LICENSES PREVIOUSLY ISSUED

This amendment to Title 10, CFR Part 50, "Licensing of Production and Utilization Facilities," is published for the purpose of adding § 50.24 *Effect of finding of practical value upon licenses previously issued*, to the regulation. Inasmuch as this amendment is designed to clarify existing regulations and not to effect any change in the Commission's procedures and requirements, the Atomic Energy Commission has found that general notice of proposed rule making and public procedure are unnecessary, and that good cause exists why the regulation should be made effective without the customary period of notice.

Title 10, Chapter I, Part 50, Code of Federal Regulations, entitled "Licensing of Production and Utilization Facilities," is hereby amended by adding the following section to follow § 50.23:

§ 50.24 *Effect of finding of practical value upon licenses previously issued.* The making of a finding of practical value pursuant to section 102 of the act will not be regarded by the Commission as grounds for requiring:

(a) The conversion to a Class 103 license of any Class 104 license prior to the date of expiration contained in the license; or

(b) The conversion to a Class 103 license of any construction permit, issued under section 104 of the act, prior to the date designated in the permit for expiration of the license.

(60 Stat. 755-775; 42 U. S. C. 1801-1819)

Dated at Washington, D. C., this 23rd day of November 1956.

For the Atomic Energy Commission.

K. E. FIELDS,
General Manager.

PART 55—OPERATORS' LICENSES

APPLICATIONS FOR SPECIFIC LICENSES AND STATEMENTS; ELIMINATION OF REQUIREMENT FOR SIGNATURE UNDER OATH OR AFFIRMATION

This amendment to Title 10, Part 55, Operators' Licenses, eliminates the requirement that applications for specific licenses and statements must be signed under oath or affirmation. Because this amendment merely eliminates a present procedural requirement, the Atomic Energy Commission has found that general notice of proposed rule making and public procedure thereon are unnecessary and would be contrary to the public interest; and that good cause exists why this amendment should be made effective without the customary 30-day period of notice.

Paragraph (d) of § 55.10 is amended by deleting the words "under oath or affirmation" from the second sentence thereof. Paragraph (a) of § 55.33 is amended by deleting the words "under oath or affirmation" from the first sentence thereof.

(Sec. 161, 68 Stat. 948; 42 U. S. C. 2201)

Dated at Washington, D. C., this 17th day of September 1956.

For the Atomic Energy Commission.

K. E. FIELDS,
General Manager.

PART 60—DOMESTIC URANIUM PROGRAM ALLOWANCES

Notice is hereby given that the following amendment has been adopted by the Atomic Energy Commission effective upon publication in the FEDERAL REGISTER.

10 CFR 60.5a (3) (i) is amended to read as follows:

(3) *Allowances.* (i) A development allowance of $0.50 per pound U_3O_8 in ores assaying 0.10 percent U_3O_8 or more in recognition of expenditures incurred or likely to be incurred in the development or exploration necessary for maintaining and increasing developed reserves of uranium ores. Fractional parts of a pound will be paid for on a pro rata basis to the nearest cent.

* * * * *

Dated at Washington, D. C., this 9th day of August 1956.

K. E. FIELDS,
General Manager.

PART 60—DOMESTIC URANIUM PROGRAM

BONUS FOR INITIAL PRODUCTION OF URANIUM ORE FROM NEW DOMESTIC MINES

Section 60.6 (c) of Title 10 is amended by extending the period for payment of bonus for initial production of uranium ore from new domestic mines from February 28, 1957, to March 31, 1960, so that § 60.6 (c) shall read as follows:

§ 60.6. *Bonus for initial production of uranium ores from new domestic mines.* * * *

(c) *Term of this section.* This section will apply to deliveries made under its terms between March 1, 1951, and March 31, 1960, inclusive.

Dated at Washington, D. C., this 7th day of November 1956.

(60 Stat. 755-775; 42 U. S. C. 1801-1810)

By order of the Commission.

R. W. COOK,
Acting General Manager.

PART 60—DOMESTIC URANIUM PROGRAM

URANIUM LEASES ON LANDS CONTROLLED BY COMMISSION

Notice is hereby given that the following regulations have been adopted by the Atomic Energy Commission, effective upon publication in the FEDERAL REGISTER:

§ 60.8 *Uranium leases on lands controlled by the Commission*—(a) *What this section does.* This section sets forth regulations governing the issuance of leases for mining deposits of uranium in public lands withdrawn from entry and location under the general mining laws for the use of the Commission, and in certain other lands under Commission control.

(b) *Statutory authority.* The Atomic Energy Act of 1954 (68 Stat. 919) is the authority for this section.

(c) *Who may hold leases.* Only parties who are (1) citizens of the United States; (2) associations of such citizens; or (3) corporations organized under the laws of the United States or territories thereof, are eligible lessees under this section. Persons under 21 years of age or employees of the Commission are not eligible.

(d) *Issuance of leases through competitive bidding.* Except under special circumstances as provided in this section a lease will be issued only to the acceptable bidder offering the highest cash bonus. Before any lease is awarded the Commission may require high bidders to submit a detailed statement of the facts.

(e) *Solicitation of bids.* Invitation to bid for a lease will be publicly posted and published. Copies will also be mailed to parties who submit to the Commission's Grand Junction, Colorado, Operations Office written request that their names be placed on a mailing list for the receipt of such invitations. The invitation will set forth the location of the land or deposits to be leased, the term, royalty rate, work requirements and certain other conditions which will become a part of the lease. The invitation will specify a period following notice of award during which the successful bidder may explore the land or deposit, and will also specify the percentage of the bonus offered which must be transmitted with the bid and set the place and time the bids will be publicly opened. A detailed statement of the terms of the invitation and the factual data pertinent to the land or deposit obtained from Commission exploration will be available for public inspection at offices listed in the invitation and upon payment of a nominal charge copies of these statements and data may be acquired from the Grand Junction Operations Office.

(f) *Bidding requirements; deposits.* All bids must be filed at the place and prior to the time set in the invitation. Each bid must be sealed and accompanied by a deposit, in the form of a certified check, cashier's check, bank draft or cash, equal to the specified percentage of the bonus offered. Deposits of unsuccessful bidders will be returned. If the bidder is an individual he must submit with his bid a statement of his citizenship and age. If the bidder is an association (including a partnership), the bid shall be accompanied by a certified copy of the articles of association together with a statement as to the citizenship and age of its members. If the bidder is a corporation, evidence that the officer signing the bid had authority to do so and a statement as to the state of incorporation shall also be submitted.

(g) *Award of lease.* Following public opening of the bids the Commission, subject to the right to reject any and all bids, will determine the successful bidder. In the event the highest acceptable bids are tie bids, a public drawing will be held by the Commission to determine the successful bidder. After notice of award and prior to expiration of the period prescribed in the invitation, the successful bidder may explore the land or deposit, shall execute and return to the Commission three (3) copies of the lease and shall pay the balance of the bonus unless the bidder chooses to forfeit his deposit. Should the successful bidder fail to execute the lease and pay the balance of the bonus within the time specified in the invitation, or fail to otherwise comply with applicable regulations, he will also forfeit his deposit. In such event the Commission may offer the lease to the second highest acceptable bidder. If the awarded lease is executed by the bidder through an agent, evidence of authorization must be submitted.

(h) *Dating of lease.* A lease issued under this section will ordinarily be effective as of the date it is signed by the Commission.

(i) *Term of lease.* A lease shall be for the period specified in the invitation to bid. When deemed desirable by the Commission it will state in the invitation that the lease term may be extended for a specified period and upon stipulated conditions at the option of the lessee. In such event the lease will include this option.

(j) *Royalty.* Royalty shall be at the rate specified in the invitation to bid.

(k) *Direction of ore shipments.* The lessee shall ship all ore with reasonable diligence to such uranium ore receiving station or purchaser within the United States as the Commission may designate, and shipment shall be at lessee's own expense up to 100 miles. The Commission reserves the right to take and remove all ores not so shipped with reasonable diligence, and to credit the lessee with the value of such ores less sums due the Government from the lessee, including the cost of such taking and removal. The Commission also reserves the property and right to property in and to all ores not shipped within sixty (60) days after the expiration or other termination of the lease. Unless the Commission directs otherwise, all ores which are of too low a grade to be acceptable under the Commission's published price schedule applicable to such ore shall remain on the leased premises and be kept separate from and not mixed with waste.

(l) *Initial production bonus.* Bonus payments under Domestic Uranium Program Circular 6 will not be made on ores produced from properties leased to private operators by the Commission except under special circumstances and as provided for in the lease.

(m) *Work requirements.* A condition of every lease entered into under these regulations will be the conduct on the leased premises of exploration, development, and mining activities with reasonable diligence, and the skill and care required to achieve and maintain maximum production of uranium ore consistent with good and safe mining practice. A lease may require a minimum number of man-shifts during a designated period.

(n) *Lessee's records.* Leases shall provide that the lessee keep proper records of (1) shifts worked; (2) wages and salaries paid; (3) expenditures for supplies and services and costs of operation of every kind; (4) tonnage and grade of ore mined; (5) development work and drilling performed; and (6) such other matters as in the Commission's opinion would be of assistance to it in determining the cost of the operation.

(o) *Rights of Commission.* The Commission reserves the right to enter upon the leased property and into all parts of the mine for inspection and other purposes. The Commission and its contractors shall have free access to the property for conducting exploratory work. The Commission also reserves the right to grant to other persons easements or rights of way upon, through, or in the leased premises. The Commission and the Comptroller General of the United States or any of his duly authorized representatives shall, until the expiration of three years after termination or expiration of the lease, have access to and the right to examine any directly pertinent books, documents, papers, and records of the lessee involving transactions related to the lease.

(p) *Relinquishment of leases.* A lease may be surrendered by the lessee upon filing with and approval by the Commission of a written application for relinquishment. Approval of the application shall be contingent upon the delivery of the leased premises to the Commission in good condition and the continued liability of the lessee to make payment of all royalty and other debts due the Commission.

(q) *Assignment of leases.* Any transfer of a lease, or of any interest therein or claim thereunder, by assignment, sublease, operating agreement or otherwise, will not be recognized unless and until approved by the Commission in writing. Ordinarily the Commission will not approve any transfer of a lease which involves over-riding royalties or deferred payments of any kind.

(r) *Cancellation.* Any lease may be canceled by the Commission whenever the lessee fails to comply with the provisions of the lease. Failure of the Commission to exercise its right to cancel shall not be deemed a waiver thereof.

(s) *Form of lease.* Leases will be issued on forms prescribed by the Commission.

(t) *Non-competitive leases.* Under special circumstances, where the Commission believes it is to the best interest of the Government or where the use of competitive bidding may be impracticable, the Commission at its discretion may award or extend leases on the basis of negotiation.

(u) *Commission decisions.* All matters connected with the issuance and administration of leases will be determined by the Commission whose decisions shall be final and conclusive.

(v) *Definitions.* "Commission" as used in this section means the Atomic Energy Commission established by the Atomic Energy Act of 1954 or its duly authorized representative or representatives.

(w) *Multiple use of lands.* Leases issued under this section shall provide that operations under them will be conducted so as not to interfere with the lawful operations of any third party having a lease, permit, easement, or other right or interest in the premises.

(60 Stat. 755-775: 42 U. S. C. 1801-1819)

APPENDIX 7

Current Commission Unclassified Research Contracts in Physical and Biological Sciences, Raw Materials, and Reactor Development [1]

PHYSICAL RESEARCH CONTRACTS

Chemistry

Alabama, University of. J. L. Kassner and E. L. Grove, A Study of the Principles, Theory and Practice of High Frequency Titrimetry.

Alabama, University of. D. F. Smith, Cryoscopic Determinations in Fused Salt Systems.

Arizona, University of. D. S. Chapin, The Mechanism of the Heterogeneous Low Temperature Ortho Hydrogen Conversion.

Arkansas, University of. E. S. Ames, Electron-Transfer Reactions.

Arkansas, University of. A. Fry, Nuclear Chemistry Research Using Cockcroft-Walton Accelerator.

Arkansas, University of. T. C. Hoering and P. K. Kuroda, Nuclear Geochemistry.

Boston University. L. C. W. Baker, Preparations, Structures, and Properties of Heteropoly Ions.

Boston University. A. H. A. Heyn, Analytical Separations in the Presence of a Large Proportion of Bismuth.

Brooklyn, Polytechnic Institute of. R. B. Mesrobian and H. Morawetz, Study of Radiation Induced Solid State Polymerization.

Buffalo, University of. G. M. Harris, Applications of Isotopes in Chemical Kinetics.

California Institute of Technology. H. Brown, Study of Fundamental Geochemistry of Critical Materials and Development of Economic Processes for Their Isolation.

California Institute of Technology. N. Davidson, Complex Ions and Reaction Mechanisms in Solution.

California, University of. C. S. Garner, Isotope Exchange Reactions.

California, University of. J. H. Hildebrand, Studies in Intermolecular Forces and Solubility.

California, University of. R. L. Scott, Fluorocarbon Solutions.

Carnegie Institute of Technology. T. P. Kohman, Nuclear Chemistry Research.

Catholic University of America. F. O. Rice, The Thermal Production and Identification of Free Radicals.

Chicago, University of. E. Anders, Radiochemical and Geochemical Studies.

Chicago, University of. C. A. Hutchison, Paramagnetic Resonance Absorption.

Chicago, University of. J. E. Mayer, Statistical and Quantum Mechanics of Interacting Atoms.

Chicago, University of. N. Sugarman and A. Turkevich, Operation of Synchrocyclotron.

Chicago, University of. N. Sugarman and A. Turkevich, Nuclear Chemical Research.

Chicago, University of. H. Taube, Reactions of Solvated Ions.

[1] Contracts listed as of November 30, 1956.

Chicago, University of. A. Turkevich, Natural Abundance of Deuterium and Other Isotopes.
Clark University. A. E. Martell, Reactions of Partially-Chelated Metal Ions.
Clark University. T. T. Sugihara, Low Energy Fission of Bismuth.
Clarkson College of Technology. M. Kerker, A Study of the Size and Shape of Colloidal Particles by Light Scattering and Electron Microscopy.
Clarkson College of Technology. H. L. Shulman, The Determination of Interfacial Area in Packed Absorption and Distillation Columns.
Colorado, University of. R. N. Keller, The Scintillation Properties of Coodination Compounds.
Columbia University. P. F. Kerr, Rock Alteration and Uranium Mineralization.
Columbia University. J. L. Kulp, Helium in the Atmosphere and Lithosphere.
Columbia University. J. L. Kulp, Isotope Geology of Uranium and Lead.
Columbia University. V. K. LaMer, Fundamental Investigation of Phosphate Slimes.
Columbia University. J. M. Miller, Research in the Field of Radiochemistry.
Columbia University. R. M. Noyes, Photochemical Reactions of Iodine.
Columbia University. T. I. Taylor, Separation of Isotopes by Chemical Exchange.
Connecticut, University of. R. Ward, Tracer Element Distribution between Melt and Solid.
Cornell University. R. Bersohn, Gradient of the Electric Field in Ionic Crystals.
Cornell University. R. M. Diamond, Studies of Ion Exchange Resin and Solvent Extraction Mechanisms.
Cornell University. F. A. Long, Kinetic and Equilibrium Salt Effects.
Delaware, University of. R. L. Pigford, Thermal Diffusion in Liquids.
Duke University. H. A. Strobel, Ion Exchange in Polar Nonaqueous Solvents.
Duquesne University. N. C. Li, Solution Chemistry of Metal Complexes.
Emory University. A. L. Underwood, Anion Analysis by Infrared Spectrophotometry.
Florida State University. R. E. Johnson, Exchange Between Labeled Halogens and Certain Inorganic Halides.
Florida State University. R. H. Johnsen, Radiation Induced Effects in Heterogeneous Organic Systems.
Florida State University. R. Sheline, Search for Long-Lived Radioactivities; Theoretical Nuclear Studies.
Florida, University of. G. B. Butler and A. H. Gropp, Studies in the Preparation and Properties of Quaternary Ammonium Ion Exchange Resins.
Fordham University. M. Cefola, Studies of Formation of Complexes by Thenoyltrifluoroacetate and Other Chelating Agents.
Harvard University. C. Frondel, Synthesis of Uranium and Thorium Minerals.
Howard College. J. A. Southern, Cyclotron Research.
Illinois Institute of Technology. M. L. Bender, Correlation of Isotopic Effect on Reaction Rate with Reaction Mechanism.
Illinois Institute of Technology. G. Gibson, Fundamental Chemistry of Uranium.
Illinois Institute of Technology. H. E. Gunning Decomposition of Organic Molecules by Metal-Photosensitization.
Illinois, University of. H. G. Drickamer, The Mechanism of Molecular Motion as Determined from Diffusion and Thermal Diffusion Measurements.
Illinois, University of. R. H. Herber, Isotopic Exchange Reactions in Ion Aqueous Solvents.
Illinois, University of. P. E. Yankwich, Studies in Radiochemistry.
Indiana University. L. L. Merritt, Study with Radioactive Tracers.
Indiana University. W. J. Moore, Rate Processes in Inorganic Solids at High Temperatures.

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Indiana University. J. S. Peake, Study of Inorganic Salts at High Temperatures.
Indiana University. W. B. Schaap and F. C. Schmidt, Electrochemical Research in Amine Solvents.
Iowa, State University of. L. Eyring, Preparation of Rare Earth Oxides.
Iowa, State University of. K. Kammermeyer, Separation of Gases by Diffusion Through Permeable Membranes.
John Hopkins University. W. S. Koski, Nuclear Chemistry Studies.
Kansas State College. R. E. Hein, Labeled Chemical Species Produced by Neutron Irradiation of Phosphorous Trichloride and Related Compounds.
Kansas, University of. P. W. Gilles, High Temperature Research.
Kansas, University of. P. W. Gilles, Hot Laboratory Assistance.
Kansas, University of. J. Kleinberg and E. Griswold, Some Problems in the Chemistry of Low Oxidation States of Metals.
Kansas, University of. F. S. Rowland, The Chemical Reactions of Energetic Recoil Atoms.
Kentucky Research Foundation. A. W. Fort, Rearrangement in the 3-Phenyl-1-butyl-1-14C.
Little, Inc., Arthur D. G. A. Bleyle, Study of Deuterium Separation.
Louisville, University of. R. H. Wiley, The Synthesis and Properties of Ion Exchange Resins.
Louisville, University of. R. H. Wiley, Radiation Chemistry of Organic Compounds.
Maryland, University of. E. R. Lippincott, Raman Spectra of Colored and Absorbing Substances.
Maryland, University of. E. A. Mason, Thermal Diffusions in Gases.
Massachusetts Institute of Technology. A. M. Gaudin, Techniques in Mineral Engineering.
Massachusetts Institute of Technology. P. M. Hurley, Investigations of Isotopic Abundances of Strontium, Calcium and Argon in Certain Minerals.
Massachusetts Institute of Technology. C. D. Coryell, D. N. Hume, J. D. Sheehan, and C. G. Swain, Nuclear Chemistry Research.
Massachusetts Institute of Technology. T. K. Sherwood, Mechanism of Mass Transfer to Drops.
Michigan State University. C. H. Brubaker, Investigations into Aperiodic Oxidation States.
Michigan State Unversity. C. H. Brubaker, Studies of Certain Complex Compounds of Platinium.
Michigan State University. J. L. Dye, Thermodynamic Investigation of Dilute Solutions of the Alkali Metals in Liquid Ammonia.
Michigan State University. M. T. Rogers, A Physico-Chemical Investigation of Interhalogen Compounds.
Michigan, University of. R. B. Bernstein, Fundamental Research on Isotopic Reactions.
Michigan, University of. P. J. Elving, Polarographic Behavior of Organic Compounds.
Michigan, University of. W. W. Meinke, Nuclear Chemical Research.
Michigan, University of. E. F. Westrum, Low Temperature Chemical Thermodynamics.
New Hampshire, University of. A. R. Amell, The Beta Decay of Carbon 14 in Doubly Labelled Ethane in the Presence of Methyl Amine.
New York State College for Teachers. O. E. Lanford, Concentration of Nitrogen 15 by Chemical Exchange.
North Carolina State College. F. P. Pike, Performance of Contactors for Liquid-Liquid Extraction.

North Carolina, University of. K. Knox, The Preparation and Properties of Compounds of Technetium and Rhenium.
Northwestern University. M. Dole, The Mechanism of High Energy Radiation Effects on Polyethylene.
Northwestern University. R. G. Pearson and F. Basolo, Mechanism of Substitution Reactions of Inorganic Complexes.
Notre Dame, University of. M. Burton, Radiation Chemistry Studies.
Ohio State University. R. J. Kline, The Reactions of Uranium with Solutions of Ammonium Salts in Liquid Ammonia.
Oklahoma Agriculture & Mining College. E. M. Hodnett, The Isotope Effect in the Study of Chemical Reactions.
Oklahoma Agriculture & Mining College. T. E. Moore, The Separation of Inorganic Salts by Liquid-Liquid Extraction.
Oklahoma, University of. J. R. Nielsen, Spectroscopic Properties of Fluorocarbons and Fluorinated Hydrocarbons.
Oregon State College. T. H. Norris, A Study of Generalized Acid-base Phenomena with Radioactive Tracers.
Oregon, University of. D. F. Swinehart, Study of Gaseous Chemical Reaction Kinetics, Using a Mass Spectrometer.
Pennsylvania State University. T. F. Bates, An Investigation of the Mineralogy and Petrography of Uraniferous Shales and Lignites.
Pennsylvania State University. W. C. Fernelius, Stabilities of Coordination Compounds and Related Problems.
Pennsylvania State University. B. F. Howell, Studies of the Dielectric Constant of Rocks and Minerals.
Pennsylvania State University. C. R. Kinney, An Investigation of the Chemical Nature of the Organic Matter of Uraniferous Shales.
Pennsylvania State University. W. W. Miller, Chemical Reactions Induced in Condensed Systems by B-decay.
Pennsylvania State University. R. P. Seward, Chemical Properties of Fused Sodium Hydroxide.
Pennsylvania State University. H. D. Wright, Mineralogy of Uranium-Bearing Deposits in the Boulder Batholith, Montana.
Pennsylvania, University of. J. O'M. Brockris, A Study of the Structure of Molten Salts and Silicates.
Pittsburgh, University of. H. Freiser, The Development of Organic Reagents for Use in Inorganic Analysis.
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Johns Hopkins University. L. S. Maynard, A Study of Metabolism and Active Transport of Certain Divalent Metals in Tissues and In Isolated Mitochondria, with Special Attention to the Possible Role of Complexing Agents in These Processes.

Johns Hopkins University. W. H. Price, The Mechanism of the Activation of Latent Epidemic Typhus Infections in the Laboratory Animals and In Humans by Cortisone and X-ray.

Kansas, University of. Max Berenbom, Biochemical Studies into the *in vivo* Effects of Radiation on Mammalian Nucleic Acids.

Kansas, University of. F. E. Hoecker, Investigation of Organic Substances Tagged with Iodine 131 by Human Thyroid Gland *in vivo.*

Kresge Eye Institute (Detroit). V. E. Kinsey, Effects of Neutrons and Other Radiations on the Ocular Lens.

Lovelace Foundation for Medical Education and Research (Albuquerque, N. Mex.). W. R. Lovelace II, *et al,* Indirect Blast Injuries.

Massachusetts Eye and Ear Infirmary (Howe Laboratory of Ophthalmology). J. H. Kinoshita, A Study of the Metabolism of the Ocular Lens with the Use of Radioactive Compounds.

Massachusetts Eye and Ear Infirmary. William Stone, Jr., Study of the Healing of Corneal Wounds, with Special Reference to the Plastic Artificial Cornea.

Massachusetts General Hospital. G. L. Brownell, Positron Scanning in Organs Other than Brain.

Massachusetts General Hospital. Oliver Cope and J. B. Stanbury, Effects of Radioactive Iodine on Biology of the Thyroid Gland.

Massachusetts General Hospital. H. L. Hardy, Establishment of a Beryllium Case Registry.

Massachusetts General Hospital. J. B. Stanbury, The Metabolism of Calcium and Strontium as Disclosed by Tracer Studies on Patients with Thyroid and Related Diseases.

Massachusetts General Hospital. W. H. Sweet, The Use of Thermal and Epithermal Neutrons in the Treatment of Neoplasms.

Massachusetts General Hospital. W. H. Sweet, External Localization of Brain Tumors Employing Positron-Emitting Isotopes.

Massachusetts General Hospital. P. C. Zamecnik and I. T. Nathanson, A Biochemical Study of the Effects of Radiation on Cells.

Massachusetts Memorial Hospitals. Charles Emerson, Physiological and Therapeutic Investigations and Fundamental Blood Studies Using Radioactive Isotopes.

Meharry Medical College. Horace Goldie, Effect of X and Beta Irradiation on Free Growth of Malignant Cells and on Organized Malignant Tumors, and Effect of Pretreatment with Biological and Chemical Agents.

Meharry Medical College. P. F. Hahn, Use of Radioactive Gold in Treatment of Tumors.

Meharry Medical College. C. W. Johnson, Autoradiographic Study of the Distribution of Ag^{111} in the Rat Following Administration by Various Routes.

The Methodist Hospital, The Texas Medical Center (Houston). H. C. Allen, Jr., A Pilot Study on the External Localization of Intracranial Lesions.

Miami, University of. A. L. Chambers. A Quantitative Study of The Effects of Radiation on the Blood Capillaries of Normal Animals.

Miami, University of. S. A. Gunn, A Study of Factors Affecting the Selective Uptake and Retention of Zinc 65 by the Dorsolateral Prostate of the Rat, and a Study of the Role of Zinc in the Physiology of the Prostate.

Michigan, University of. I. A. Bernstein, Effects of Radiation on the Intermediary Metabolism of Mammalian Skin.

Michigan, University of. A. B. French, Effect of Irradiation on the Pituitary Adrenal Axis.

Michigan, University of. H. J. Gomberg, Studies with an X-ray Monochromator and X-ray Irradiation Service Operation.

Michigan, University of. F. J. Hodges and Isadore Lampe, Clinical Evaluation of Teletherapy.

Michigan, University of. W. J. Nungester, Immunological Study of Tumors.

Michigan, University of. R. L. Potter. The Biological Effects of Radiation.

Minnesota, University of. W. D. Armstrong and W. O. Caster, Effect of Ionizing Radiation upon Tissue Metabolism.

Minnesota, University of. L. A. French and S. N. Chou, Study of Mechanisms of Radioactive Isotopic Localization in Tissues of the Central Nervous System.

Minnesota, University of, Medical School. Bruce Jarvis and J. G. Brunson, The Effects of Gram Negative Bacterial Endotoxin on Irradiated Rabbits.

Minnesota, University of, Medical School. C. W. Lillehei, 1. Investigations Upon the Simultaneous Determination of Both Red-Cell and Plasma Volume Using a Single Radio-Tracer Element (Chromium 51); 2. Investigations Upon the Regional Pooling of Blood in Shock Utilizing Tracer Methods; 3. Observations on Cross Circulation and Irradiation Death.

Minnesota, University of. J. F. Marvin and F. J. Lewis, Toxic Effects of Irradiation.

Minnesota, University of. Samuel Schwartz, Studies on the Relationships of Porphyrin, Tumors, and X-rays.

Minnesota, University of. C. J. Watson. Investigation of Porphyrin and Bile Pigment Metabolism.

Montefiore Hospital (Pittsburgh, Pa.). Richard Abrams, Synthesis of Nucleic Acid Purines in Bone Marrow.

Montefiore Hospital for Chronic Diseases (New York City). Daniel Laszlo, A Study of the Distribution and Excretion of Lanthanum and the Rare Earth Elements.

Montefiore Hospital for Chronic Diseases (New York City). Daniel Laszlo, Dynamics of Strontium Distribution in the Body.

Nebraska, University of. W. J. Arnold, Effects of Cranial X-irradiation on Psychological Processes in Rats.

New England Center Hospital. William Dameshek, Physiopathology of Platelets and Development of Platelet Substitutes.

New England Deaconess Hospital. S. P. Hicks, The Effects of Ionizing Radiation on the Developing Mammalian Nervous System.

New England Deaconess Hospital. Shields Warren, Acute and Chronic Radiation Injury.

New York University, Bellevue Medical Center. Bernard Altshuler, The Distribution and Persistence of Radioactive Aerosols in the Lungs of Animals.

New York University, Bellevue Medical Center. J. M. Converse, The Transfer of Cellular Antibodies in Relation to the Immunological Aspects of the Homograft Rejection Reaction.

New York University, Bellevue Medical Center. Marvin Kuschner, Tissue Reactions to Intrapulmonary Radiation.

New York University, Bellevue Medical Center. Norton Nelson, Aerosol Retention Studies.

New York University, Bellevue Medical Center. Norton Nelson, Immunochemical Studies on Beryllium.

New York University, Bellevue Medical Center. H. W. Smith, Body Fluid and Electrolyte Distribution and Collateral Physiological Studies.

New York University, Bellevue Medical Center. Marion B. Sulzberger, Study of the Biological Effects of Ionizing Radiation (Alpha and Beta) on Human Skin.

New York University Post Graduate Medical School. C. J. Umberger, Determination of the Variable Concentrations of Trace Elements in Human Tissue and Body Fluids.

New York, Research Foundation of State University of. J. H. Ferguson and M. F. Hilfinger, Experimental Transfusion of Bone Marrow into Rabbits after Total Body Irradiation.

New York, Research Foundation of State University of. Jack Gross, The Metabolism of Radioactive Thyroid Hormones in Tumor Bearing Animals and Tumor Tissue.

New York, Research Foundation of State University of. Albert Hirschman, Effects of Irradiation on the Calcifying Mechanisms of Epiphyseal Cartilage.

New York, State University of, Upstate Medical Center. Alfred Farah, Changes in Protein-Bound Sulfhydryl in Renal Cells Under Varying Experimental Conditions.

North Carolina, University of. B. G. Stall III, A Study of Ion Transport Across Smooth Muscle Cell Membrane.

North Carolina, University of. C. D. Van Cleave, The Double Isotope Effect of Calcium 45 and Strontium 89 on the Pattern of Distribution in the Body, Particularly in Bone.

North Dakota, University of. W. E. Cornatzer, A Study of Methionine as a Source of Methyl and Sulfur in Intermediary Metabolism.

Northwestern University Medical School. Chiadao Chen, Synthesis and Metabolic Studies of Rings A and/or B Labeled Estradiol and Related Compounds.

Northwestern University Medical School. D. P. Earle, The Effects of Irradiation on Renal Transport Systems.

Nuclear Science and Engineering Corp. (Pittsburgh). Abraham Edelmann, A Toxic Substance Produced by Irradiation.

Oklahoma Medical Research Foundation. L. P. Eliel, Characterization of Changes in the Growth Rate of Human Neoplasms Using Radioactive Isotopes.

Oklahoma Medical Research Foundation. C. D. Kochakian, Metabolism of Radioactive Sex Hormones.

Oklahoma Medical Research Foundation. C. D. Kochakian, Androgen Regulation of the Incorporation of Radioactively Labeled Amino Acids into Tissues.

Oregon, University of, Medical School. E. E. Osgood and A. J. Seaman, Studies of Hemic Effects of Radioisotopes, X-rays and of Adrenocortical Hormones.

Oregon, University of, Medical School. J. T. Van Bruggen, Studies on Lipogenesis.

Parke, Davis and Co. (Detroit). J. K. Weston, Factors Elaborated by Animal Tissues which Stimulate Rate of Regeneration of Hematopoietic Organs of Animals Exposed to Total Body Irradiation with Gamma Rays.

Pennsylvania, University of. H. L. Conn, Jr., Kinetics and Mechanisms of Ion Transfer in the Heart; and, Studies of Altered Cardiovascular Physiology in Cardiovascular Disease States.

Pennsylvania, University of. G. M. Austin, F. C. Grant, An Investigation of the Use of Sodium 24, in Cerebral Edema, Brain Tumors, and Focal Epileptic Lesions.

Peter Bent Brigham Hospital (Boston). F. D. Moore, Injury, Wounding and Convalescence; A Study by Isotopic and Metabolic Methods.

Philadelphia General Hospital. H. P. Schwarz, The Effect of X-ray Radiation of the Lipids of the Skin.

Pittsburgh, University of. L. V. Beck, Attempted Modification of Mammalian Tumor Radiosensitivity with Agents and Procedures Altering Host Sensitivity.

Pittsburgh, University of, School of Medicine. F. J. Dixon, The Study of the Effects of Radiation on the Immune Response.

The Retina Foundation (Boston). M. A. Jakus, A Comparison of the Fine Structure of the Normal and the Irradiated Lens.

Rheumatic Fever Research Institute (Chicago). R. W. Schayer, Metabolism of Biologically Active Amines.

Rochester, University of. G. B. Forbes, Metabolism of Bone Sodium.

Rochester, University of, School of Medicine and Dentistry. L. H. Hempelmann, Individual Response to Ionizing Radiation in Animals and Patients.

The Saranac Laboratory (Saranac Lake, N. Y.). G. W. H. Schepers, Studies on the Experimental Pathology and Biochemistry of Pulmonary Granulomatosis.

Setón Hall University (South Orange, N. J.). E. V. Brown, Metabolism of a New Carcinogen Using Radioactive Carbon.

Sloan Kettering Institute for Cancer Research, Memorial Hospital, (New York City). C. P. Rhoads, *et al.*, Biological Effects of Radiation, and Related Bio-Chemical and Physical Studies.

Southern California, University of, School of Medicine. W. E. Goodwin, Intracavitary Application of Beta Sources.

Southern California, University of. P. D. Saltman and E. M. Butt, The Mechanism of Ion Secretion.

Southwestern Medical School, University of Texas (Austin). W. W. Burr, D. S. Wiggans and H. W. Rumsfeld, Jr., The Metabolism of Doubly Labeled Serum Albumin.

Southwest Foundation for Research and Education (San Antonio). N. T. Werthessen, Investigation of the Production and the Possible Isolation of Substances Capable of Stimulating Recovery from Radiation by Utilizing Techniques of *in vitro* Maintenance of Spleen and Other Organs.

Stanford University (Palo Alto, Calif.). H. S. Kaplan and E. L. Ginzton, Biological and Medical Investigations with the 70 Mev Linear Electron Accelerator.

St. Louis University. Henry Pinkerton, Study of the Relation of Rickettsial and Viral Infections to Radiation Injury.

St. Luke's Hospital (New York City). E. H. Reisner, Jr., Isotopic Labeling of Blood Platelets.

Tennesse, University of. N. R. DiLuzio, The Response of the Reticulo-Endothelial System to X-irradiation.

Tennessee, University of. Aaron Ganz, Factors Influencing the Distribution of Intravenously Administered Radiogold Colloids.

Tennessee, University of. W. M. Hale, A Study of the Effects of Cobalt 60 Gamma Irradiation on Infection and Immunity.

Tennessee, University of. R. E. Koeppe, The Metabolism of Serine in the Intact Rat.

Tennessee, University of. R. R. Overman, Physiology of Water and Ionic Balance in Monkeys Subjected to Whole Body Radiation.

Tennessee, University of. R. R. Overman, Protective Action of Bone-Marrow Perfusates and Thiouronium Compounds in Irradiated Monkeys.

Tennessee, University of. J. D. Perkinson, Jr., Effect of Internal Irradiation on Cellular Metabolism.

Tennessee, University of. Lester Van Middlesworth, Studies in Iodide Metabolism.

Tennessee, University of. J. L. Wood, The Origin and Fate of Thiocyanate Ion.

Texas Technological College. S. J. Kaplan, The Effects on Rat Behavior of Development Aberrations Induced by Ionizing Radiation *in utero.*

Texas, University of, M. D. Anderson Hospital and Tumor Institute (Houston). W. K. Sinclair, Physical and Radiobiological Investigations with 22 Mev X-rays and Electrons, as Compared with Cobalt 60 and 250Kv X-rays.

Tufts College Medical School. W. C. Moloney and F. H. L. Taylor, Investigation of Enzymic, Biochemical and Other Cytological Activities of Human Leukocytes.

Tufts College. David Rapport, Study of the Effects of Radiation on Growth.

Tufts College. Richard Wagner, Enzyme Studies on White Blood Cells and Blood Platelets.

Tulane University of Louisiana. R. H. Turner, Physiology of Serum Lipids.

Utah, University of. M. M. Wintrobe and G. E. Cartwright, Metabolism of Trace Elements in Animals and Man with Special Reference to Their Role in Erythropoiesis.

Utah, University of. S. R. Dickman, The Pathways of Glucose Oxidation in the Pancreas.

Vanderbilt University, School of Medicine. M. T. Bush, Metabolic Fate of Barbituric Acid Anesthetics with Special Reference to Evipal.

Vanderbilt University, School of Medicine. W. J. Darby, Study of the Absorption and Metabolism of Lipids and Vitamins and the Alterations which Occur in Acute Radiation Injury.

Vanderbilt University. G. W. Meier, Fetal Irradiation and the Patterns of Behavior Development.

Virginia, University of, Medical School. C. L. Gemmill, The Metabolic Exchange of Radioactive Isotopes in Isolated Cell Systems.

Virginia, Medical College of. H. G. Kupfer and N. F. Young, An Investigation of Certain Tissue Protein Changes in Irradiated Animals.

Wake Forest College—Bowman Gray School of Medicine. Camillo Artom, Formation of Tissue Phospholipides and Toxicity of Phosphorus 32 as Related to Dietary Factors.

Washington University (St. Louis, Mo.). David Lipkin, Synthesis of Nucleotides and Related Compounds.

Washington, University of (Seattle, Wash.). C. A. Finch, Erythropoiesis and Iron Metabolism.

Washington, University of (Seattle, Wash.). B. W. Gabrio and F. M. Huennekens, Enzymatic Components and Physiological Function in the Erythrocyte.

Washington, University of (Seattle, Wash.). R. L. Huff, Hemodynamics; Blood Dynamics as Measured by Simultaneous Multiple Port Scintillation Detection of Iodine 131 Human Serum Albumin.

Washington, University of (Seattle, Wash.). R. H. Williams and H. H. Tomizawa, Studies of Isotopically Labeled Hormones.

Wayne University, College of Medicine. J. E. Lofstrom, Studies on the Effects of Maternally Administered Phosphorus 32 on Foetal and Post-Natal Development of the Rat.

Wayne University. J. E. Lofstrom, Evaluation of Radioactive Isotope Gamma Ray Source for Medical Teletherapy.

Western Reserve University. B. M. Dobyns, A Study of the Physiological Function and Histological Changes of Thyroids Irradiated with Radioactive Iodine.

Western Reserve University. Hymer Friedell, Investigations of the Biological Effects of Internally Deposited Radioisotopes and Related Radio-Biology Studies.

Western Reserve University. L. O. Krampitz, Synthesis of Nucleic Acids by *Escherichia coli* and Bacteriophage Systems.

Western Reserve University. H. G. Wood, A Study of Intermediary Metabolism with Isotopically Labeled Compounds in Perfused Organs, Whole Animals, and Humans.

West Virginia University, School of Medicine. R. F. Krause, Investigation into the Uptake of Phosphorus by the Tissues of the Rat as Influenced by Carotene-Vitamin A Metabolism.

Wisconsin, University of. H. F. Harlow and P. H. Settlage, The Effect of Various Forms of Irradiation of the Brain on Learned and Unlearned Behavior of Monkeys and Chimpanzees.

Worcester Foundation for Experimental Biology (Shrewsbury, Mass.). Gregory Pincus, Investigation of the Effects of Radiation on the Biosynthesis and Metabolism of Adrenocortical Steroids.

Yale University, School of Medicine. C. E. Carter, Phosphorylation Mechanisms in Nucleic Acid Synthesis in Hematopoietic Tissue.

Yale University, School of Medicine. J. W. Hollingsworth, Investigation of Rapid Freezing of Bone Marrow and Spleen, and Their Radioprotective Value.

Yale University. S. R. Lipsky, The Formation and Utilization of the Saturated and "Essential" Fatty Acids in the Biosynthesis of Various Lipids in Man.

Yerkes Laboratory of Primate Biology, Inc. (Orange Park, Fla.). H. W. Nissen, Behavioral Effects of Ionizing Radiation on Chimpanzees of Various Ages.

Radiation Instrumentation

Airborne Instruments Laboratory, (Mineola, Long Island, N. Y.). K. C. Speh, Automatic Scanning of Nuclear Emulsions.

Allen B. DuMont Laboratories, Inc., (Clifton, N. J.). Stanley Koch, Photomultiplier Tube Development.

Armour Research Foundation of the Illinois Institute of Technology. Leonard Reiffel, Detection of Airborne Beryllium Dust.

Army, U. S. Department of, Corps of Engineers (Fort Belvoir, Va.). N. F. Blackburn, Program of Research and Development on Scintillation Crystals.

The Borden Company, Philadelphia Research Laboratory. B. D. Halpern, Development of Plastic Scintillators.

Levinthal Electronic Products, Inc., (Redwood City, Calif.). W. J. Van Sciver, Study of Scintillation and Other Related Properties of Sodium Iodide Crystals.

Louisville, University of. R. H. Wiley, Synthesis and Properties of Organic Scintillators.

National Bureau of Standards, U. S. Department of Commerce. Scott Smith, Evaluation and Testing of Radiation Instruments.

National Bureau of Standards, U. S. Department of Commerce. Louis Costrell, Radiation Monitoring Systems.

National Bureau of Standards, U. S. Department of Commerce. W. A. Wildhack, Basic Instrumentation Program.

New England Center Hospital, Pratt Diagnostic Clinic. C. V. Robinson, Small GM and Proportional Counters for Medical Research.

New York University, Washington Square College. M. H. Shamos and S. Z. Lewin, Investigation of Certain Physical and Chemical Dosimetric Techniques.

Notre Dame, University of. E. A. Coomes, Fundamental Research on Photoemission.

Pilot Chemicals, Inc., (Waltham, Mass.). Mark Hyman, Jr., Research and Development Work on Plastic Scintillators Containing High Z Materials.

Radio Corporation of America, RCA Laboratories, (Princeton, N. J.). G. A. Morton, Photomultiplier Tube Research and Development.

St. Procopius College, (Lisle, Ill.). F. R. Shonka, Special Problems in Nuclear Instrumentation

Special Training

Duke University. E. I. Gray, Radiation Biology Course for High School Teachers.
Harvard University, Graduate School of Education. A. K. Solomon and Fletcher Watson, Intensive Summer Program Devoted to Furthering the Scientific Education of High School Teachers with Particular Emphasis on the Use of Radioactive Materials.
New Mexico, University of. S. D. Aberle and John Harty, Radiation Biology Course for High School Teachers.

RAW MATERIALS RESEARCH CONTRACTS

Colorado School of Mines Research Foundation. Fred L. Smith, Determine Solvent or Precipitation Reaction of Sufficient Magnitude to Effect Localization of Uranium Deposits.
Columbia University. H. D. Hassialis, Recovery of Uranium from the Chattanooga Shale.
Dow Chemical Co. W. Kirschkind and R. H. Bailes, Solvent Extraction Techniques for Recovery of Uranium from Ores.
Isotopes, Inc. H. L. Volchok, Development of Radiometric Assaying Method for Uranium Ores not in Equilibrium.
Minnesota, University of. J. W. Gruner, Mineralogic and Petrographic Nature and Genesis of Uranium Ores in the Western United States.
Minnesota, University of. Harold W. Mooney, Investigations of Spontaneous Electrical Potentials as Related to Geophysical Exploration for Uranium.
National Lead Co., Inc. J. S. Breitenstein, Process Development Studies on the Recovery of Uranium from its Ores.
Nevada, University of. V. E. Scheid, Development Studies on the Beneficiation of Uranium Ores, and Extractive Metallurgy for Recovery of Uranium from Ores.
New Mexico, University of. Dr. Vincent C. Kelley,[2] Studies of Regional Fracture Patterns in Relationship to Uranium Deposits of the Colorado Plateau and Adjacent Areas.
Pennsylvania State University. Harold Wright, Research on Trace Quantities of Uranium in Sulfides of Veins.

REACTOR DEVELOPMENT RESEARCH CONTRACTS

Arcos Corp. R. D. Thomas, Jr., Welding of Specialized Reactor Materials.
Armour Research Foundation. H. B. Karplus, Measurement of Sound Velocity in a Liquid Containing Gas Bubbles.
Armour Research Foundation. F. B. Forzel, Study of Reactor Containment.
Army Ordnance Corps. Joe Sperraza, Safety Design Requirements of Reactor Retaining Structures.
California, University of. Dr. W. J. Kaufman and Dr. Gerhard Klein, Disposal of Radioactive Wastes into the Ground.
California, University of. R. K. Forster, Study of the Dynamics of Vapor Bubbles and on Boiling Heat Transfer.
Carnegie Institute of Technology. Robert B. Beckmann, Thermal and Hydraulic Studies at High Reynolds Numbers.
Columbia University. Charles F. Bonilla, Boiling and Condensing of Liquid Metals.

[2] Contract with Dr. Kelley personally.

Ford Instrument Co. Theodor Jarvis, Application of Digital Techniques to Reactor Control Systems.

Harvard University. Dr. Leslie Silverman, Air Cleaning Research and Development.

Harvard University. Prof. H. A. Thomas, Jr., Mechanisms of Dilution of Radiocontaminants in Surface Waterways.

Illinois, University of. Dr. H. F. Johnstone, Investigation of Fundamental Properties of Aerosols as Related to Air Cleaning.

Johns Hopkins University. Dr. Walter A. Patrick, Separation and Fixation of Specific Isotopes from Radioactive Wastes.

Johns Hopkins University. Dr. Charles E. Renn, Ultimate Disposal of Radioactive Wastes to the Natural Environment.

Kentucky, University of. Joseph P. Hammond, Study of Zirconium-base Alloys for Air Exposure at High Temperature.

Massachusetts Institute of Technology. Dr. Rolf Eliassen, Decontamination of Radioactive Liquid Wastes.

Michigan, University of. Dr. L. E. Brownell, Industrial Utilization of Fission Products.

Minnesota, University of. Herbert S. Isbin, Two-phase Heat Transfer Studies to Steam-Water Flows.

National Academy of Sciences. Drs. R. J. Russell and W. Thurston, Disposal of Radioactive Wastes into Surface and Subsurface Geologic Structures.

Naval Bureau of Ordnance. E. C. Noonan, Damage from the Excursion of Nuclear Reactors.

Northwestern University. Dr. Carlos G. Bell, Study of Waste Disposal Dilution Factors in the Des Plaines River and Chicago Drainage Canal.

Pennsylvania State University. Prof. Joseph Marin, Stresses at Nozzle Connections of Pressure Vessels.

Purdue Research Foundation. Dr. A. Sesonske, Free Convection and Natural Circulation Heat Transfer Variables in Ordinary Fluids Containing Volume Heat Sources.

Rensselaer Polytechnic Institute. Prof. Paul Harteck, Operation of a Modified Distillation-Diffusion Apparatus in the Separation of Isotopes of Metals and a Study of the Reaction Rates of Gases Under Pile Irradiation.

Texas, University of. Dr. E. Gloyna, Storage of Radioactive Wastes in Salt Formations.

Yale University. Prof. R. H. Bretton, Research on Effect of Radiations from Fission Products, Particularly Gamma Radiation on Chemical Reactions.

U. S. Bureau of Mines. R. C. Corey, Incineration of Radioactive Wastes. To Develop a Practical Incinerator for Disposal of Solid Combustible Radioactive Wastes.

U. S. Weather Bureau. H. A. Thomas, Jr., Research on the Dispersal of Atmospheria Wastes Which May Be of Practical Use in the Location, Design and Operation of Nuclear Energy Facilities.

APPENDIX 8

Production and Utilization Facility Licenses Applied For and Issued

New applications were received as follows:

Yankee Atomic Electric Company, Boston, Mass., for construction and operation of a power reactor at a site on the Deerfield River near Rowe, Mass. The proposed facility is a pressurized water reactor and is designed to operate at 134,000 electrical kilowatts. The entire electrical output of this facility will be sold to 12 utilities serving the New England area.

Aerojet-General Nucleonics, San Ramon, Calif., for construction and operation at its San Ramon site of three 100-milliwatt nuclear reactors for ultimate sale or lease to properly licensed institutions.

Aerojet-General Nucleonics, San Ramon, Calif., for construction and operation at its San Ramon site of five additional 100-milliwatt nuclear reactors for ultimate sale or lease to properly licensed institutions.

Aerojet-General Nucleonics, San Ramon, Calif., for a license to transfer its AGN–201, Serial #100 reactor to the parent company, Aerojet-General Corp., Azusa, Calif. *Aerojet-General Corp.* in turn applied for a license to acquire, possess and operate the above-described reactor, with no changes in operating personnel and no physical transfer of the reactor involved. *Aerojet-General Corp.* also applied for a license to transfer the AGN–201, Serial #100 reactor, complete with core, to the U. S. Naval Postgraduate School, Monterey, Calif.

Curtiss-Wright Corp., Clifton, N. J., for construction and operation of a 1,000-kilowatt, light water moderated, pool-type research reactor at Quehanna, Pa. The facility will be used in research and development work in both military and civilian applications of atomic energy.

Daystrom, Inc., Elizabeth, N. J., for construction and operation of an "Argonaut"-type research reactor near Princeton, N. J. This is the prototype of a reactor which the applicant plans to produce in quantity for sale to licensed institutions.

General Atomic Division of General Dynamics Corp., San Diego, Calif., for construction and operation of a critical experiment facility at Torrey Pines Mesa in the city and county of San Diego, Calif. The facility will be used for research and development leading to the design, construction and operation of a research reactor by the applicant.

The Glenn L. Martin Company, Baltimore, Md., for construction and operation of a critical experiment facility at Middle River, Md. The facility will be used initially to conduct experiments relating to fuel element assemblies for a heterogeneous, pressurized water reactor which Glenn L. Martin proposes to construct.

The National Advisory Committee for Aeronautics, Washington, D. C., for construction and operation of a 60-megawatt research reactor near Sandusky, Ohio.

The U. S. Naval Postgraduate School, Monterey, Calif., to acquire and operate at Monterey the AGN–201, Serial #100 research reactor. The facility will be used in the school's program for the education of officers in nuclear engineering and allied fields.

In addition to the above, the following applications involving export transactions were received:

ACF Industries, Inc., New York, N. Y., for an export license to cover shipment of a 5-megawatt, tank type, heavy water cooled and moderated research reactor to Comitato Nazionale per le Ricerche Nucleari, Italy.

AMF Atomics, Inc., New York, N. Y., for an export license to cover shipment of a 1-megawatt pool-type research reactor to Laboratorium fur Technische Physik der Technischen Hochschule Munchen, Munich, Federal Republic of Germany.

AMF Atomics, Inc., New York, N. Y., for an export license to cover shipment of a 10-kilowatt light-water moderated pool-type reactor to the Ministry of Education, Kingdom of the Netherlands. The reactor is to be erected at the International Exhibition "Het Atoom" in Amsterdam under the auspices of the Laboratorium Voor Chemische Werktuigen der Technische Hogeschool (Delft Institute of Technology).

Marubeni-Iida Co. (New York), Inc., New York, N. Y., for an export license to cover shipment of one 50-kilowatt homogeneous solution-type research reactor (manufactured by Atomics International, a division of North American Aviation Inc.) to the Japan Atomic Energy Research Institute, Tokyo, Japan. An export license was issued on November 2, 1956.

The Babcock and Wilcox Company, New York, N. Y., for an export license to cover shipment of a 5-megawatt, pool-type, light water moderated research reactor to Conselho Nacional de Pesquisas do Brazil, for Comissao de Energia Atomica, University of Sao Paulo, Sao Paulo, Brazil. A notice of proposed issuance of the export license was published in the *Federal Register* on January 4, 1957.

Actions on facility license applications were taken as follows:

Power Reactor Development Co., Detroit, Mich., was granted a provisional construction permit on Aug. 4, 1956, authorizing construction at Lagoona Beach, Monroe County, Michigan, of a nuclear power reactor having an electrical capacity of 100,000 kilowatts.

Aerojet-General Nucleonics, San Ramon, Calif., was issued a construction permit on August 16, 1956, authorizing construction at its San Ramon site of a self-contained nuclear reactor designed to operate at a power level of 100 milliwatts. On October 9, 1956, AGN was granted a license to operate the completed facility. AGN was also granted a special nuclear material license allocating 1 kilogram of uranium 235 contained in uranium enriched to 20 percent in uranium 235 for the fabrication of core assemblies for the reactor.

AMF Atomics, Inc., New York, N. Y., was advised that a notice of proposed issuance of construction permit was published in the *Federal Register* on December 29, 1956. This permit would authorize AMF Atomics to construct in Plainsboro Township, N. J., a 5,000-kilowatt, pool-type research reactor for applied research by a group of industrial firms.

Armour Research Foundation, Chicago, Ill., was issued a facility license, valid for 10 years from the date of the construction permit issued on March 28, 1955, authorizing operation of its 50-kilowatt homogeneous research reactor constructed in Chicago.

Battelle Memorial Institute, Columbus, Ohio, was issued a facility license, valid for 10 years from the date of the construction permit issued on August 5, 1955, authorizing operation of its 1000-kilowatt pool research reactor constructed near West Jefferson, Ohio.

Naval Research Laboratory, Washington, D. C., was issued a facility license, valid for 20 years from the date of the construction permit issued on April 29,1955, authorizing operation of the laboratory research reactor.

Westinghouse Electric Corporation, Pittsburgh, Pa., was advised that a notice of proposed issuance of construction permit was published in the *Federal Register* on January 5, 1957. This permit would authorize Westinghouse to construct and operate a 20,000-kilowatt engineering test reactor near Yukon, Westmoreland County, Pa.

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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 and was granted a license to receive 5 grams of contained uranium 235 in the form of uranyl nitrate of 80 to 89 percent enrichment, for developing and testing a fission counter to be used in monitoring the AGN–201 reactor.

Air Force Institute of Technology, Wright Patterson Air Force Base, Ohio, applied for and was issued a license to receive and use as calibrating sources in shielding experimentation 0.024 milligram of plutonium 239.

American Machine and Foundry Co., Advanced Research Dept., Alexandria, Va., applied for a license to receive and possess four spent fuel elements from the Commission's Materials Testing Reactor for use as gamma radiation sources in research work.

Applied Radiation Corp., Walnut Creek, Calif., applied for and was issued a license to receive at any one time up to 400 grams of contained uranium 235 for radiation processing of reactor core pieces.

Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill., applied for and was issued a license to receive 32.1 grams of plutonium contained in two plutonium-beryllium sources for use in dosimetry studies and as a neutron source for the licensee's research reactor.

Atomics International, Canoga Park, Calif., applied for and was granted a revised license increasing the authorized material from 3.5 grams to 50 grams of uranium 235 contained in fission counters incorporated in reactors constructed by North American Aviation, Inc.

Battelle Memorial Institute, Columbus, Ohio, was issued a revised license and allocation to increase from 3 kilograms to 8 kilograms the quantity of uranium 235 for use in fuel element research and development. The revised license also authorized receipt of 1.71 grams of uranium 235 contained in a fission chamber to be used at the Battelle Critical Experiment Laboratory. (Battelle subsequently requested that its license be amended to authorize possession of up to a total of 150 kilograms of uranium 235 and to authorize BMI to receive, process and analyze such byproduct and special nuclear material as may be produced by irradiation of research quantities of source material.)

Boston University, Chemistry Department, Boston, Mass., applied for a license to receive approximately 2 milligrams of uranium 233 for use in tracer research work.

Carnegie Institution of Washington was issued a license authorizing possession and use of 500 milligrams of uranium 235 and 100 micrograms of uranium 233 in coulomb excitation studies and mineral age investigations.

Continental Oil Co., Ponca City, Okla., applied for and was issued a license to receive and possess uranium 235 and fission products contained in four spent fuel rods of the Commission's Materials Testing Reactor for use in research.

Department of the Navy (Bureau of Ships) was issued a license and allocation to receive a plutonium-beryllium source (containing up to 4 grams of plutonium) for use by the Material Laboratory of the New York Naval Shipyard at Brooklyn, N. Y. in measuring the neutron absorption characteristics of various overlays of fiberglass and resinous materials.

Department of the Navy, Bureau of Ships, applied for a license to receive six plutonium 239 neutron sources for use by its contractor, the Cook Research Laboratories, Skokie, Ill., in the production of neutron dosimeters.

General Atomic Division of General Dynamics Corp., San Diego, Calif., applied for and was issued a license to receive 6.1 grams of U–235 contained in three fission counters to be used in conjunction with the critical assembly facility to be constructed by the applicant.

General Dynamics Corp., San Diego, Calif., applied for a license to receive uranium enriched in the isotope uranium 235 to conduct experiments in its critical experiment facility.

General Electric Co., Atomic Power Equipment Department, San Jose, Calif., applied for and was issued a license to receive at Vallecitos Atomic Laboratory, for use in a fuel-element development program, 20 pounds of uranium dioxide containing uranium enriched in uranium 235 (and the byproduct and special nuclear material produced by irradiation of these materials). The company also applied for and was issued a license to receive and use uranium enriched in the isotope uranium 235 for fabrication of fuel elements at its San Jose plant.

General Electric Co., Metallurgical Products Department, Detroit, Mich., applied for and was issued a license to receive uranium dioxide enriched in uranium 235 for conversion into pellets.

Hercules Powder Co., Wilmington, Del., was issued a license to receive 25 grams of enriched uranium in the form of uranyl nitrate for chemical research work.

Leland Stanford Junior University, Stanford, Calif., applied for and was issued a license to receive 80 grams of plutonium contained in five plutonium-beryllium sources for a subcritical assembly to be used in the nuclear engineering program of the University.

Magnolia Petroleum Co., Dallas, Tex., applied for and was issued a license to receive 16 grams of plutonium contained in a plutonium-beryllium source for use in nuclear research and radioactive well logging.

Mallinckrodt Chemical Works, St. Louis, Mo., was issued a license to receive at its Hematite, Mo., plant enriched uranium hexafluoride (UF_6) for conversion to uranium dioxide (UO_2).

Glenn L. Martin Co., Baltimore, Md., was issued a revised license and allocation increasing the quantity of special nuclear material the licensee may receive and possess from 50 grams to 1.0 kilogram of uranium 235 for fuel element research.

Glenn L. Martin Co. also applied for and was issued a license to receive at its Middle River, Md. plant 50 kilograms of enriched uranium oxide for fabrication of fuel elements for a pressurized water reactor.

Metals and Controls Corp., Attleboro, Mass., was issued a revised license authorizing receipt of up to 61 kilograms of contained uranium 235 for fabrication of fuel elements.

Leslie E. Johnson of Neutronics Laboratory, Tinley Park, Ill., applied for and was issued a license to receive and use in the construction of neutron sensitive devices 10 grams of the uranium 235, 5 grams of uranium 233, and 1 gram of plutonium nitrate.

North Carolina State College, Raleigh, N. C., applied for and was issued a license to possess and use in the measurement of the distribution of indium resonance neutrons 80 grams of uranium 235.

North Carolina State College also applied for a license to receive 75 grams of plutonium contained in five plutonium-beryllium sources to be used in the operation of the subcritical assembly located in the Burlington Nuclear Laboratories of North Carolina State College.

Nuclear Instrument & Chemical Corp., Chicago, Ill., applied for and was issued a license to possess, for chemical research work, up to 1 microgram of plutonium produced by irradiation of enriched uranium oxide-organic slurries.

Sinclair Research Laboratories, Inc., New York, N. Y., was issued a license to receive and use as a source of radiation in petroleum research work 800 grams of uranium 235 contained in four spent fuel elements of the Commission's Materials Testing Reactor.

Nuclear Metals, Inc., Cambridge, Mass., applied for a license to receive approximately 2.9 kilograms of uranium 235 in connection with the corrosion testing of Island PT Type fuel elements.

Owens-Corning Fiberglas Corp., Newark, Ohio, requested a license to receive 100 grams of uranium oxide containing uranium enriched in the isotope uranium 235, 100 grams of thorium oxide and 10 grams of plutonium, for incorporation into fiber glass for use by Rensselaer Polytechnic Institute in radiation chemistry research.

Pennsylvania State University, University Park, Pa., applied for and was issued a license to possess the uranium 233 produced by irradiation of 15 kilograms of thorium oxide powder in conducting research work.

Stanford Research Institute, Menlo Park, Calif., applied for and was issued a license to receive at any one time up to 400 grams of uranium 235 for radiation processing of reactor core pieces.

Sylvania Electric Products, Bayside, N. Y., was issued a license authorizing its receipt and use of uranium enriched in the isotope uranium 235 in the fabrication of fuel elements.

The Army Chemical Corps, Army Chemical Center, Md., was issued a revised license and allocation increasing the quantities of special nuclear material from 40 to 90 grams of plutonium, from 500 to 1500 milligrams of neptunium 235 and from 150 to 500 grams of uranium metal foil. The revised license also authorized the licensee to possess the special nuclear and byproduct material produced by the irradiation of the additional 350 milligrams of normal uranium.

The Babcock and Wilcox Co., New York, N. Y., was issued a revised license and allocation increasing the quantity of special nuclear material from 50 grams to 125 grams of enriched uranium which the company is authorized to receive for use in a breeder element test loop. The company was also issued a license to receive and use enriched uranium at Babcock and Wilcox, Lynchburg, Va., fuel element fabrication plant. Babcock and Wilcox was also granted a license to receive at its Alliance, Ohio, Research and Development Center 4.2 kilograms of enriched uranium for use in fuel element studies.

The University of Arkansas, Dept. of Chemistry, Fayetteville, Ark., applied for and was issued a license authorizing its receipt of 0.05 gram of uranium 233 for use as a tracer in research work.

The University of Florida, Gainesville, Fla., applied for and was issued a license to receive 16 grams of plutonium contained in a plutonium-beryllium source for a subcritical assembly to be used in a nuclear engineering educational program.

The University of Maryland, College Park, Md., applied for and was issued a license to receive 32 grams of plutonium contained in two plutonium-beryllium sources for a subcritical assembly to be used in a nuclear engineering educational program

The University of Michigan, Department of Physics, Ann Arbor, Mich., applied for a license to receive up to 60 milligrams of plutonium contained in sources to be used in spectrometers for the study of nuclear energy levels.

The University of Minnesota, Institute of Technology, Minneapolis, Minn., applied for a license to receive four plutonium-beryllium neutron sources for use in nuclear energy training and education.

The University of Wisconsin, Madison, Wis., applied for a license to receive a plutonium-beryllium source to be used as a gamma-free neutron source in the University's nuclear engineering research program.

U. S. Geological Survey, Department of Interior, was issued a license to receive and use in uranium analyses 10 milligrams of uranium 235.

U. S. Naval Radiological Defense Laboratory, San Francisco, Calif., was issued a license to receive and use in research and development work 10 grams of uranium 235, 6 grams of uranium 233, 3 grams of plutonium 239, and small quantities of special nuclear and byproduct material produced during the in-pile irradiation of approximately 1 kilogram of source material and 16 grams of special nuclear material.

Westinghouse Electric Corp. was issued a license to receive at its Forest Hills, Pa., plant uranium enriched up to 5 per cent in the isotope uranium 235 for use in the fabrication of fuel elements. Westinghouse subsequently requested and was granted an amended license authorizing (in addition to the foregoing) receipt and use of 100 grams of UO_3 containing uranium enriched in the isotope U–235, and the special nuclear material produced during the neutron irradiation of the UO_3 in research and development studies. *Westinghouse* also was issued a license to receive at its Blairsville, Pa., plant uranium fully enriched in the isotope uranium 235 for use in the fabrication of fuel elements. *Westinghouse* also applied for and was issued a license to receive at the Westinghouse Reactor Evaluation Center (WREC) 15 kilograms of uranium 235 contained in fabricated fuel assemblies for conducting critical experiments for the Westinghouse Test Reactor.

Westinghouse Electric Corp., Radiation and Nucleonics Laboratory, East Pittsburgh, Pa., applied for and was issued a license to possess approximately 32 milligrams of uranium 233 and plutonium 239 and byproduct material produced by irradiation of thorium dioxide slurries and natural or depleted uranium. This activity relates to research and development work on slurry reactors.

Yale University, Sloane Physics Laboratory, New Haven, Conn., applied for and was issued a license to receive 80 grams of plutonium contained in 5 plutonium-beryllium sources to be used in a subcritical assembly for training purposes.

APPENDIX 10

Statement of President to International Atomic Energy Agency Conference

Statement by the President of the United States Read at the Closing Session of the Conference on the Statute of the International Atomic Energy Agency by Lewis L. Strauss, Chairman of the Atomic Energy Commission, at the United Nations, Friday Morning, October 26, 1956

Mr. President and Delegates to the Conference on the Statute of the International Atomic Energy Agency:

Almost 3 years have passed since I was honored by an invitation to speak to the General Assembly of the United Nations. On that occasion, I proposed in behalf of the United States that atomic power—the greatest force science ever placed in man's hand—be put to work for peace.

Specifically, my proposal was: *first,* that governments begin, and continue, to make from their atomic materials stockpiled for war joint contributions to an International Agency; and, *second,* that this Agency be responsible for finding methods to apply these atomic materials to the needs of agriculture, medicine, and other peaceful pursuits of mankind.

The United States then pledged its entire heart and mind to finding how the miraculous inventiveness of man should be dedicated, not to his death, but consecrated to his life.

The atom was regarded, in 1953, as a terrible weapon for war. Since the first explosion in 1945, man had fearfully multiplied its destructiveness. People knew that a single airgroup could carry a more devastating cargo than all the bombs that fell on Britain in World War II. Several nations had learned to make atomic weapons and swiftly transport them across oceans and continents. To many people the doom of civilization in a nuclear war seemed inevitable. When they looked ahead, they saw no hope for a peaceful future.

The proposal made in 1953 by the United States offered: for apathy, action; for despair, hope; for the whirlpool of general war, a channel to the harbor of future peace.

From the time that proposal was made, I watched with ardent expectation the outcome of all the work done by the sponsoring powers and the working groups, and the debates in the General Assembly and at this culminating Conference. The planning and framing of the International Atomic Energy Agency has required many months of patience and intelligent effort. These labors have now been completed by the Conference's approval of the Statute.

I congratulate the Conference for what it has accomplished. The Statute, and the International Agency for which it provides, hold out to the world a fresh hope for peace.

Since the United States made its proposal in 1953, the intensity of the atom's destructiveness has again been greatly multiplied. For their own salvation, men are under a compulsion that must not be denied to turn this furious, mighty power from the devastation of war to the constructive purposes and practices of peace.

That is why the world needs fresh hope—a new chance for man working with man to root out past frustration and past hopelessness.

That is why the United States will never cease from seeking trustworthy agreements under which all nations will cooperate to disarm the atom.

To spur the coming of such a day, the peace-loving nations have pressed forward with benign uses of the atom for man's well-being and welfare. As increased knowledge makes more terrible the atom's might, it also brings closer the realization of its potential for good.

Peace can come from nations working together. When they have a common cause and a common interest, they are drawn together by this bond.

We—as one of the peace-loving nations—have sought to share our atomic skills and materials.

Last February, we offered to make available to friendly nations, for peaceful use, 20,000 kilograms of nuclear materials—an amount equal to that allocated for like use within the United States. And we have entered into agreements with 37 nations represented at the Conference—and are negotiating with 14 more—to cooperate in building in their lands atomic reactors, of all types and sizes, for peaceful works.

People have shown their hunger to learn the intricate mysteries of the new atomic science. We have tried to satisfy that hunger, to break open doors that sealed off the knowledge they sought—through initiating great scientific congresses and by providing libraries and training courses and schools. We have been happy to offer our knowledge of ways to use the atom for peace, of ways to use the atomic isotope in medical care and cure and in agriculture and industry. Because science is without boundaries, a common knowledge of the peaceful application of this new science can help us all to a better understanding of each other.

In all those things that we do as a Government, the United States does not seek for domination or control or profit. Nor shall we as a Government ever do so.

It is now for nations assembled at this Conference formally to adopt the Statute.

Here is what I, in behalf of the United States, propose.

First: It shall be my care, when our Congress reassembles, to present the Statute for official ratification by our Senate in accordance with our Constitution, and to request appropriate Congressional authority to transfer special nuclear materials to the International Atomic Energy Agency. I wish my country to be among the first to recognize by official action what you at this Conference have accomplished.

Second: To enable the International Atomic Energy Agency—upon its establishment by appropriate governmental actions—to start atomic research and power programs without delay, the United States will make available to the International Agency, on terms to be agreed with the Agency, 5,000 kilograms of the nuclear fuel uranium 235 from the 20,000 kilograms of such material allocated last February by the United States for peaceful uses by friendly nations

Third: In addition to the above-mentioned initial 5,000 kilograms of uranium 235, the United States will continue to make available to the International Atomic Energy Agency nuclear materials that will match in amount the sum of all quantities of such materials made similarly available by all other members of the International Agency, and on comparable terms, for the period between the establishment of the Agency and July 1, 1960. The United States will deliver these nuclear materials to the International Agency as they are required for Agency-approved projects.

Assuming that all nations represented at the Conference undertake parallel steps—within their capabilities—together we can overcome the obstacles that lie ahead and prove to each other that international controls are not only feasible but generally acceptable as a way to achieve peace.

The prompt and successful functioning of the Agency can begin to translate the myriad uses of atomic energy into better living: in our homes, at our work, during our travel and our rest.

At present, we see only the first fruits of this atomic growth. Atomic-fueled plants, which are being planned or built in this and several countries, will in a few years be producing power for civilian uses: to turn the wheels of factories—to light the darkness in countless homes.

We will not lead people to expect the advent overnight of an atomic millenium. In many countries, long and patient scientific experimentation and trial must precede the generation from atomic sources of electric power that can compete with that produced by using available coal, oil, gas, or water power. But, in the meantime, this International Agency will be encouraging those scientific labors and research to hasten the looked-for day.

The benefits of our daily living which will result from putting the atom to work for peace—more abundant and cheaper power and light, irrigation of arid lands, less costly transportation, the opening to industry of territories hitherto denied—may come to us more slowly than we would wish. But there is something more important than these material benefits. I mean those highways that lead to a settled tranquillity among nations.

People have long been seeking a channel for peaceful discussion. The International Atomic Energy Agency offers one such channel. During the last 3 years of deliberations upon its establishment and functioning, this channel has been kept open. It shall be the purpose of the United States to broaden this channel and to encourage its general use.

Some day, we fervently hope, sanity will overcome man's propensity to destroy himself. Then, the world can beat its swords into ploughshares. All nations can turn their plants that make nuclear fuel to an exclusively civilian use, and the fuel in their stockpiled nuclear weapons can also be put to work for man's health and welfare. In that happy time, the giant of atomic energy can become, not a frightening image of destructive war, but an obedient servant in a prosperous and peaceful world.

The real vision of the atomic future rests not in the material abundance which it should eventually bring for man's convenience and comfort in living. It lies in finding at last, through the common *use* of such abundance, a way to make the nations of the world friendly neighbors on the same street.

APPENDIX 11

STATEMENTS AND ADDITIONAL MATERIAL ISSUED BY WHITE HOUSE ON URANIUM PROGRAM

Statement by the President

This Nation attaches highest importance to the development of nuclear power both at home and abroad. We are determined that this product of man's inventiveness shall be made available to serve the people of the world.

We have taken many actions to this end. We have initiated and actively supported the formation of an International Atomic Energy Agency, we have negotiated bilateral agreements for cooperation with 37 countries, and we have expressed our support for European efforts to form an integrated atomic energy community. On February 22, 1956, I announced that I approved the recommendations of the chairman of the Atomic Energy Commission to make available 20,000 kilograms of uranium 235 for distribution abroad.

Today I have approved further important actions by the United States Atomic Energy Commission. These actions will set the terms and conditions on which nuclear fuel will be available under agreements for cooperation. These and other actions are designed to enable other nations or groups of nations to have firm assurance of the fuel supplies necessary to the continued operation of nuclear power installations, and thus to facilitate arrangements for financing.

Under these new actions, the United States will make available to other nations supplies of nuclear fuel at prices identical with those charged by the Atomic Energy Commission under our domestic nuclear power program.

One of the steps I have approved is an offer to purchase at specified prices plutonium and uranium 233 produced in reactors abroad that are fueled with material furnished under our agreements for cooperation. The materials so acquired by the United States will be used solely for peaceful purposes.

Today's actions, summarized in the attached statement by the Chairman of the Atomic Energy Commission, will permit closer estimate of net nuclear fuel costs and will add firmness to the planning now underway in friendly nations for nuclear power, thereby accelerating their atomic power development.

It will be our policy, of course, to seek to conduct our operations in support of nuclear power development abroad in consonance with the policy of the International Atomic Energy Agency, in whose endeavors we shall take our full part.

We shall strive ceaselessly to attain the day when the uses of the energy of the atom fulfill mankind's peaceful purposes.

Statement by Lewis L. Strauss, Chairman, United States Atomic Energy Commission

With the approval of the President, the Atomic Energy Commission is taking six additional steps to accelerate the development of nuclear power abroad under the Atoms for Peace program.

These steps include:

a. Establishment of a schedule of charges for uranium 235 furnished by the Commission to other nations or groups of nations for use in power or research reactors under agreements for cooperation. The schedule sets charges for various degrees of enrichment; for example about $16 per gram of uranium

235 at 20 percent enrichment. The charges are the same as those made by the Commission to domestic users.

b. Adoption of a policy under which assurances can be made to nations with agreements for cooperation that the Commission—within the limits of the amounts of material made available from time to time by the President—is prepared to furnish uranium 235 in specified quantities based on estimated fuel requirements of a given power installation over a fixed period, beyond the present term of 10 years. Such commitments would, of course, be subject to observance of all terms and conditions of the covering agreement for cooperation. In carrying out this policy, it is recognized, the present term of agreements for cooperation would require extension.

c. Establishment of prices to be offered by the Commission for plutonium, and uranium 233 produced in reactors abroad which are fueled under agreements for cooperation. These prices are the estimated fuel value of these special nuclear materials when a practicable method of using them for fuel develops from the research now being carried on. For plutonium metal, it is $12 per gram; for uranium 233 nitrate, it is $15 per gram of Uranium 233. Material so acquired by the Commission will be used only for peaceful purposes.

d. Decision by the Commission that it stands ready to purchase during the period ending June 30, 1963, at the above mentioned prices, all plutonium and uranium 233 produced in reactors abroad which are fueled with material obtained from the United States. Under existing authority in the Atomic Energy Act of 1954, such purchases will, of course, be made on an annual basis and subject to the availability of appropriations.

e. The Commission expects to recommend at the forthcoming session of the Congress legislation to provide authority to the Commission, with the approval of the President, to establish guaranteed prices for periods not in excess of 7 years for plutonium and uranium 233 which is delivered to the Commission and which has been produced in reactors abroad fueled with material supplied by the United States. Such authority will enable the Commission to provide the same assurance to foreign nuclear power programs that the 7-year guarantee period for prices under existing law provides to the domestic nuclear power program.

f. Decision to consider exchange of United States uranium 235 for source material (for example uranium ore or concentrates) from nations with agreements for cooperation.

The steps taken today will be of material assistance to the foreign nuclear power program. The information and assurances given are necessary for estimating cost of power, for justifying the capital required and for assuring operation of special nuclear power plants over a period of years.

Attached is a summary of the general terms and conditions for governing international transactions in special nuclear materials under agreements for cooperation together with general background information of the new actions approved today. The announcements made today and the attached terms and conditions apply to agreements for cooperation under the Atoms for Peace Program.

The policies and undertakings to seek new authority which have today been approved by the President should substantially promote the advance of the free world toward abundant nuclear power. The Commission will continue to explore additional means to encourage the development of nuclear power.

There are obstacles to be overcome. Skilled manpower is presently in serious shortage. Large capital resources are required. The best technology remains to be worked out area by area.

But I am confident that steps being taken in the United States and the progress being made by our friends abroad, are speeding the day when electrical energy from the atom will help lighten man's burden of work and lift the standards of living of peoples everywhere.

Additional Details on Actions Facilitating Power Reactor Development by Other Nations Under Agreements for Cooperation

1. The enriched uranium which will be supplied as needed under the schedule of charges will be taken from the 20,200 kilograms of uranium 235 made available by President Eisenhower in 1954, 1955, and 1956 for use in fuel for power and research reactors abroad and from such additional amounts as may be made available subsequently. (The 5,000 kilograms for the International Atomic Energy Agency's initial operations plus the amounts matching contributions of other nations also will be drawn from quantities made available by the President.)

2. The new schedule of charges supersedes the charge of $25 per gram of uranium 235 in uranium enriched to 20 percent announced on August 8, 1955, for the leasing of fuel for research reactors abroad. Under the new schedule, the charge for uranium 235 at 20 percent enrichment will be equivalent to slightly more than $16 per gram. (The detailed schedule of charges is included in the attached "General Terms and Conditions.") The same schedule applies to the charges for enriched uranium made available to domestic users.

3. The Commission's newly established prices for plutonium and uranium 233 which it may acquire from foreign reactors operating with fuel obtained from the United States under agreements for cooperation are based on the estimated value of these substances as nuclear fuels.

4. The charge of $40 per kilogram for normal uranium metal, and of $28 per pound for heavy water, as announced at the Geneva Conference on August 8, 1955, remain unchanged. [International Conference on the Peaceful Uses of Atomic Energy.] Under the new schedule, the charges for uranium 235 range from an equivalent of $5.62 per gram for 0.72 percent enrichment—fuel barely enriched over the normal seven-tenths of one percent found in nature—to $17.07 per gram for 90 percent enrichment.

5. The conditions of transfer under the new schedule differ from those prevailing under the "Geneva price." While the earlier charge was for uranium as metal, the new schedule of charges is for uranium hexafluoride (UF_6). The cost of conversion to metal or other forms will be borne by the user.

6. Also, the former charge applied to transactions essentially limited in each case to six kilograms of uranium 235 contained in uranium with an enrichment not to exceed 20 percent. At that time, the quantity made available for use abroad in research reactors was only 200 kilograms of uranium 235.

7. The new schedule of charges applies to transactions of this type as well as to much larger transactions with other nations or groups of nations. Economies will be achieved in preparing and handling large quantities of material. The schedule applies as well to Commission repurchases of enriched uranium returned to the Commission from abroad and will also be used in calculating charges to be applied to leased fuel for use, consumption, and isotopic depletion or dilution. Appropriate adjustments will be made for processing costs incurred by the Commission in reclaiming the material in the form of UF_6.

8. Commitments thus far made to other nations approximate 1,700 kilograms of uranium 235. The three power reactor agreements recently concluded with Switzerland, the Netherlands and Australia involve supplying approximately 1,500 kilograms of uranium 235 over the next 10 years.

9. Sale or lease transactions with other nations under the new prices will involve for the most part reactor fuel containing 20 percent uranium 235 or less.

However, in five agreements concluded so far, relatively small quantities of 90 percent fuel are authorized for use in materials testing reactors. This is the highest degree of enrichment quoted in the new schedule.

10. In addition to sale or lease of uranium 235, the Commission is now undertaking, as noted in the announcements, to consider arrangements under which it would supply uranium 235 in exchange for source material such as uranium ore or concentrates. The basis for exchange and the quantities involved on each side would be worked out on a case-by-case basis.

11. The announcements made today and the attached terms and conditions apply to agreements for cooperation under the Atoms for Peace Program. The arrangements under which 5,000 kg. ofuranium 235 will be made available to the IAEA will be agreed with the Agency.

Summary of General Terms and Conditions Governing International Transactions in Special Nuclear Materials

I. *Agreements for Cooperation.*

Special nuclear material may be distributed outside the United States only pursuant to an agreement for cooperation.

The term of present agreements for cooperation in power reactor technology and fueling stands at 10 years. However, recognizing that the provision of fuels must be guaranteed for a longer period in order to facilitate financing and operation, the Commission will now consider extending agreements beyond 10 years.

II. *Form of Transactions.*

In general, special nuclear material distributed abroad under research agreements will be leased and that distributed under power agreements will be sold. The contract of sale or the lease, as the case may be, will contain terms relating to delivery, form of material, quantity and price. The pertinent document will also contain procedures for assaying material and such other provisions as may be appropriate or necessary in a given case.

III. *Form of Material.*

All quoted prices relate to enriched uranium as (uranium hexafluoride (UF_6)).

IV. *Charges.*

The charges for uranium in the form of UF_6, in the various degrees of enrichment, shall be in accordance with a schedule adopted by the Commission for use in transactions both at home and abroad. Although these prices are subject to adjustment, it is the intention of the Commission to maintain them as stable as possible. The schedules are as follows:

Weight fraction uranium-235	Official charge dollars per kilogram of uranium	Dollars per gram of uranium-235 content	Weight fraction uranium 235	Official charge dollars per kilogram of uranium	Dollars per gram of uranium-235 content
0.0072	40.50	5.62	.040	535.50	13.39
.0074	42.75	5.78	.045	616.50	13.70
.0076	45.25	5.95	.050	698.25	13.96
.0078	47.50	6.09	.060	862.50	14.38
.0080	50.00	6.25	.070	1,028.00	14.68
.0082	52.50	6.40	.080	1,195.00	14.94
.0084	55.00	6.55	.090	1,362.00	15.13
.0086	57.50	6.69	.10	1,529.00	15.29
.0088	60.00	6.82	.15	2,374.00	15.83
.0090	62.75	6.97	.20	3,223.00	16.12
.0092	65.25	7.09	.25	4,078.00	16.31
.0094	67.75	7.21	.30	4,931.00	16.44
.0096	70.50	7.34	.35	5,793.00	16.55
.0098	73.00	7.45	.40	6,654.00	16.64
.010	75.75	7.58	.45	7,515.00	16.70
.011	89.00	8.09	.50	8,379.00	16.76
.012	103.00	8.58	.55	9,245.00	16.81
.013	117.00	9.00	.60	10,111.00	16.85
.014	131.25	9.38	.65	10,979.00	16.89
.015	145.50	9.70	.70	11,850.00	16.93
.020	220.00	11.00	.75	12,721.00	16.96
.025	297.00	11.88	.80	13,596.00	17.00
.030	375.50	12.52	.85	14,475.00	17.03
.035	455.00	13.00	.90	15,361.00	17.07

The above schedule will also provide the basis for use charges to be applied to leased fuel, as well as in calculating charges for uranium 235 consumption and isotopic depletion or dilution in leased fuel, and for any AEC repurchases of enriched uranium returned from abroad. Appropriate adjustments will be made for processing costs incurred by the AEC in reclaiming the material in the form of UF_6.

The schedule does not include any costs that may be incurred by the Commission as a result of activities conducted under agreements for cooperation to safeguard uranium 235 distributed abroad. If it later becomes necessary to add a surcharge to the charge schedule on account of such expense, that surcharge will moderate.

V. *"Buy-Back" Prices for Plutonium and Uranium 233.*

The following prices shall be applied in any Commission purchases of plutonium or uranium 233 produced abroad for the period ending June 30, 1963, through the use of fuel obtained from the Commission under agreements for cooperation:

For plutonium metal—$12/gram.

For uranium 233 nitrate—$15/gram of uranium 233.

The above are based on the estimated values of plutonium and uranium 233 as reactor fuel. Since, initially, material is expected to be delivered in forms other than the above, the prices to be paid will be the above, less the cost of conversion to the specified form. Material so acquired by the Commission from nations with agreements for cooperation, as noted in today's announcement, will be used only for peaceful purposes. To assure this, in any case where such material cannot, during its reprocessing, be kept separate from material produced in the United States, an equal amount of United States material will be reserved for peaceful uses.

VI. *Enrichment of Material.*

Uranium distributed abroad will be limited to 20 percent enrichment in uranium 235, with the exception that six (6) kilograms of uranium 235 enriched up to 90 percent may be made available for use in materials testing reactors under power agreements, and gram quantities of uranium enriched above 90 percent in uranium 235 may be made available for research purposes under research or power agreements.

VII. *Quantity.*

a. *Research agreements:*

Generally, up to 6 kilograms of contained uranium 235 will be made available under research agreements. However, in some cases, the Commission may increase this amount, by way of amendment to an agreement, up to 12 kilograms. The reference here is to the amount of material being utilized in reactors within the cooperating country at any one time. In addition, the Commission will make available such further quantities as, in its opinion, are necessary to permit the efficient and continuous operation of the reactor or reactors while replaced fuel elements are radioactively cooling in the cooperating country or while fuel elements are in transit.

b. *Power agreements:*

The amount of material allocated under a power agreement generally refers to the required operating inventory plus the net amount of uranium 235 to be consumed over the life of the agreement. The amount of uranium enriched in the isotope uranium 235 in the custody of a cooperating country shall not at any time be in excess of the amount of material necessary to assure continuous operation of each defined reactor project undertaken.

VIII. *Reprocessing.*

When special nuclear material received by a cooperating country from the United States requires reprocessing, such reprocessing shall be performed at the discretion of the Commission in either Commission facilities or facilities acceptable to the Commission. Cost of such reprocessing will be borne by the users of the material.

IX. *Safeguards and Controls.*

All agreements for cooperation contain appropriate safeguards and controls against diversion of special nuclear material to other than peaceful purposes and contain all of the guarantees required by Section 123 of the Atomic Energy Act of 1954.[1]

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[1] Section 123 reads as follows:

"Sec. 123. COOPERATION WITH OTHER NATIONS.—No cooperation with any nation or regional defense organization pursuant to sections 54, 57, 64, 82, 103, 104, or 144 shall be undertaken until—

"a. the Commission or, in the case of those agreements for cooperation arranged pursuant to subsection 144b, the Department of Defense has submitted to the President the proposed agreement for cooperation, together with its recommendation thereon, which proposed agreement shall include (1) the terms, conditions, duration, nature, and scope of the cooperation, (2) a guaranty by the cooperating party that security safeguards and standards as set forth in the agreement for cooperation will be maintained; (3) a guaranty by the cooperating party that any material to be transferred pursuant to such agreement will not be used for atomic weapons, or for research on or development of atomic weapons, or for any other military purpose; and (4) a guaranty by the cooperating party that any material or any restricted data to be transferred pursuant to the agreement for cooperation will not be transferred to unauthorized persons or beyond the jurisdiction of the cooperating party, except as specified in the agreement for cooperation;

"b. the President has approved and authorized the execution of the proposed agreement for cooperation, and has made a determination in writing that the performance of the proposed agreement will promote and will not constitute an unreasonable risk to the common defense and security; and

"c. the proposed agreement for cooperation, together with the approval and the determination of the President, has been submitted to the Joint Committee and a period of 30 days has elapsed while Congress is in session (in computing such 30 days, there shall be excluded the days on which either House is not in session because of an adjournment of more than 3 days)."

APPENDIX 12

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

Main Commission. Dr. R. Sievert, Institute of Radiophysics, Sweden, chairman; Dr. G. Failla, Columbia University, New York, N. Y., vice chairman and chairman, subcommittee I, Permissible Dose for External Radiation; W. Binks, Radiological Protection Service, England, secretary; Prof. L. Bugnard, Ministry of Health, France; Dr. H. Holthusen, Direcktor de Strahleninstitut, Germany; Prof. J. C. Jacobsen, Radium Centre, Denmark; Dr. R. G. Jaeger, Physikalisch Technische Bundesanstalt, Germany, chairman, subcommittee III, Protection Against X-rays up to 3 Million Volts and Gamma Rays from Beam Equipment; Dr. W. V. Mayneord, Royal Marsdon Hospital, England; Dr. K. Z. Morgan, Oak Ridge National Laboratory, Oak Ridge, Tenn., chairman, subcommittee II, Permissible Dose for Internal Radiation; Dr. R. S. Stone, University of California, San Francisco, Calif.; Dr. L. S. Taylor, National Bureau of Standards, Department of Commerce, Washington, D. C.; Dr. E. A. Watkinson, National Health & Welfare, Canada; Sir Ernest Rock Carling, Home Office, England, chairman emeritus.

Subcommittee chairmen. Prof. H. E. Johns, Canada, chairman, subcommittee IV, Protection Against High Energy X-rays, and Heavy Particles Including Neutrons and Protons; Dr. Conrad P. Straub, Oak Ridge National Laboratory, Oak Ridge, Tenn., chairman, subcommittee V, Handling of Radioactive Isotopes and the Disposal of Radioactive Waste.

Committee members. No. I, Dr. A. R. Gopel-Ayengar, India; Dr. G. Bonnier, Sweden; Prof. D. G. Catcheside, England; Dr. T. Kemp, Denmark; Dr. R. Laterjet, France; Dr. J. F. Loutit, England; Dr. H. J. Muller, United States; Dr. Jens Nielsen, Denmark; Prof. R. M. Sievert, Sweden; Prof. R. S. Stone, United States; Dr. Shields Warren, United States. No. II, Dr. A. M. Brues, United States; Dr. W. H. Langham, United States; Dr. L. D. Marinelli, United States; Dr. W. G. Marley, England; Dr. N. K. Nakaidzumi, Japan; Dr. G. J. Neary, England; Prof. M. N. Pobedinski, Union of Soviet Socialist Republics; Dr. E. E. Pochin, England; Dr. C. Gordon Stewart, Canada. No. III, E. E. Smith, England; Dr. S. Benner, Sweden; Dr. J. Bouchard, Canada; Dr. C. B. Braestrup, United States; Dr. B. Combee, Netherlands; C. Garrett, Canada; Dr. T. Gauwerky, Germany; Prof. H. Holthusen, Germany; Dr. P. Ronne-Nielsen, Denmark; Dr. H. O. Wyckoff, United States; Dr. J. Zakovsky, Austria; Dr. Zuppinger, Switzerland. No. IV, Dr. E. E. Pochin, England; Dr. H. P. Jammet, France; A. W. Kenny, England; Dr. W. G. Marley, England; Dr. C. A. Mawson, Canada; Prof. Aldo Perussia, Italy; Dr. E. H. Quimby, United States; Dr. F. D. Sowby, Canada; Dr. F. W. Wester, United States.

APPENDIX 13

National Committee on Radiation Protection and Measurement

Dr. Lauriston S. Taylor, committee chairman; National Bureau of Standards, Department of Commerce, Washington, D. C.; chairman, subcommittee 10, Regulations of Radiation Exposure Dose; acting chairman, subcommittee 14, Permissible Exposure Doses Under Emergency Conditions.

Dr. H. L. Andrews, U. S. Public Health Service, Department of Health, Education, and Welfare, Washington, D. C.; chairman, subcommittee 7, Monitoring Methods and Instruments.

E. C. Barnes, Westinghouse Electric Corp., Pittsburgh, Pa.; representing American Industrial Hygiene Association.

A. C. Blackman, California Department of Industrial Relations, San Francisco; representing International Association of Government Labor Officials.

Dr. C. B. Braestrup, Francis Delafield Hospital, New York, N. Y.; chairman, subcommittee 9, Protection Against Radiations from Radium, Cobalt 60, and Cesium 137, Encapsulated Sources.

Dr. John C. Bugher, Rockefeller Foundation, New York, N. Y.; representative at large.

Dr. Richard S. Chamberlain, University of Pennsylvania Hospital, Philadelphia, Pa.; representing the American College of Radiology.

Dr. Walter D. Claus, U. S. Atomic Energy Commission, Washington, D. C.

Dr. Charles L. Dunham, U. S. Atomic Energy Commission, Washington, D. C.; member of Executive Committee.

Dr. T. P. Eberhard, representing American Radium Society.

Dr. Giaocchino Failla, Columbia University, New York, N. Y.; member of Executive Committee; chairman, subcommittee 1, Permissible Dose from External Radiation, and subcommittee M–3, Standards and Measurement of Absorbed Radiation Dose.

Dr. Paul C. Hodges, University of Chicago, Chicago, Ill.; representing the American Medical Association.

Dr. H. W. Koch, National Bureau of Standards, Department of Commerce, Washington, D. C.; chairman, subcommittee 5, Electrons, Gamma Rays and X-rays over 2 Million Volts.

Dr. W. H. Langham, Los Alamos Scientific Laboratory, Los Alamos, N. Mex., U. S. Atomic Energy Commission; chairman, subcommittee M–4, Relative Biological Effectiveness.

R. M. Leehausse, Colonel, U. S. Air Force.

E. A. Lodmell, Colonel, U. S. Army.

Dr. W. B. Mann, National Bureau of Standards, Department of Commerce, Washington, D. C.; chairman, subcommittee M–1, Standards and Measurement of Radioactivity for Radiological Use.

Dr. G. W. Morgan, U. S. Atomic Energy Commission, Oak Ridge, Tenn.; chairman, subcommittee 11, Incineration of Radioactive Waste.

Dr. K. Z. Morgan, Oak Ridge National Laboratory, Oak Ridge, Tenn.; U. S. Atomic Energy Commission; representative at large and chairman, subcommittee 2, Permissible Internal Dose.

Dr. R. J. Nelsen, Rockville, Md.; representing American Dental Association.

Dr. R. R. Newell, Stanford University, San Francisco, Calif.; American Roentgen Ray Society.

Dr. H. M. PARKER, General Electric Co., Hanford Works, U. S. Atomic Energy Commission, Richland, Wash.; chairman, subcommittee 6, Handling of Radioactive Isotopes and Fission Products.

Dr. E. H. QUIMBY, Columbia University, New York, N. Y.; representing American Radium Society; chairman, subcommittee 13, Safe Handling of Cadavers Containing Radioactive Isotopes.

J. A. REYNOLDS, Picker X-ray Corp., Cleveland, Ohio; representing National Electrical Manufacturer Association.

Dr. H. H. ROSSI, Columbia University, New York, N. Y.; chairman, subcommittee 4, Heavy Particles (Neutrons, Protons, and Heavier).

Dr. M. D. SCHULTZ, Massachusetts General Hospital, Boston, Mass.; representing American College of Radiology.

Dr. L. S. SKAGGS, Argonne Cancer Research Hospital, Chicago, Ill., U. S. Atomic Energy Commission; chairman, subcommittee 12, Electron Protection.

Dr. J. H. STERNER, Eastman Kodak Co., Rochester, N. Y., representing American Industrial Hygiene Association.

Dr. R. S. STONE, University of California, San Francisco, Calif.; representing Radiological Society of North America.

Dr. I. R. TABERSHAW, New York State Department of Labor, New York, N. Y.; representing International Association of Government Labor Officials.

E. D. TROUT, General Electric Co., Milwaukee, Wis.; representing National Electrical Manufacturer Association.

Dr. SHIELDS WARREN, New England Deaconess Hospital, Boston, Mass.; representative at large.

Dr. JAMES L. WEATHERWAX, Philadelphia, Pa.; representative at large.

S. F. WILLIAMS, Captain, U. S. Navy.

Dr. H. O. WYCKOFF, National Bureau of Standards, Department of Commerce, Washington, D. C.; chairman, subcommittee 3, X-rays Up to 2 Million Volts and subcommittee M–2, Standards and Measurements of Radiological Exposure Dose.

S. W. RASKIN (Mrs.), committee secretary; National Bureau of Standards, Department of Commerce, Washington, D. C.

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APPENDIX 14

Table of Nuclear Reactor Facilities

The following tabulation includes as reactors all facilities built, building, or planned in the United States as of December 31, 1956, which are capable of sustaining a nuclear chain reaction, with the exception of experiments being conducted at weapons laboratories. A few of these are for installation in other countries. 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.

Start-up dates shown for 1957 or later are estimates based on the best available information. The dates for non-Commission projects are the estimates announced by the sponsoring organizations.

Reactors are listed as "being built" category 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.

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 filed with the Commission or public announcement is made, whichever is first.

Listings in the "builder" column refer to the prime contractor in the case of Federal Government reactors and to the principal manufacturer in other cases. Builders' names, abbreviated in the column listing, are given in full in the list below.

Abbreviation	*Builder*
ACF	ACF Industries, Inc.
AGC	Aerojet-General Corps.
AGN	Aerojet-General Nucleonics, a Division of Aerojet-General Corp.
ALCO	Alco Products, Inc., a Subsidiary of American Machine & Foundry Co.
AMF	AMF Atomics, Inc.
ANL	Argonne National Laboratory, University of Chicago, Contractor.
B&W	The Babcock & Wilcox Co.
BAC	Bendix Aviation Corp.
CE	Combustion Engineering, Inc.
Convair	Consolidated Vultee Aircraft Corp.
Daystrom	Daystrom, Inc.
DuPont	E. I. du Pont de Nemours & Co., Inc.
Fluor	The Fluor Corp., Ltd.
Ford Instr	Ford Instrument Co.
F-W	Foster Wheeler Corp.
GDC	General Atomic Division of General Dynamics Corp.
GE	General Electric Co.

Abbreviation	*Builder*
HKF	The H. K. Ferguson Co.
KE	Kaiser Engineers, Division of Henry J. Kaiser Co.
LASL	Los Alamos Scientific Laboratory, University of California, Contractor.
Lockheed	Lockheed Aircraft Corp.
Martin	The Glenn L. Martin Co.
Met. Lab	Metallurgical Laboratory, 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, Union Carbide Nuclear Co. of Union Carbide & Carbon Corp., Contractor.
PPC	Phillips Petroleum Co.
PRDC	Power Reactor Development 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 DECEMBER 31, 1956

	Operated, later dismantled	Operated or licensed to operate	Being built	Planned	Total
A. *Low temperature (Not useful for power generation)*					
1. Research and test reactors—Wholly or primarily for:					
a. Research—United States locations	6	14	5	20	45
b. Research—Foreign locations		1	1	14	16
c. Personnel training			1		1
d. General testing—United States locations		1	1	2	4
e. General testing—Foreign locations				1	1
f. Specialized testing		12	4	3	19
2. Critical experiments and zero power reactors:					
a. Unclassified—United States locations	5	17	6	6	34
b. Unclassified—Foreign locations				1	1
c. Classified—United States locations (not listed)		7	4		11
3. Production reactors		13			13
Total—Low temperature	11	65	22	47	145
B. *High temperature power producing reactors*					
4. Military prototypes and experiments:					
a. Unclassified	1	3	7	2	13
b. Classified (not listed)				4	4
5. Full scale military power reactors		2	8	17	27
6. Civilian power reactor experiments	5	4	4	5	18
7. Full scale civilian power reactors:					
a. AEC power demonstration reactor program			1	6	7
b. United States locations—other than PDRP			4	6	10
c. Foreign locations				7	7
Total—High temperature	6	9	24	47	86
Grand Total	17	74	46	94	231

NUCLEAR REACTORS BUILT, BUILDING, OR PLANNED IN THE UNITED STATES AS OF DECEMBER 31, 1956

A. *Low Temperature (Not Useful for Power Generation)*

1. Research and Test Reactors

(a) Wholly or Primarily for Research, U. S. Locations

Name and/or Owner	*Designation*	*Location*	*Builder*	*Type*	*Start-Up*	*Dismantled*
Operated, Later Dismantled:						
Chicago Pile 1 (AEC)	CP–1	Chicago, Ill	Met. Lab	Graphite	1942	1943
Chicago Pile 2 (AEC)	CP–2	Argonne Lab	Met. Lab	do	1943	1954
Argonne CP–3 (rebuilt as CP–3′) (AEC).	CP–3	do	Met. Lab	Heavy Water	1944	1950
Argonne CP–3′ (AEC)	CP–3′	do	ANL	do	1950	1955
Low Power Water Boiler (AEC)	LOPO	Los Alamos	LASL	Homogeneous	1944	1944
High Power Water Boiler (AEC)	HYPO	do	LASL	do	1944	1950
Operated or Licensed to Operate:						
Oak Ridge X–10 Area Reactor (AEC).	X–10–100	Oak Ridge	ORNL	Graphite	1943	
Brookhaven Research Reactor (AEC).		Brookhaven Lab	HKF	do	1950	
Low Intensity Test Reactor (AEC)	LITR	Oak Ridge	ORNL	Tank	1950	
Super Power Water Boiler (AEC)	SUPO	Los Alamos	LASL	Homogeneous	1951	
North American Aviation Water Boiler Neutron Source (AEC).	WBNS	Van Nuys, Calif	NAA	do	1952	
Livermore Water Boiler (AEC)	LIWB	Livermore, Calif	NAA	do	1953	
North Carolina State College (Raleigh Research Reactor).		Raleigh, N. C		Homogeneous	1953	
Argonne Research Reactor (AEC)	CP–5	Argonne Lab	ANL	Heavy Water	1954	
Pennsylvania State University		University Park, Pa		Pool	1955	
Aerojet-General Nucleonics	AGN–201	San Ramon, Calif	AGN	Homogeneous Solid	1956	
Armour Research Foundation		Chicago, Ill	NAA	Homogeneous	1956	
Battelle Memorial Institute		West Jefferson, Ohio	AMF	Pool	1956	

Naval Research Laboratory		Washington, D. C	NRL	do	1956
Omega West Reactor (AEC)		Los Alamos	LASL	Tank	1956
Being Built:					
Livermore Pool Type Reactor (AEC).	LPTR	Livermore, Calif	F–W	Pool	1957
Oak Ridge Research Reactor (AEC).	ORR	Oak Ridge	ORNL	Tank	1957
Brookhaven Medical Reactor (AEC).		Brookhaven Lab	Daystrom	do	1957
University of Michigan		Ann Arbor, Mich	B&W	Pool	1957
Massachusetts Institute of Technology.		Cambridge, Mass	ACF	Heavy Water	1957
Planned:					
Aerojet-General Nucleonics (8 reactors).[1]		San Ramon, Calif	AGN	Homogeneous Solid	1957
Curtiss-Wright Corporation [1]		Quehanna Pa	Daystrom	Pool	1957
Dow Chemical Company [1]		Midland. Mich		Liquid Metal	
Industrial Research Laboratories, Inc.[1]		Plainsboro, N. J	AMF	Pool	1957
The Prosperity Company [1]		Coral Gables, Fla		do	
University of California (Medical Reactor).[1]		Los Angeles, Calif	NAA	Homogeneous	
Gamma Corporation [2]		Mansfield, Mass		do	
Stanford Research Institute [2]		Palo Alto, Calif			
University of Buffalo [2]		Buffalo, N. Y	AMF	Pool	
University of Washington [2]		Seattle, Wash			
Watertown Arsenal [2]		Watertown, Mass	BAC	do	1958
State College of Washington [1]		Pullman, Wash	GE	do	1959
University of Virginia		Charlottesville, Va		do	
Daystrom Nuclear Division of Daystrom, Inc.[1]		Near Princeton, N. J		Graphite-water	1957

See footnotes at end of table.

NUCLEAR REACTORS BUILT, BUILDING, OR PLANNED IN THE UNITED STATES AS OF DECEMBER 31, 1956—Con.

A. *Low Temperature (Not Useful for Power Generation)—Continued*

1. Research and Test Reactors—Continued

(b) Wholly or Primarily for Research, Foreign Locations

Location	*Builder*	*Type*	*Start-Up*
Operated:			
Switzerland (Wurelinger) [3]	ORNL	Pool	1955
Being Built:			
Japan (Tokai-mura)	NAA	Homogeneous	
Planned:			
Asian Nuclear Center [2]			
Brazil (Sao Paulo) [4]	B&W	Pool	1957
Denmark (Roskilde) [4]	F-W	do	
Italy (near Milan) [2]	ACF	Heavy Water	1958
Japan (Tokai-mura) [2]	AMF	Tank	
Argentina (Buenos Aires) [2]	GE	Pool	
Netherlands [2]	ACF	Tank	
Netherlands (Amsterdam International Exhibit) [4]	AMF	Pool	1957
Spain (Madrid) [2]	GE	do	
Venezuela (near Caracas) [2]	GE	do	
Federal Republic of Germany (Munich) [4]	AMF	do	1957
Sweden (Studsvik) [2]	ACF	Tank	
Federal Republic of Germany (Hamburg) [2]	B&W	Pool	
Federal Republic of Germany (University of Frankfurt) [2]	NAA	Homogeneous	

(c) Wholly or Primarily for Personnel Training

Name and/or Owner	Designation	Location	Builder	Type	Start-Up
Being Built:					
Argonne Naught Power Reactor (AEC).	Argonaut	Argonne Lab	ANL	Graphite	1957

(d) Wholly or Primarily for General Testing, United States Locations

Operated:					
Materials Testing Reactor (AEC)	MTR	NRTS, Idaho	Fluor	Tank	1952
Being Built:					
Engineering Test Reactor (AEC)	ETR	do	KE	do	1957
Planned:					
National Advisory Committee for Aeronautics.[1]	NACA-TR	Sandusky, Ohio	NACA	do	1959
Westinghouse Testing Reactor [1]	WTR	Westmoreland County, Pa.	West	do	1957

(e) Wholly or Primarily for General Testing, Foreign Locations

Planned:					
Centre d'Etude pour les Applications de l'Energie Nucleaire of Belgium (CEAN).[2]	BR-II	Mol, Belgium	NDA		1959

See footnotes at end of table.

A. *Low Temperature (Not Useful for Power Generation)—Continued*

1. Research and Test Reactors—Continued

(f) Wholly or Primarily for Specialized Testing

Name and/or Owner	*Designation*	*Location*	*Builder*	*Type*	*Start-Up*
Operated:					
Savannah River Test Pile 305 (AEC)	SR–305	Savannah River	DuPont	Graphite	1953
Hanford 305 Test Reactor (AEC)	HEW–305	Hanford, Wash	DuPont	do	1944
Process Development Pile (AEC)	PDP	Savannah River	DuPont	Heavy Water	1953
45′ Thermal Test Reactor (AEC)	SP	do	DuPont	Graphite	1953
Thermal Test Reactor (AEC)	TTR	Hanford, Wash	GE	do	1955
Bulk Shield Test Facility (AEC)	BSTF	Oak Ridge	ORNL	Pool	1950
Tower Shielding Facility (AEC)	TSF	do	ORNL	do	1954
Special Power Excursion Reactor Test No. 1 (AEC).	SPERT–1	NRTS, Idaho	PPC	Heterogeneous	1955
Kinetic Experiment on Water Boilers No. 1 (AEC).	KEWB–1	Santa Susana, Calif	NAA	Homogeneous	1956
Thermal Test Reactor (AEC)	TTR	Schenectady, N. Y	GE	Graphite	1951
Ground Test Reactor (USAF)	GTR	Fort Worth, Texas	Convair		1953
Aircraft Shield Test Reactor (USAF)	ASTR	do	Convair		1954
Being Built:					
Special Power Excursion Reactor Test No. 2 (AEC).	SPERT–2	NRTS, Idaho	PPC	Pressurized Water	1957
Special Power Excursion Reactor Test No. 3 (AEC).	SPERT–3	do	PPC	do	1957
Kinetic Experiment on Water Boilers, No. 2.	KEWB–2	Santa Susana, Calif	NAA	Homogeneous	1958
Nuclear Engineering Test Reactor (USAF).	NETR	Dayton, Ohio	ACF		1958

Planned:					
Food Irradiation Reactor (AEC)[2,5,6]	FIR	Stockton, Calif.		Pressurized Water	1958
Shield Test Reactor (AEC)[5]		NRTS, Idaho	GE	do	
Radiation Effects Reactor (USAF).[1,2,5]	RERL	Marietta, Ga.	Lockheed	Pool	1958

2. Critical Experiment Facilities and Zero Power Reactors [7]

(a) U. S. Locations

Name and/or Owner	*Designation*	*Location*	*Builder*	*Type*	*Start-Up*	*Dismantled*
Operated, Later Dismantled:						
Zero Power Reactor No. 1 (AEC)	ZPR–1	Argonne	ANL	Water	1950	1953
Zero Power Reactor No. 2 (AEC)	ZPR–2	do	ANL	Heavy Water	1952	1955
Zero Power Reactor No. 4 (AEC)	ZPR–4	do	ANL	Light Water	1953	1956
Army Package Power Reactor—Critical (AEC).	APPR–OR	Oak Ridge	ORNL	Pressurized Water	1955	1956
X–10 Critical	X–10–200	do	ORNL	Homogeneous	1946	1948
Operated:						
Zero Power Reactor No. 3 (AEC)	ZPR–3	NRTS, Idaho	ANL		1955	
ORNL Critical Experiment Facility No. 1 (AEC).	ORNL–1	Oak Ridge	ORNL		1950	
ORNL Critical Experiment Facility No. 2 (AEC).	ORNL–2	do	ORNL		1950	
Fast Exponential Experiment (AEC).	FEE	Argonne	ANL		1954	
Physical Constants Test Reactor (AEC).	PCTR	Hanford, Wash.	GE		1955	
PWR Flexible Critical Assembly (AEC).	PWR–FA	Pittsburgh	West		1954	
PWR Mockup (AEC)	PWR Mock-up.	do	West		1954	

See footnotes at end of table.

NUCLEAR REACTORS BUILT, BUILDING, OR PLANNED IN THE UNITED STATES AS OF DECEMBER 31, 1956—Con.

A. *Low Temperature (Not Useful for Power Generation)—Continued*

2. Critical Experiment Facilities and Zero Power Reactors [7]—Continued

(a) U. S. Locations—Continued

Name and/or Owner	*Designation*	*Location*	*Builder*	*Type*	*Start-Up*	*Dismantled*
Two Region Critical Experiment (AEC).	TRX	Pittsburgh	West		1953	
Preliminary Pile Assembly (AEC)[8]	PPA	Schenectady	GE		1948	
Spare Plate Critical Assembly (AEC).	SPCA	Pittsburgh	West			
Danger Coefficient Test Facility (AEC).	DCTF	do	West			
Flexible Plastic Reactor (SAR) (AEC).	FPR	Schenectady	GE			
Flexible Critical Experiment (AEC).	S1C–FC	Windsor, Conn	CE			
Evendale Critical Experiment Facility (USAF).	GEANP–1	Evendale, Ohio	GE			
APPR Criticality Assembly (AEC)	APPR–s	Schenectady	Alco		1956	
Reactivity Measurement Facility (AEC).	RMF	NRTS, Idaho	PPC		1954	
Zero Power Reactor No. 5 (AEC)	ZPR–5	Argonne Lab	ANL		1956	
Being Built:						
Evendale Critical Experiment Facility No. 2 (USAF).	GEANP–2	Evendale, Ohio	GE			
CANEL Nuclear Physics Laboratory (USAF).	CANEL–1	Middletown, Conn	P&W			
Babcock & Wilcox Co		Lynchburg, Va	B&W		1957	

Battelle Memorial Institute	BMI–CX	West Jefferson, Ohio			1957
General Electric Co		Near Livermore, Calif.	GE		1957
Nuclear Development Corporation of America.	NDA–CX	Pawling, N. Y	NDA		1957
Planned:					
Low Power Test Facility (AEC)[2,9]	LPTF	NRTS, Idaho	GE		
Zero Power Reactor No. 6 (AEC)	ZPR–6	Argonne	ANL		
Lockheed Aircraft Co.[1,2]		Palo Alto, Calif			1957
Westinghouse Electric Corporation.[1,2]		Westmoreland County, Pa.	West		1957
The Glenn L. Martin Co.[1,2]		Middle River, Md	Martin		1957
General Atomic Division of General Dynamics Corp.[2]		San Diego, Calif	GDC		1957

(b) Foreign Locations

Planned:					
Denmark[2]		Roskilde, Denmark	NAA		1957

3. Production Reactors—all owned by AEC

Designation	*Builder*	*Type*	*Location*
Operated:			
B Reactor	DuPont	Graphite	Hanford, Wash.
D Reactor	DuPont	do	Do.
F Reactor	DuPont	do	Do.
C Reactor	GE	do	Do.
DR Reactor	GE	do	Do.
H Reactor	GE	do	Do.
KE Reactor	GE	do	Do.
KW Reactor	GE	do	Do.
R Reactor	DuPont	Heavy Water	Savannah River, S. C.
P Reactor	DuPont	do	Do.
K Reactor	DuPont	do	Do.
L Reactor	DuPont	do	Do.
C Reactor	DuPont	do	Do.

See footnotes at end of table.

NUCLEAR REACTORS BUILT, BUILDING, OR PLANNED IN THE UNITED STATES AS OF DECEMBER 31, 1956—Con.

B. *High Temperature Power Producing Reactors*

4a. Military Prototypes and Experiments—all owned by AEC

Name	*Designation*	*Location*	*Builder*	*Type*	*Start-Up*
Operated, Later Dismantled:					
Aircraft Reactor Experiment	ARE	Oak Ridge	ORNL		
Operated:					
Submarine Thermal Reactor, Mark I.	S1W	NRTS, Idaho	West	Pressurized Water	1953
Submarine Intermediate Reactor, Mark A.	S1G	West Milton, N. Y.	GE	Sodium	1955
Heat Transfer Reactor Experiment No. 1.	HTRE-1	NRTS, Idaho	GE		1956
Being Built:					
Army Package Power Reactor No. 1	APPR-1	Fort Belvoir, Va	Alco	Pressurized Water	1957
Large Ship Reactor Prototype (2 reactors).	A1W	NRTS, Idaho	West	do	
Submarine Advanced Reactor	S3G	West Milton, N. Y.	GE	do	
Heat Transfer Reactor Experiment No. 2.	HTRE-2	Lockland, Ohio	GE		
Small Submarine Reactor Prototype.	S1C	Windsor, Conn	CE	Pressurized Water	
Aircraft Reactor Test	ART	Oak Ridge	ORNL		
Planned:					
Argonne Low Power Reactor [1]	ALPR	NRTS, Idaho	ANL	Boiling Water	
Gas Cooled Reactor Experiment [2]	GCRE	do	AGC	Gas Cooled	

5. Full Scale Military Power (all owned by Federal Government)

Type of Use	Designation	Designer	Type	Start-Up
Operated:				
Submarine USS *Nautilus*	SSN571	West	Pressurized Water	1955
Seawolf	SSN575	GE	Sodium	1956
Being Built:				
Submarine *Skate*	SSN578	West	Pressurized Water	
Swordfish	SSN579	West	do	
Sargo	SN583	West	do	
Seadragon	SSN584	West	do	
Skipjack	SSN585	West	do	
Submarine (2 reactors) *Triton*	SSN586	GE	do	
Submarine *Halibut*	SSN587	West	do	
Planned:				
Army Package Power Reactor (Alaska) [2]	APPR-1a	Alco	do	
6 Submarines [2]		West	do	
Guided Missile Cruiser (2 reactors) [2]	CLGN	West	do	
Aircraft Carrier (8 reactors) [2]	CVA(N)	West	do	

6. Civilian Power Reactor Experiments—all owned by AEC

Name	Designation	Location	Type	Builder	Power (Elec. Kw)	Start-Up	Dismantled
Operated, Later Dismantled:							
Boiling Reactor Experiment No. 1.	BORAX-1	NRTS, Idaho	Boiling Water	ANL	No elec	1953	1954
Boiling Reactor Experiment No.2 (modified to BORAX-3).	BORAX-2	NRTS, Idaho	do	ANL	do	1954	1955
Los Alamos Fast Reactor	Clementine	Los Alamos	Liquid Metal	LASL	do	1946	1953
Homogeneous Reactor Experiment No. 1.	HRE-1	Oak Ridge	Aqueous Homogeneous.	ORNL	140	1952	1954
Boiling Reactor Experiment No.3 (modified to BORAX-4).	BORAX-3	NRTS, Idaho	Boiling Water	ANL	3,400	1955	1956

See footnotes at end of table.

NUCLEAR REACTORS BUILT, BUILDING, OR PLANNED IN THE UNITED STATES AS OF DECEMBER 31, 1956—Con.

B. *High Temperature Power Producing Reactors—Continued*

6. Civilian Power Reactor Experiments—all owned by AEC—Continued

Name	*Designation*	*Location*	*Type*	*Builder*	*Power (Elec. Kw)*	*Start-Up*	*Dismantled*
Operated:							
Los Alamos Power Reactor Experiment No. 1.	LAPRE–1	Los Alamos	Aqueous Homogeneous.	LASL	No elec	1956	
Experimental Breeder Reactor No. 1.	EBR–1	NRTS, Idaho	Fast Breeder	ANL	1,400	1951	
Boiling Reactor Experiment No. 4.	BORAX–4	do	Boiling Water	ANL	2,400	1956	
Experimental Boiling Water Reactor.	EBWR	Argonne Lab	do	ANL	5,000	1956	
Being Built:							
Los Alamos Power Reactor Experiment No. 2.	LAPRE–2	Los Alamos	Aqueous Homogeneous.	LASL	No elec	1957	
Sodium Reactor Experiment	SRE	Santa Susana	Sodium Graphite	NAA	6,000	1957	
Organic Moderated Reactor Experiment.	OMRE	NRTS, Idaho	Organic Moderated.	NAA	No elec	1957	
Homogeneous Reactor Experiment No. 2.	HRE–2	Oak Ridge	Aqueous Homogeneous.	ORNL	300–1,000	1957	
Planned:							
Los Alamos Molten Plutonium Reactor Expt.[2]	LAMPRE	Los Alamos	Fast Molten Plutonium.	LASL	No elec	1958	
Experimental Breeder Reactor No. 2.[2]	EBR–2	NRTS, Idaho	Fast Breeder	ANL	15,000	1959	
Liquid Metal Fuel Reactor Experiment.[2]	LMFRE		Liquid Metal	B&W	Undetermined.	1960	

Argonne Boiling Reactor Facility.	ARBOR	NRTS, Idaho	Boiling Water	--------	No elec	1959
Plutonium Recycle Reactor Experiment.	PURRE	Hanford	Heavy Water	GE	----------	------

7a. Full Scale Civilian Power Reactors (AEC Power Demonstration Reactor Program)

Name and/or Owner	*Location*	*Builder*	*Type*	*Power (Elec. Kw)*	*Start-Up*
Being Built:					
Power Reactor Development Co. Inc.	Monroe, Mich	PRDC	Fast Breeder	100, 000	1960
Planned:					
Yankee Atomic Electric Co.[2,9]	Rowe, Mass	West	Pressurized Water	134, 000	1960
Consumers Public Power District[2,5]	Beatrice, Nebr	NAA	Sodium Graphite	75, 000	1960
Rural Cooperative Power Association.[2,10]	Elk River, Minn	AMF	Boiling Water	22, 000	1960
Wolverine Electric Cooperative[1,2,10]	Hersey, Mich	F-W	Aqueous Homogeneous	10, 000	1959
Chugach Electric Association, Inc., and Nuclear Development Corp. of America.[2,5]	Anchorage, Alaska	NDA	Sodium, Heavy Water	10, 000	1962
City of Piqua, Ohio[2,5]	Piqua, Ohio	NAA	Organic Moderated	12, 500	1960

See footnotes at end of table.

NUCLEAR REACTORS BUILT, BUILDING, OR PLANNED IN THE UNITED STATES AS OF DECEMBER 31, 1956—Con.

B. *High Temperature Power Producing Reactors—Continued*

7b. Full Scale Civilian Power Reactors, U. S. Locations (other than Power Demonstration Program)

Name and/or Owner	*Designation*	*Location*	*Builder*	*Type*	*Power (Elec. Kw)*	*Start-up*
Being Built:						
General Electric Co. and Pacific Gas & Electric Co.	--------	Near Livermore, Calif.	GE	Boiling Water	3,000	1958
AEC and Duquesne Light Co. (AEC).	PWR	Shippingport, Pa.	West.	Pressurized Water	60,000	1957
Commonwealth Edison Co. (Nuclear Power Group).	--------	Dresden, Ill.	GE	Boiling Water	180,000	1960
Consolidated Edison Co. of New York.	--------	Indian Point, N. Y.	B&W	Pressurized Water	250,000	1960
Planned:						
Pennsylvania Power & Light Co.[2]	--------	Eastern Pennsylvania	West.	Aqueous Homogeneous	150,000	1962
Nuclear Merchant Ship Reactor.[2] [5] (AEC).	MSR	Shipboard	B&W	Pressurized Water	16,400	1960
Florida Power Corp., Florida Power & Light Co., and Tampa Electric Co.[2]	Florida	--------	--------	--------	200,000	1962
New England Electric Co.[2]	--------	--------	--------	--------	200,000	1964
Carolina-Virginia Nuclear Power Associates, Inc.[2]	--------	--------	--------	--------	--------	
Middle South Utilities, Inc.[2]	--------	--------	--------	--------	--------	

7c. Full Scale Civilian Power Reactors, Foreign Locations

Location	Owner	Builder	Type	Power (Elec. Kw)
Planned:				
Belgium [2]	Syndicate d'Etude de l'Engerie Nucleaire	West	Pressurized Water	11, 500
Dominican Republic [2, 13]	Dominican Republic	Martin	do	12, 000
Latin America (Brazil) [2, 13]	American & Foreign Power Company	GE	Boiling Water	10, 000
Latin America (Cuba) [2, 13]	do	GE	do	10, 000
Latin America (Mexico?) [2, 13]	do	NAA	Organic Moderated	10, 000
Philippines (Manila) [2, 13]	General Public Utilities Corp.			
Italy (Milan) [13]	Edison Volta	West	Pressurized Water	134, 000

[1] License application received by AEC.
[2] Publicly announced.
[3] Geneva Conference Reactor which is being rebuilt at Wurelinger, Switzerland.
[4] Export license application received by AEC.
[5] AEC contract negotiations authorized.
[6] Authorized by Congress.
[7] Critical experiments at Los Alamos and other weapons sites not included.
[8] Formerly located at Sacandago, N. Y.
[9] Contract awarded by AEC.
[10] Of total thermal output of 73.3 Mw., 58 Mw. is to be nuclear and 15.3 conventional.
[11] Of total thermal output of 38 Mw, 31 Mw is to be nuclear and 7 Mw conventional.
[12] 140,000 electrical kw nuclear; 110,000 kw conventional.
[13] Bilateral agreements for cooperation prerequisite to supplying these reactors have not been executed.

Appendix 15

Commission's Financial Report for Fiscal Year 1956

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON 25, D. C.

October 18, 1956

MEMORANDUM TO THE COMMISSIONERS

Transmitted herewith is the unclassified financial report of the Atomic Energy Commission for fiscal year 1956. It contains financial statements which set forth the financial position of AEC at June 30, 1956, the results of operations for fiscal year 1956, and other information of general use to the Commission.

The financial statements are similar to those of industrial firms in form and content and are derived from the accounts maintained directly by AEC and cost-type contractors who have established cost and accounting systems for their AEC operations. The accounts are audited by the AEC audit staff.

Consistent with accepted commercial accounting principles, costs and income are recorded on an accrual basis and financial control is maintained over all inventories and other assets of the Commission.

Don S Burrows

DON S. BURROWS,
Controller.

Honorable LEWIS L. STRAUSS, *Chairman.*
Commissioner THOMAS E. MURRAY.
Commissioner WILLARD F. LIBBY.
Commissioner JOHN VON NEUMANN.
Commissioner HAROLD S. VANCE.

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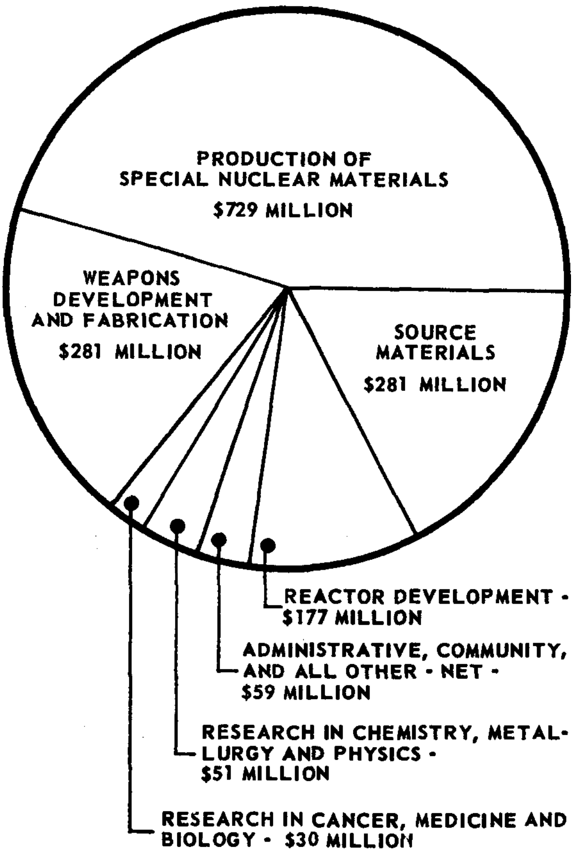
Operations

Because of the rapid expansion by AEC, private industry and other nations in nearly every field of atomic energy from basic research to planning for and constructing full scale power reactors, AEC operating costs increased 25 percent in fiscal year 1956 to $1.6 billion. The chart, "costs of operations," shows the portion of costs related to the various AEC activities.

COST OF OPERATIONS
FISCAL YEAR 1956
$1.6 BILLION



The increased emphasis placed on the development of reactors for use in the generation of electric power and the propulsion of aircraft, ships and submarines brought the costs of AEC work in this field up 48 percent over 1955, to $177 million for fiscal year 1956.

The cost of uranium and other source materials purchased, the production of enriched uranium, plutonium and other special materials and weapons development and fabrication increased 24 percent over 1955 to $1.3 billion in fiscal year 1956.

The cost of research in cancer, medicine, biology, chemistry, metallurgy and other studies of the nature and behavior of the atom and its multiple possibilities of improving the standard of living throughout the world increased 11 percent to $81 million in fiscal year 1956.

Sale of nuclear materials, heavy water and income from other sources increased to $15 million in fiscal year 1956 from $6 million in 1955.

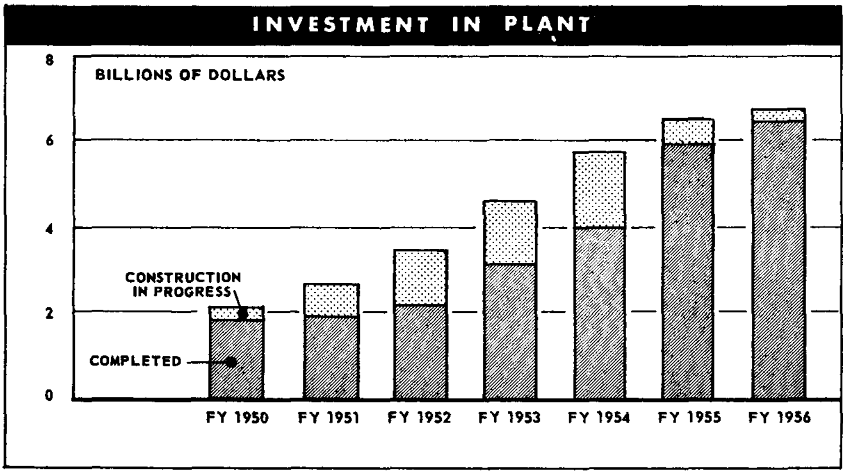
Significant developments during fiscal year 1956 included increased participation by private industry in financing plants which will process nuclear materials and use atomic energy. This participation is particularly apparent in planning plants for generation of electric power with nuclear energy and in the construction of plants to extract uranium concentrates from ores.

In fiscal year 1956 the Commission also extended its domestic uranium procurement program from April 1, 1962 through December 31, 1966. The new program, under stipulated conditions, provides a guaranteed market of $8 a pound for uranium concentrates produced by domestic mills from domestic ores.

Charges for materials sold or leased and prices to be paid for certain products produced by private reactors were established.

Plant

The cost of AEC-owned production plants, research laboratories and other facilities existing at June 30, 1956 amounted to $6.5 billion, nearly 50 percent of the appropriated funds spent by AEC and its predecessor organizations for the atomic energy program. The chart "Investment in Plant", shows the increase in these facilities over the past seven years. The principal additions to completed plant during the year included gaseous diffusion facilities at Portsmouth, Ohio, and production reactor facilities at Hanford, Washington. Expenditures for plant and equipment decreased 64 percent to $302 million in fiscal year 1956 from $843 million in fiscal year 1955. Construction work in progress at the end of the year decreased, 61 percent to $247 million at June 30, 1956 from $629 million at June 30, 1955. A major portion of the construction in progress at June 30, 1956 was in the production reactor areas at the Hanford and Savannah River plants, at



the feed materials plants in Fernald, Ohio, and St. Louis, Missouri, and at the gaseous diffusion plants.

Changes in the investment in plant and equipment during fiscal year 1956 were as follows:

INVESTMENT IN PLANT
(in thousands)

	Completed Plant	*Construction in Progress*	*Total*
Investment—July 1, 1955	$5, 858, 349	$628, 952	$6, 487, 301
Construction costs incurred during the year	—	301, 682	301, 682
Facilities completed during the year	683, 610	(683, 610)	—
Plant retirements	(29, 309)	—	(29, 309)
Transfers to other Federal agencies	(46, 613)	—	(46, 613)
Investment—June 30, 1956	$6, 466, 037	$247, 024	$6, 713, 061

The investment in the various types of facilities at June 30, 1956 is shown on page 372.

INVESTMENT IN PLANT AND EQUIPMENT
June 30 1956
(in thousands)

	Completed Plant	Construction in Progress	Total	Percent of Total
Production facilities:				
Raw materials	$6, 565	$2, 268	$8, 833	0. 1
Feed materials	220, 839	43, 602	264, 441	4. 0
Gaseous diffusion plants	2, 284, 172	31, 242	2, 315, 414	34. 5
Production reactors and separation areas	1, 511, 079	61, 738	1, 572, 817	23. 4
Weapons	489, 957	21, 690	511, 647	7. 6
Other	737, 522	27, 654	765, 176	11. 4
Total production	5, 250, 134	188, 194	5, 438, 328	81. 0
Research facilities:				
Laboratories	472, 684	8, 321	481, 005	7. 2
Reactors	101, 364	29, 578	130, 942	1. 9
Accelerators	44, 847	8, 584	53, 431	. 8
Other	97, 215	8, 672	105, 887	1. 6
Total research	716, 110	55, 155	771, 265	11. 5
Communities	299, 292	3, 317	302, 609	4. 5
Other	200, 501	358	200, 859	3. 0
Total	$6, 466, 037	$247, 024	$6, 713, 061	$100. 0

Inventories

For security reasons the assets shown in this report do not include substantial inventories of certain products. The inventories shown in the following table increased to $1.6 billion at June 30, 1956 from $1.3 billion at June 30, 1955 or $265 million.

	June 30, 1956	June 30, 1955 (in thousands)	Increase
Production inventories in process	$1, 236, 359	$1, 061, 383	$174, 976
Source and special nuclear research material	189, 743	143, 612	46, 131
Source and special nuclear materials leased	666	—	666
Special reactor material	45, 074	16, 689	28, 385
Other special materials	18, 391	11, 296	7, 095
Stores	83, 384	75, 578	7, 806
	$1, 573, 617	$1, 308, 558	$265, 059

Production inventories in process include uranium and other materials in the process of refinement and manufacture of special nuclear materials and weapons. Source and special nuclear research material includes uranium, thorium, plutonium and other products used in research and development activities. A large portion of these inventories is nuclear materials that could be used for peaceful purposes.

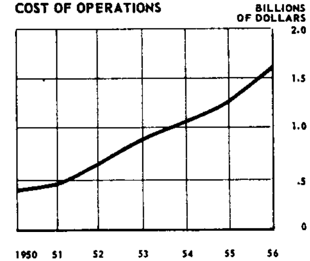
UNITED STATES ATOMIC ENERGY COMMISSION SUMMARY OF FINANCIAL DATA

(in thousands of dollars)

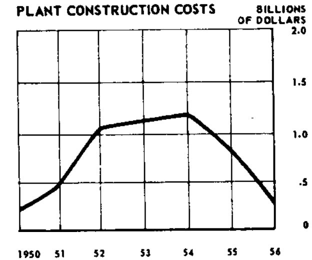
	1956	1955	1954	1953	1952	1951	1950
Cost of operations[1]	$1, 607, 973	$1, 289, 535	$1, 039, 178	$ 904, 596	$ 684, 181	$ 494, 638	$ 414, 766
Procurement and production of nuclear materials	1, 009, 918	782, 031	552, 528	400, 408	278, 256	188, 312	168, 544
Weapons development and fabrication	280, 765	259, 706	251, 066	257, 888	229, 228	163, 644	111, 970
Development of nuclear reactors	176, 961	119, 404	99, 715	104, 492	64, 884	44, 472	31, 530
Research in chemistry, metallurgy and physics	51, 282	43, 898	43, 149	42, 452	36, 147	31, 595	31, 197
Research in cancer, medicine and biology	30, 126	29, 144	27, 237	26, 728	25, 234	21, 866	18, 673
Community operations—net	8, 954	10, 321	11, 822	15, 157	16, 363	17, 322	19, 895
Administrative expenses	38, 195	34, 027	34, 671	35, 514	31, 432	24, 541	22, 868
Other expenses and income—net	11, 772	11, 004	18, 990	21, 957	2, 637	2, 886	10, 089
Plant construction costs incurred during the year	$ 301, 682	$ 842, 504	$1, 215, 141	$1, 125, 579	$1, 082, 174	$ 459, 192	$ 256, 126
Total AEC assets, excluding inventories of certain products, at June 30	$8, 602, 519	$9, 139, 219	$8, 951, 800	$8, 577, 007	$4, 692, 584	$3, 680, 333	$2, 216, 487
Completed plant at June 30	$6, 466, 037	$5, 858, 349	$4, 090, 271	$3, 149, 513	$2, 133, 875	$1, 924, 812	$1, 809, 645
Production plants	5, 250, 134	4, 654, 408	2, 957, 784	2, 118, 137	1, 327, 335	1, 287, 447	1, 251, 022
Research facilities	716, 110	698, 449	616, 548	548, 009	338, 836	233, 702	184, 393
Communities	299, 292	299, 290	300, 248	298, 454	287, 999	281, 727	261, 831
Other	200, 501	206, 202	215, 691	184, 913	179, 705	121, 936	112, 399
Plant construction in progress at June 30	$ 247, 024	$ 628, 952	$1, 615, 134	$1, 429, 576	$1, 363, 082	$ 591, 202	$ 294, 788
Appropriations received	$ 834, 227	$1, 209, 860	$1, 042, 492	$4, 136, 476	$1, 605, 756	$2, 032, 143	$ 702, 931
Operations	1, 146, 400[2]	1, 098, 978	886, 483	808, 935	—	—	—
Plant and equipment	(312, 173)[2]	110, 882	156, 009	3, 327, 541	—	—	—
Number of employees	110, 143	112, 555	141, 949	148, 799	149, 371	99, 126	63, 739
AEC employees	6, 583	6, 013	6, 123	6, 894	6, 662	5, 646	4, 941
Operating contractor employees	90, 238	82, 936	73, 312	71, 775	58, 101	47, 745	39, 095
Construction contractor employees	13, 322	23, 606	62, 514	70, 130	84, 608	45, 735	19, 703

[1] Includes depreciation.
[2] Includes transfer to operations of $571 million appropriated in prior years as plant and equipment funds.

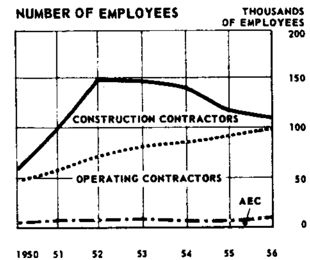
COST OF OPERATIONS



PLANT CONSTRUCTION COSTS



NUMBER OF EMPLOYEES



UNITED STATES ATOMIC ENERGY COMMISSION
COMPARATIVE BALANCE SHEET

ASSETS

	June 30, 1956 (in thousands)	June 30, 1955
Cash:		
In U. S. Treasury	$1, 409, 115	$2, 215, 329
With integrated contractors	23, 204	31, 949
	1, 432, 319	2, 247, 278
Working capital advances:		
With other Federal agencies	75, 277	99, 773
With nonintegrated contractors	5, 514	4, 418
	80, 791	104, 191
Accounts receivable:		
From other Federal agencies	2, 007	1, 182
Other, less allowance for uncollectible accounts of $129 thousand in 1956 and $192 thousand in 1955	12, 994	9, 483
	15, 001	10, 665
Inventories:		
Production inventories in process	1, 236, 359	1, 061, 383
Source and special nuclear material at research installations	189, 743	143, 612
Source and special nuclear materials leased	666	—
Stores, less allowance for loss of $10,635 thousand in 1956 and $9,929 thousand in 1955	83, 384	75, 578
Special reactor material	45, 074	16, 689
Other special materials	18, 391	11, 296
	1, 573, 617	1, 308, 558
Plant:		
Completed plant and equipment	6, 466, 037	5, 858, 349
Less—Accumulated depreciation	1, 269, 719	1, 069, 620
	5, 196, 318	4, 788, 729
Construction work in progress	247, 024	628, 952
	5, 443, 342	5, 417, 681
Collateral funds and other deposits	25, 016	29, 352
Prepayments and deferred charges	32, 433	21, 494
Total assets	$8, 602, 519	$9, 139, 219

NOTES TO THE BALANCE SHEET

1. For security reasons inventories of certain products are not included in assets in this report.
2. The balance sheet does not include 64,751,316 troy ounces of silver loaned to AEC by the Treasurer of the United States for use as electrical conductors in plants. Based on market quotations at June 30, 1956, this silver had a value of $59 million.
3. In addition to the liabilities shown on the balance sheet, AEC had at June 30, 1956:
   a. contingent liabilities for claims against the Federal Government or AEC contractors of approximately $33 million;

LIABILITIES AND AEC EQUITY

	June 30, 1956	June 30, 1955
	(in thousands)	
Liabilities:		
Accounts payable and accrued expenses:		
To other Federal agencies	$21, 313	$24, 192
Other	198, 826	210, 653
	220, 139	234, 845
Working fund advances from other Federal agencies	51, 792	57, 017
Funds held for others	7, 041	6, 997
Deferred credits	726	353
Total liabilities	279, 698	299, 212
AEC Equity, July 1	8, 840, 007	8, 652, 224
Additions:		
Appropriated funds—net	834, 227	1, 209, 860
Nonreimbursable transfers from other Federal agencies	36, 779	3, 002
	871, 006	1, 212, 862
Deductions:		
Net cost of operations and adjustments to costs of prior years	1, 558, 194	1, 276, 280
Less—change in inventories of research materials, work in process and materials leased	221, 773	293, 893
	1, 336, 421	982, 387
Nonreimbursable transfers to other Federal agencies	42, 589	29, 454
Funds returned to U. S. Treasury	9, 182	13, 238
	1, 388, 192	1, 025, 079
AEC Equity, June 30	8, 322, 821	8, 840, 007
Total liabilities and AEC equity	$8, 602, 519	$9, 139, 219

b. contingent liabilities as guarantor on loans under the Defense Production Act of 1950 to the extent of $10 million;

c. commitments for vacation pay of AEC and contractor employees of $14 million; and

d. commitments applicable to future periods represented by unpaid obligations of $719 million.

4. The AEC has guaranteed minimum prices through December 1966 for domestic uranium ores and concentrates. In addition, bonuses are payable under certain specified circumstances to stimulate the discovery of new uranium sources. The AEC also has long-term commitments for the purchase of foreign ores, the development of foreign ore sources, and the return of residues of foreign ores processed in this country.

UNITED STATES ATOMIC ENERGY COMMISSION
COMPARATIVE STATEMENT OF OPERATIONS

	Fiscal year ended June 30, 1956 (in thousands)	Fiscal year ended June 30, 1955
Production costs:		
Procurement and production of source and special nuclear materials	$1, 009, 918	$782, 031
Weapons development and fabrication	280, 765	259, 706
	1, 290, 683	1 041, 737
Research expenses:		
Development of nuclear reactors	176, 961	119, 404
Chemistry metallurgy and physics	51, 282	43, 898
Cancer medicine and biology	30, 126	29, 144
Vocational and educational training	1, 702	1, 382
	260, 071	193, 828
Community operations:		
Expenses	29, 417	31, 918
Less—Revenues	20, 463	21, 597
	8, 954	10, 321
AEC administrative expenses	38, 195	34, 027
Security investigations	7, 526	9, 817
Cost of materials sold and other expenses	17, 151	5, 488
Less—Income:		
Sales of source and special nuclear materials	3, 295	997
Sales of heavy water	5, 059	—
Sales of isotopes	2, 297	1, 692
Miscellaneous	3, 956	2, 994
	14, 607	5, 683
Net cost of operations	1, 607, 973	1, 289, 535
Credits applicable to prior years' costs—net	(49, 779)	(13, 255)
Net cost of operations—less credits applicable to prior years' costs	$1, 558, 194	$1, 276, 280

NOTE.—Costs of operations shown in this statement represent costs incurred for procurement and production of source and special nuclear materials and weapons parts and assemblies. Net cost of operations includes depreciation of $260 million in 1956 and $237 million in 1955.

AUDITOR'S REPORT

We have examined the balance sheet of the Atomic Energy Commission as at June 30, 1956 and the accompanying statement of operations for the fiscal year then ended.

These statements are a consolidation of financial statements of the ten AEC Operations Offices, the Washington Office, and their integrated contractors. In the AEC-wide audit examination thereof, the systems of control and related procedures affecting the principal activities including the accounting systems of the AEC and its integrated contractors were reviewed, and without performing detailed audits of transactions, examinations or tests of the accounting records and supporting evidence were made by methods and to the extent contemplated by the AEC internal audit program and considered necessary in the circumstances. However, the audit program did not provide for nor did the audits include the verification of quantities and values of production inventories in process, and source and special nuclear research materials.

Subject to the qualification noted in the preceding paragraph, and based upon the opinions furnished by the Chief Auditor of each Operations Office, it is my opinion that the balance sheet and accompanying statement of operations, together with the notes thereto, fairly present the assets, liabilities and equity of the Atomic Energy Commission as at June 30, 1956 and the operating costs for the fiscal year then ended, in conformity with applicable AEC policies, contractual provisions, and generally accepted accounting principles.

Charles F. Schank

Assistant Controller for Auditing.

SEPTEMBER 1956.

SOURCE AND USE OF AEC FUNDS

(in millions)

	Fiscal year 1956	*Fiscal year 1955*
Cash balance, July 1	$2, 215	$2, 897
Funds provided by:		
Congressional appropriations—net	834	1, 210
Working fund advances	44	9
Community revenues	20	22
Decreases in working capital	—	26
Other sources	61	19
Total available	3, 174	4, 183
Funds used for:		
Operations:		
Procurement and production of source and special nuclear materials	824	620
Weapons development and fabrication	247	228
Development of nuclear reactors	159	101
Chemistry, metallurgy and physics	47	38
Cancer, medicine and biology	28	27
Vocational and educational training	2	1
Community expense	18	19
AEC administrative expense	37	33
Security investigations	8	10
	1, 370	1, 077
Plant and equipment	300	836
Work for others	54	40
Increases in working capital	30	—
Funds returned to U. S. Treasury	9	13
Other uses	2	2
Total used	1, 765	1, 968
Cash balance, June 30	$1, 409	$2, 215

U. S. GOVERNMENT INVESTMENT IN THE ATOMIC ENERGY PROGRAM

From June 1940 through June 1956

	Amount (in millions)	
Appropriation payments net of reimbursement:		
National Defense Research Council	$0. 5	
Office of Scientific Research and Development	14. 6	
War Department (including Manhattan Engineer District):		
Fiscal year 1943	77. 1	
Fiscal year 1944	730. 3	
Fiscal year 1945	858. 6	
Fiscal year 1946	366. 3	
Fiscal year 1947—part	186. 0	
		$2, 233. 4
Atomic Energy Commission:		
Fiscal year 1947—part	146. 1	
Fiscal year 1948	477. 6	
Fiscal year 1949	627. 3	
Fiscal year 1950	534. 3	
Fiscal year 1951	920. 5	
Fiscal year 1952	1, 669. 4	
Fiscal year 1953	1, 812. 7	
Fiscal year 1954	1, 930. 5	
Fiscal year 1955	1, 861. 9	
Fiscal year 1956	1, 633. 5	
		11, 613. 8
Total payments—Net		13, 847. 2
Unexpended balance of appropriations, June 30, 1956		1, 355. 4
Total appropriated funds		15, 202. 6
Less:		
Collections paid to U. S. Treasury	52. 6	
Property and services transferred to other Federal agencies without reimbursement, net of such transfers received from other Federal agencies	32. 4	
		85. 0
Total investment through June 30, 1956		15, 117. 6
Less:		
Cost of operations including depreciation and obsolescence from June 1940 through June 30, 1956		6, 794. 8
AEC equity at June 30, 1956		$8, 322. 8

SALES AND SERVICES

Sale and Lease of Source and Special Nuclear Materials

AEC has established prices for the sale or lease of source and special nuclear materials for use in the generation of electric power and for research and other purposes. Through June 30, 1956 applications have been approved and commitments made to furnish approximately $200 million worth of special nuclear materials over the next 40 years.

Since AEC retains title to special nuclear materials, such material is leased rather than sold. The lessee is required to pay a use-charge of four percent per annum and the established price for the quantity of material consumed. To encourage the development of a nuclear power industry, contracts executed under the power reactor demonstration program have waived this use-charge for a period of five years. At June 30, 1956, $666 thousand worth of material was under lease to licensees. In fiscal year 1956 sales of source materials to other countries totaled $2.6 million and sales to domestic organizations totaled $652 thousand.

Nuclear fuels are also committed to the military services for propulsion of submarines, ships, electric power and other uses. Under an agreement with the services AEC provides the initial fuel requirements for these reactors without charge and is to be reimbursed for fuel consumed and for the cost of recovery of fissionable material from spent cores.

Sales of Heavy Water

The first sales of heavy water to aid foreign nations and domestic industrial and research organizations in developing peacetime uses of atomic energy were made in fiscal year 1956. The price established by AEC for the sale of heavy water is $28 a pound. Sales consummated during fiscal year 1956 were as follows:

United Kingdom of Great Britain	$1, 849, 714
Canada	1, 693, 860
India	1, 177, 391
France	308, 549
Belgium	151
Domestic organizations	29, 286
Total	$5, 058, 951

Isotopes

During fiscal year 1956, 13,035 shipments of radioisotopes were made to users in all forty-eight states of the United States and the District of Columbia, as well as Alaska, Hawaii, Panama, Puerto Rico, and numerous foreign countries, compared with 12,775 shipments during fiscal year 1955. The AEC furnishes isotopes to qualified users for biomedical research, including research in medical therapy and diagrams, and for agricultural research, at 20 percent of the established price.

In fiscal year 1956, 375 shipments of stable isotopes were made for use in physical, biological and medical research.

The following table shows costs of production of isotopes, sales and other isotope distribution costs during fiscal years 1956 and 1955:

	Fiscal year 1956 (in thousands)	Fiscal year 1955
Cost of production	\$2, 776	\$2, 041
Sales	2, 297	1, 692
Discounts allowed	220	244
Used for AEC programs	167	38

Irradiation Services

Occasionally industrial and research organizations need irradiated materials in forms and quantities not normally available. In such cases, irradiations are performed on special target materials. Generally, this includes the irradiation of such items as gears, piston rings, seeds, etc., and, in some cases, the irradiation of special chemical compounds.

Charges amounting to \$458 thousand were made by AEC during fiscal year 1956 for 488 of these irradiation services. The charges include a share of the reactor operating cost, special processing, special handling, or any other special services directly related to the requested service.

Vocational and Educational Training

AEC sponsors training for scientists, engineers and others who will be engaged in the development of peaceful uses of atomic energy. The training is conducted through the Oak Ridge School of Reactor Technology and the Oak Ridge Institute of Nuclear Studies at Oak Ridge, Tennessee, the International School of Nuclear Science and Engineering at Argonne National Laboratory, Lemont, Illinois, and the Life Science Fellowship Program. A portion of the training is conducted at state universities and colleges. The courses provide training in reactor technology, the use and handling of radioisotopes, and in life sciences related to hazards resulting from exposure to radioactive materials.

In fiscal year 1956 the cost of this training totaled \$1.7 million. Tuition fees from students sponsored by industrial firms and foreign countries totaled \$187 thousand.

Other Services

The Commission also charges for security investigations, use of Commission-owned facilities and equipment, and other services performed for private individuals or organizations. Charges during fiscal year 1956 for security investigations and the use of AEC-owned facilities and equipment totaled $152 thousand and $242 thousand, respectively. Charges for miscellaneous other services performed during 1956 totaled $166 thousand.

NUCLEAR POWER REACTORS

Experimental Power Reactors

The cost of development and construction of experimental power reactors increased to $51.6 million in fiscal year 1956 from $28.4 million in fiscal year 1955, an increase of 82 percent. The rate of acceleration of developing these reactors is shown by the following table:

Fiscal year	Total	Research and Development (in millions)	Construction
1956	$51.6	$42.2	$9.4
1955	28.4	26.3	2.1
1954	18.9	18.9	—
1953	10.1	10.0	.1
1952	6.3	5.9	.4
1951	5.1	3.2	1.9
1948–50	3.1	2.2	.9
Total	$123.5	$108.7	$14.8

The investment by AEC in research, development and construction on each type of reactor is as follows:

DEVELOPMENT AND CONSTRUCTION OF EXPERIMENTAL POWER REACTORS (*in millions*)

	Fiscal year 1956			Cumulative from July 1, 1947		
	Total	Development	Construction	Total	Development	Construction
Pressurized Water	$22.3	$15.2	$7.1	$41.4	$33.1	$8.3
Boiling Water	5.3	4.7	.6	14.6	13.9	.7
Sodium Graphite	5.0	5.0	—	10.0	10.0	—
Fast Power Breeder	6.2	4.7	1.5	22.5	17.7	4.8
Homogeneous	10.8	10.7	.1	33.0	32.1	.9
Liquid Metal Fuel	1.6	1.6	—	1.6	1.6	—
Organic Moderator	.4	.3	.1	.4	.3	.1
Total	$51.6	$42.2	$9.4	$123.5	$108.7	$14.8

The *pressurized water reactor* now under construction at Shippingport, Pennsylvania is the first of the above reactor types that will produce large quantities of electric power. The Duquesne Light Company is building the electric generation portion of the plant at an estimated cost of $10 million and is contributing $5 million to AEC toward the cost of development and construction of the reactor portion of the plant. The Westinghouse Electric Corporation is building the reactor under a cost-type contract with AEC and is contributing $500 thousand to the project. It is estimated that construction of the reactor portion of the plant will cost approximately $45 million, with AEC contributing $39.5 million and the two companies a total of $5.5 million. It is expected the plant will begin producing electric power in the latter part of 1957. For steam supplied to the turbine generators from the nuclear portion of the plant, the Duquesne Light Company will pay AEC at the rate of 8 mills per kilowatt hour for the net electrical output of the generators.

The *experimental boiling water reactor* under construction at Argonne National Laboratory, Lemont, Illinois is expected to be in operation by February of 1957 with an output of 5,000 kilowatts of electricity. Construction costs for a building to house the reactor are estimated at $1.0 million. Cumulative research and development costs from 1953 total $13.9 million of which $1.9 million was spent on fabrication of the experiment.

The *experimental sodium graphite reactor* at Santa Susana, California is expected to be in operation early in 1957. It is estimated the cost of this reactor will total $17.3 million, of which approximately $14.5 million will be borne by AEC and $2.8 million by North American Aviation, Inc. The Southern California Edison Company will install a turbine-generator plant, electrical equipment and heat exchangers and will pay AEC 45 cents per million BTU for the heat used to generate electricity.

Construction of the *fast power breeder reactor* at the National Reactor Testing Station, Arco, Idaho, is expected to start in July of 1957. Beginning of operations is expected late in 1959 with gross electrical output rated at 20,000 kilowatts. Construction costs of this experimental reactor are estimated at $15.3 million.

Construction of the *experimental homogeneous reactor* at Oak Ridge National Laboratory, Oak Ridge, Tennessee was completed in April 1956. Tests are now being conducted and the reactor is expected to become critical in November 1956. Costs through June 30, 1956 totaled $32.1 million for research and development on this type of reactor and $.9 million for construction.

In addition to the five types of power reactors listed above, the Commission is planning work on four new types. In the latter part of fiscal year 1956 the Commission executed a contract with North

American Aviation, Inc., for work on an organic-moderated reactor experiment. Estimated cost of the initial phase of this project is $1.8 million of which $750 thousand will be furnished by North American Aviation, Inc. Through June 30, 1956 development and construction costs of work on the organic-moderated reactor totaled $.4 million. Research and development costs on the liquid metal fuel reactor totaled $1.6 million through June 30, 1956. Contracts are being negotiated for work on the liquid metal fuel reactor experiment and a gas-cooled reactor experiment. In fiscal year 1957 work will be done at Hanford on the experimental plutonium recycle reactor.

Power Demonstration Program

Under the Power Demonstration Reactor Program, a contract has been executed with the Yankee Atomic Electric Company for construction of a power reactor estimated to cost $39.5 million, and five other industry proposals with a potential investment by industry of more than $100 million are under consideration.

Army Power Reactors

The army package power reactor under construction at Fort Belvoir, Virginia is scheduled for operation in early 1957. The reactor is intended to produce 1,825 kilowatts of electricity. Development and construction cost of this project are expected to total $4.9 million, $3.3 million to be provided by AEC and $1.6 million by the Department of the Army. Through June 30, 1956 development costs totaled $1.2 million and construction costs $.3 million.

A smaller army power reactor, the Argonne Low Power Reactor, scheduled to produce approximately 200 kilowatts of electricity, will be constructed at the National Reactor Testing Station in Idaho. Construction costs of this project are extimated at $1.2 million. Through June 30, 1956 development costs totaled $.2 million.

Reactor Technology

The technology of building nuclear reactors for generation of electric power is also benefited by research directed primarily toward the development of nuclear-powered aircraft, ships, and submarines. The table on page 385 summarizes AEC research and construction costs related primarily to the development of reactors.

	Research and development 1956	Research and development 1955	Construction 1956	Construction 1955
	(in millions)			
Experimental Power Reactors	$42. 2	$26. 3	$9. 4	$2. 1
Army Power Reactors	. 9	. 6	. 3	—
Aircraft Reactors	49. 6	22. 6	2. 4	3. 3
Naval Propulsion Reactors	40. 9	26. 8	9. 8	12. 9
Special Classified Projects	6. 7	6. 3	. 1	—
Operation of Service Facilities	5. 5	4. 7	1. 1	5. 7
General	13. 2	12. 6	9. 7	7. 0
Special nuclear materials consumed	4. 1	2. 1	—	—
Depreciation of Facilities	13. 9	17. 4	—	—
Total	$177. 0	$119. 4	$32. 8	$31. 0

AIRCRAFT REACTORS

Aircraft reactor development costs increased to $49.6 million in fiscal year 1956, or 119 percent from $22.6 million in fiscal year 1955. Construction costs during fiscal year 1956 totaled $2.4 million as compared with $3.3 million in fiscal year 1955, a decrease of 27 percent.

Cumulative costs incurred from 1950 through June 30, 1956 in the development and construction of aircraft reactors totaled $138 million, as shown in the following table:

Fiscal year	Total	Research and development (in millions)	Construction
1956	$52. 0	$49. 6	$2. 4
1955	25. 9	22. 6	3. 3
1954	22. 0	14. 6	7. 4
1953	20. 2	17. 1	3. 1
1952	11. 0	10. 6	. 4
1951	5. 5	5. 5	—
1950	1. 4	1. 4	—
Total	$138. 0	$121. 4	$16. 6

NAVAL PROPULSION REACTORS

The Naval Propulsion Reactor Program consists of the development of specific reactors for naval propulsion plants, research effort to evaluate new concepts that may produce higher performance and special purpose power plants for naval vessels, and the support and operation of a testing facility which will contribute to the technology of all water-cooled reactor plants. This program continues to be recognized as an important accelerating influence in the practical development of nuclear plants for peaceful uses of atomic energy.

Naval reactor development costs increased to $40.9 million in fiscal year 1956, or 53 percent from $26.8 million during fiscal year 1955.

Construction costs during fiscal year 1956 totaled $9.8 million as compared with $12.9 million in fiscal year 1955, a decrease of 24 percent.

Cumulative costs incurred from 1948 through June 30, 1956 in the development and construction of naval reactors totaled $273.3 million as shown in the following table:

Fiscal year	*Total*	*Research and development* (in millions)	*Construction*
1956	$50. 7	$40. 9	$9. 8
1955	39. 7	26. 8	12. 9
1954	49. 0	24. 9	24. 1
1953	57. 3	32. 9	24. 4
1952	38. 0	26. 1	11. 9
1951	29. 8	22. 2	7. 6
1948–50	8. 8	8. 7	. 1
Total	$273. 3	$182. 5	$90. 8

INTERNATIONAL COOPERATION

The International Conference on the Peaceful Uses of Atomic Energy at Geneva, Switzerland in August of 1955, was among the significant developments in fiscal year 1956 under the President's Atoms-for-Peace program. Costs in connection with the International Conference at Geneva amounted to $1.5 million which included installation, transportation and operation of a demonstration reactor; salaries, wages, and travel of security personnel; travel of other AEC employees to and from the conference; and cost of exhibits, films, pamphlets, and other materials procured specifically for use at the conference. The principal AEC exhibit was a pool type research reactor built at Oak Ridge, Tennessee, and transported to Geneva. The reactor was later sold to Switzerland for $180,000.

The United States has concluded negotiations for 39 Agreements for Cooperation with foreign nations which relate to the development of programs in the field of nuclear energy. Negotiations are in progress with 12 additional countries. In fiscal year 1957, the United States plans to grant $5,500,000 to foreign nations under existing agreements for cooperation to assist them in the construction of research reactors. Maximum aid of $350,000 is to be given each recipient nation from Mutual Security Program Funds provided through the Atomic Energy Commission. Through June 30, 1956, commitments were given to four nations for grants upon completion of their reactors, as shown on page 387.

Country	*Type of reactor*	*United States contribution*	*Total estimated cost*
Spain	3 Megawatt Pool	$350, 000	$977, 000
Brazil	5 Megawatt Pool	350, 000	1, 000, 000
Netherlands.	20 Megawatt Pool	350, 000	1, 600, 000
Denmark	5 Megawatt Pool	350, 000	1, 485, 000

In fiscal year 1956 the Commission approved sales of 129 tons of heavy water to six foreign nations for use as a moderator and coolant in reactors for developing peaceful uses of the atom. Sales consummated during the year totaled 90 tons at a total price of $5 million.

PROCUREMENT OF SOURCE MATERIALS

The cost of uranium and other source materials procured during the fiscal year 1956 amounted to $266 million. These materials were procured from sources in the United States, Australia, Belgian Congo, Canada, Portugal and South Africa. AEC exploration costs amounted to $9.4 million in fiscal year 1956 or 26 percent less than 1955 and 28 percent less than 1954. This reduction resulted principally from industry participation in physical exploration for uranium. The Commission has virtually eliminated this type of effort from its program. Bonus incentive payments for new ore production increased to $2.2 million in fiscal year 1956 from $1.7 million in fiscal year 1955.

At June 30, 1956 there were ten privately owned-and-operated uranium ore processing mills in operation in the United States and thirteen additional mills were either under construction or in the planning stage. Private industry performs all of the domestic uranium mining and milling operations in the United States, with the exception of one AEC-owned mill at Monticello, Utah. The operators of uranium ore processing mills sell concentrates to the AEC under fixed-price contracts. The magnitude of uranium ore milling industry is indicated in the table on page 388.

Operators	Location	Estimated private investment (in thousands)
Mills in operation at June 30, 1956:		
Climax Uranium Co.	Grand Junction, Colo. . . .	$3, 088
Vitro Uranium Co..	Salt Lake City, Utah. . . .	2, 500
Union Carbide Nuclear Co. . . .	Uravan, Colorado	5, 000
Union Carbide Nuclear Co. . . .	Rifle, Colorado	1, 600
Vanadium Corp. of America. . .	Naturita, Colorado.	1, 000
Vanadium Corp. of America. . .	Durango, Colorado.	813
Kerr-McGee Oil Industries, Inc. .	Shiprock, N. M	3, 161
The Anaconda Company	Bluewater, N. M.	19, 358
Rare Metals Corp	Tuba City, Ariz	3, 600
Trace Elements Corp.	Maybell, Colorado	400
Mills on which contracts were executed at June 30, 1956:		
Uranium Reduction Co	Moab, Utah.	8, 250
Mines Development Co.	Edgemont, S. D	1, 900
Continental Uranium Co	La Sal, Utah	1, 250
Atomic Fuels Extraction	Bedrock, Colo	2, 072
Union Carbide Nuclear Co . . .	Rifle, Colo.	8, 500
Contracts for uranium concentrates under consideration.		36, 333
Total.		$98, 825

The AEC owns a number of ore buying stations on and near the Colorado plateau, a pilot plant at Grand Junction, Colorado, an ore processing mill at Monticello, Utah, and handling, storage, sampling and assaying facilities at Grand Junction, Colorado. The investment in plant and equipment in these facilities at June 30, 1956 totaled $5.9 million.

In fiscal year 1956 AEC spent $3.4 million in its process development efforts. Information gained from this development effort and from operation of the pilot plant at Grand Junction, Colorado is available to commercial operators of ore processing plants. The process improvements developed have resulted in substantial savings to the government by enabling the commission to negotiate lower concentrate prices with new mills.

PRODUCTION OF NUCLEAR MATERIALS

Feed Materials

AEC plants for the production of feed materials for reactor and gaseous diffusion plant operations are located at St. Louis, Missouri, and Fernald, Ohio. The St. Louis facility, operated by Mallinckrodt Chemical Works, produces high purity uranium metal in ingot form from uranium concentrates. The Fernald facility, operated by National Lead Company of Ohio, performs the same operations as the St. Louis plant plus the rolling and machining of fuels for production reactor operations. A third plant to produce high purity uranium ingots now under construction at Weldon Spring, Missouri, will also be operated by Mallinckrodt Chemical Works. Plants for the production of uranium hexafluoride from high purity uranium oxide are located at Oak Ridge, Tenn. and Paducah, Ky., and are operated by Union Carbide Nuclear Company. An additional plant for the production of uranium hexafluoride is under construction at Portsmouth, Ohio, and will be operated by Goodyear Atomic Corporation. The estimated investment at the Weldon Spring site upon completion is $41.7 million, and at the Portsmouth plant is $11.4 million. The investment in plant and equipment at existing sites is shown in the following table:

	Plant at June 30	
	1956	*1955*
	(in millions)	
Fernald, Ohio	$91. 8	$86. 4
Richland, Washington	35. 7	35. 3
Aiken, South Carolina	31. 0	30. 5
Paducah, Kentucky	20. 8	19. 5
St. Louis, Missouri	20. 3	18. 3
Oak Ridge, Tennessee	11. 4	9. 8
Niagara Falls, New York	8. 0	8. 0
Hicksville, New York	1. 8	1. 6
Total	$220. 8	$209. 4

Enriched Uranium

Enriched uranium is produced in the gaseous diffusion plants at Oak Ridge, Tennessee and Paducah, Kentucky, operated by Union Carbide Nuclear Company and at Portsmouth, Ohio, operated by Goodyear Atomic Corporation.

	Plant at June 30	
	1956	*1955*
	(in millions)	
Oak Ridge, Tenn	$828. 4	$827. 6
Paducah, Ky	733. 2	731. 1
Portsmouth, Ohio	722. 6	473. 3
Total	$2, 284. 2	$2, 032. 0

Consumption of electric power in these plants amounts to approximately one-tenth of the electric power produced by all the electric utility companies in the United States. Principal sources of power and its unit costs per kilowatt-hour are shown below:

Power Source	*Average cost (mills per kwh)*
Electric Energy Inc	3. 93
Tennessee Valley Authority—Paducah	4. 03
Tennessee Valley Authority—Oak Ridge	4. 06
Ohio Valley Electric Co	4. 18
AEC—Oak Ridge—K-25	4. 74

Plutonium and Other Reactor Products

Plutonium and other reactor products are produced at the Hanford works, operated by General Electric Company, and at the Savannah River plant, operated by E. I. du Pont de Nemours and Company, Inc. The products of these facilities are principally for weapons use. The facilities at these locations include reactors and plants for chemical separation and processing of products. Shown below is the investment in plant and equipment for these facilities:

	June 30, 1956 (in millions)
Savannah River plant	$802. 4
Hanford works	708. 6
Total	$1, 511. 0

HEAVY WATER PRODUCTION

AEC has two large-scale heavy water production plants, the Dana, Indiana plant and the Savannah River, South Carolina plant, having capital costs of $100 million and $164 million, respectively.

These plants were built in order to obtain the quantities of heavy water required for the Savannah River Reactors. In so doing, AEC achieved cost reductions that permit the sale of heavy water at $28 per pound, less than half the cost of heavy water from other known sources.

WEAPONS DEVELOPMENT AND FABRICATION

The costs of manufacturing weapons, the development, design and testing of new weapons types, and the maintenance of stockpiled weapons in a state of constant readiness increased to $280.8 million in fiscal year 1956 from $259.7 million in fiscal year 1955.

RESEARCH LABORATORIES

The search for knowledge of the atom, its peaceful applications, and its effects on humans, plants, animals and materials, is carried out in AEC laboratories operated by industrial concerns and universities and by contracts for work in research facilities owned by these organizations. The table on page 391 shows the investment in major AEC laboratories.

	June 30, 1956 (in thousands)
Los Alamos Laboratory, Los Alamos, New Mexico	$121, 973
Argonne National Laboratory, Lemont, Illinois	80, 762
Knolls Atomic Power Laboratory, Schenectady, N. Y	66, 487
Oak Ridge National Laboratory, Oak Ridge, Tennessee	63, 978
Brookhaven National Laboratory, Long Island, N. Y	57, 746
University of California Radiation Laboratory, Livermore and Berkeley, California	52, 166

Research conducted at the laboratories benefits all AEC activities, including the development of nuclear reactors, research in chemistry, metallurgy, physics, cancer, medicine, biology, weapons development, the development of improved methods of manufacturing nuclear materials, the development and production of radioisotopes and stable isotopes, and research in other peaceful and military applications of atomic energy.

The laboratories are equipped with research reactors, accelerators, and other research devices and precision instruments necessary in nuclear research. At June 30, 1956, AEC's investment in research reactors and accelerators totaled $101.4 million and $44.8 million, respectively.

In addition to the research conducted at AEC owned installations, AEC spent $18.6 million in fiscal year 1956 for more than 800 off-site research contracts conducted by contractors in their own facilities. These contractors include nearly every research organization and major college and university in the country.

The costs of research in chemistry, metallurgy, physics, cancer, medicine and biology are set forth below. Research costs related to reactor development and other AEC functions are included with the activities discussed in other sections of this report.

RESEARCH IN CHEMISTRY, METALLURGY AND PHYSICS

	Fiscal year 1956	*Fiscal year 1955*
	(in thousands)	
Chemistry	$16, 925	$15, 097
Metallurgy	4, 826	4, 540
Physics	24, 095	19, 417
Special nuclear materials produced	(193)	(285)
Depreciation of facilities	5, 629	5, 129
Total	$51, 282	$43, 898

RESEARCH IN CANCER, MEDICINE AND BIOLOGY

	Fiscal year 1956	*Fiscal year 1955*
	(in thousands)	
Cancer	$3, 109	$2, 110
Medicine	8, 776	7, 591
Biology	10, 302	11, 458
Biophysics	3, 159	2, 929
Dosimetry and instrumentation	2, 229	2, 287
Special nuclear materials produced	(83)	(119)
Depreciation of facilities	2, 634	2, 888
Total	$30, 126	$29, 144

COMMUNITIES

Results of Operations

The net cost of operating AEC communities, totaled $9.0 million in fiscal year 1956 compared with $10.3 million in fiscal year 1955. The following table shows the results of operations of the communities for fiscal years 1956 and 1955:

Summary	*Total*	*Oak Ridge, Tennessee*	*Richland, Washington (in millions)*	*Los Alamos, New Mexico*	*Other*
Expenses:					
Municipal	$7. 0	$3. 6	$2. 1	$1. 2	$0. 1
Real Estate	5. 8	2. 3	1. 9	1. 3	. 3
Utilities	2. 2	. 8	. 7	. 7	—
Hospital	2. 7	1. 2	. 8	. 7	—
Total	17. 7	7. 9	5. 5	3. 9	. 4
Depreciation	11. 8	4. 9	3. 6	2. 9	. 4
Total cost	29. 5	12. 8	9. 1	6. 8	. 8
Less revenues	20. 5	9. 0	6. 5	4. 5	. 5
Net cost fiscal year 1956	$ 9. 0	$3. 8	$2. 6	$2. 3	$. 3
Net cost fiscal year 1955	$10. 3	$3. 8	$2. 5	$3. 9	$. 1

Investment in Facilities

AEC's investment in completed community facilities at June 30, 1956, was as follows:

Community	*Cost*	*Accumulated Depreciation (in millions)*	*Net*
Oak Ridge	$121. 0	$48. 6	$72. 4
Richland	102. 9	32. 0	70. 9
Los Alamos	66. 7	14. 2	52. 5
Other	8. 7	2. 0	6. 7
Total	$299. 3	$96. 8	$202. 5

During the fiscal year community plant additions totaled $3.0 million. Of this amount, $2.0 million represented construction of permanent-type housing at Los Alamos, New Mexico. Construction work in progress relating to community facilities at June 30, 1956 amounted to $3.3 million.

Community Disposal

In 1955 Congress authorized the sale to occupants or other interested parties of the houses, apartments and business buildings in the Oak Ridge, Tennessee, and Richland, Washington communities. The Act also provides for transferring the municipal facilities and utilities to the city governments or for selling them to other organizations. In February of 1956 the President issued an executive order making the Administrator, Housing and Home Finance Agency, responsible under the Act of 1955 for sales and financing.

The Federal Housing Administration has completed appraisal of all real property to be offered for sale and the appraised value of each property offered was posted in each community.

In fiscal year 1956 costs to AEC of the community disposal program were as follows:

	Total	*Richland, Washington*	*Oak Ridge, Tennessee*
		(in thousands)	
Appraisal expenses	$445	$182	$263
Classification and plotting of property	173	59	114
Other sales expenses	56	23	33
Assistance in organizing and establishment of local government	55	21	34
Total	$729	$285	$444

A total of 116 individual residential lots at Oak Ridge have been sold, with proceeds totaling $97 thousand. Completing a program started several years ago, 38 church sites have been sold at Oak Ridge, and 15 at Richland.

GUARANTEED LOANS

The outstanding balance of loans made by the Export-Import Bank to South African uranium producers amounted to $100 million at June 30, 1956. The maximum additional credit available to borrowers under approved guarantees at June 30, 1956, was $5 million. Since the inception of these guarantees in 1952 the Export-Import Bank has disbursed $106 million to 27 borrowers. AEC has guaranteed the entire balance of the loans and has earned guarantee fees totaling $1.1 million. Guarantee fees earned during fiscal year 1956 totaled $645 thousand.

The outstanding balance of loans to AEC contractors made by commercial banking institutions and guaranteed by AEC under the V-Loan program amounted to $10 million at June 30, 1956. Of this amount $9.5 million or an average of 92 percent was guaranteed by AEC. The maximum additional credit available to borrowers under approved guarantees at June 30, 1956, totaled $16 thousand. Since the beginning of these guarantees in 1951 the lending institutions have disbursed $33 million to 15 borrowers and have received repayments aggregating $23 million, including payment in full by 12 borrowers. AEC has earned guarantee fees totaling $205 thousand and has paid the lending institutions loan service charges totaling $8 thousand. Guarantee fees earned during fiscal year 1956 totaled $130 thousand.

At the end of the year all loans were current. Since the beginning of these guarantees AEC has not been called upon to disburse any funds under the terms of the guarantees.

AEC ADMINISTRATIVE EXPENSES

Direct AEC costs of general management, executive direction, administration of contracts, and supporting administrative services, increased 12 percent to $38.2 million during fiscal year 1956 from $34 million in fiscal year 1955.

Administrative expenses compared to the total cost of operations continued to decrease. They amounted to 2.4 percent of operating costs during fiscal year 1956 as compared to 2.6 percent in fiscal year 1955 and 3.4 percent in fiscal year 1954.

Administrative expenses for fiscal years 1956 and 1955 were as follows:

	Fiscal year 1956 (in millions)	*Fiscal year 1955*
Salaries	$28. 3	$26. 1
Travel	1. 7	1. 4
Other	7. 1	5. 5
Depreciation	1. 1	1. 0
Total	$38. 2	$34. 0

SCHEDULE OF PLANT AND EQUIPMENT

June 30, 1956
(*in thousands*)

Location	*Completed plant*	*Construction in progress*	*Total*
California:			
University of California, Livermore and Berkeley	$52, 166	$4, 311	$56, 477
Sandia Corporation, Salton Sea	6, 324		6, 324
Colorado:			
Dow Chemical Company, Rocky Flats, Denver	44, 785	8, 666	53, 451
Lucius Pitkin, Inc., Grand Junction	1, 999	1	2, 000
Walker-Lybarger Construction Company, Grand Junction	4, 684	747	5, 431
Illinois:			
Argonne National Laboratory, Lemont	80, 762	4, 386	85, 148
University of Chicago (Cancer Research Hospital), Chicago	4, 176		4, 176
Indiana:			
E. I. du Pont de Nemours and Company, Inc., Dana	100, 401		100, 401
Idaho:			
National Reactor Testing Station, Arco:			
Argonne National Laboratory	1, 114		1, 114
General Electric Company	9, 641		9, 641
Phillips Petroleum Company	74, 741	9, 435	84, 176
Westinghouse Electric Company	15, 173	1, 462	16, 635
Iowa:			
Iowa State College, Ames	6, 518	60	6, 578
Mason and Hanger (Iowa Ordnance Plant), Burlington	25, 397	61	25, 458
Kentucky:			
Union Carbide Nuclear Company, Paducah	754, 104	10, 015	764, 119
Missouri:			
Bendix Aviation Corporation, Kansas City	14, 040	153	14, 193
Mallinckrodt Chemical Works, St. Louis	20, 525	23, 502	44, 027
Nevada:			
Reynolds Electrical and Engineering Co., Inc., Mercury	12, 103	481	12, 584
New Mexico:			
Albuquerque:			
ACF Industries, Inc	7, 354	268	7, 622
Sandia Corporation	53, 300	361	53, 661
Los Alamos:			
Los Alamos Medical Center, Inc	2, 911		2, 911
University of California	121, 973	2, 309	124, 282
The Zia Company	118, 642	1, 998	120, 640

SCHEDULE OF PLANT AND EQUIPMENT—Continued

Location	*Completed plant*	*Construction in progress*	*Total*
New York:			
ACF Industries, Inc., Buffalo	$5, 107	$173	$5, 280
Brookhaven National Laboratory, Upton, Long Island	57, 746	4, 617	62, 363
Hooker Electrochemical Company, Niagara Falls	7, 982		7, 982
Knolls Atomic Power Laboratory, Schenectady	66, 487	4, 502	70, 989
University of Rochester, Rochester	2, 428	1	2, 429
Ohio:			
General Electric Company, Lockland	5, 637	4	5, 641
Goodyear Atomic Corporation, Portsmouth	722, 989	21, 392	744, 381
Monsanto Chemical Company, Miamisburg	26, 240	720	26, 960
National Lead Company of Ohio, Cincinnati	92, 193	11, 766	103, 959
Pennsylvania:			
Westinghouse Electric Corp., Pittsburgh	23, 601	11, 086	34, 687
South Carolina:			
E. I. du Pont de Nemours and Company, Inc., Aiken	1, 137, 002	48, 721	1, 185, 723
Tennessee:			
Oak Ridge:			
American Industrial Transport, Inc	1, 337		1, 337
Anderson County Board of Education	10, 995	4	10, 999
Management Services, Inc	110, 395	1, 244	111, 639
Oak Ridge Hospital, Inc	1, 401		1, 401
Oak Ridge Institute of Nuclear Studies	2, 102	25	2, 127
Oak Ridge National Laboratory	63, 978	4, 591	68, 569
Union Carbide Nuclear Company—K–25	836, 431	4, 530	840, 961
Union Carbide Nuclear Company—Y–12	440, 329	2, 982	443, 311
Texas:			
Procter and Gamble Defense Corporation, Amarillo	18, 632	97	18, 729
Utah:			
National Lead Company, Inc., Monticello	4, 248	14	4, 262
Washington:			
General Electric Company, Richland	1, 007, 987	36, 364	1, 044, 351
Marshall Islands:			
Holmes and Narver, Inc., Eniwetok	24, 672	690	25, 362
All other	263, 285	25, 285	288, 570
Total	$6, 466, 037	$247, 024	$6, 713, 061

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